ORNL/TM-13018

ornl

OAK RIDGE
NATIONAL
LABORATORY

LOCKHEED MARTIN

SNF Shipping Cask Shielding Analysis

J. O. Johnson
J. V. Pace III

MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

UCN-13673 (36 6-95)

MASTER

DLC

ORNL/TM-13018

Computational Physics and Engineering Division

SNF SHIPPING CASK SHIELDING ANALYSIS

J. O. Johnson and J. V. Pace III

DATE COMPLETED - November 1995
DATE PUBLISHED - January 1996

Research sponsored by the
Office of Nuclear Energy
U.S. Department of Energy

Prepared by
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U. S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (cont.)

Figure

Page

LIST OF FIGURES (cont.)

Figure | Page

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Waste Management and Remedial Action Division for the funding of this study, Douglas W. Turner for his patient support of this project, and to Robert N. Morris for his guidance in the areas to be analyzed. The contributions of James D. Drischler in the production of the major tables and Tamara R. Henson in the preparation of the final report are gratefully acknowledged.

ABSTRACT

The Waste Management and Remedial Action Division has planned a modification sequence for storage facility 7827 in the Solid Waste Storage Area (SWSA). The modification cycle is as follows: 1) modify an empty caisson, 2) transfer the spent nuclear fuel (SNF) of an occupied caisson to a hot cell in building 3525 for inspection and possible repackaging, and 3) return the package to the modified caisson in the SWSA. Although the SNF to be moved is in the solid form, it has different levels of activity. Thus, the following five shipping casks will be available for the task: 1) the Loop Transport Carrier, 2) the In-Pile Loop LITR HB-2 Carrier, 3) the 6.5-Inch HRLEL Carrier, 4) the HFIR Hot Scrap Carrier, and 5) the 10-Inch ORR Experiment Removal Shield Cask. This report describes the shielding tasks for the five casks. These included the determination of the shielding characteristics, any streaming avenues, estimation of thermal limits, and shielding calculational uncertainty for use in the transportation plan.

1.0 INTRODUCTION

The Waste Management and Remedial Action Division has planned a modification sequence for storage facility 7827 in the Solid Waste Storage Area (SWSA). The modification cycle will be carried out in three steps: 1) modify an empty caisson, 2) transfer the spent nuclear fuel (SNF) of an occupied caisson to a hot cell in building 3525 for inspection and possible repackaging, and 3) return the package to the modified caisson in the SWSA.

Although the SNF to be moved is in the solid form, it has different levels of activity and is in different shapes geometrically. Thus, the following five shipping casks were made available for the task: 1) the Loop Transport Carrier, 2) the In-Pile Loop LITR (Low-Intensity Test Reactor) HB-2 Carrier, 3) the 6.5-Inch HRLEL (High-Radiation-Level Experimental Laboratory) Carrier, 4) the HFIR (High-Flux Isotope Reactor) Hot Scrap Cask, and 5) the 10-Inch ORR experiment Removal Shield Cask.

For the five shipping casks, this report describes shielding tasks, which are to determine: 1) the shielding characteristics, 2) any radiation streaming avenues from inside the casks to the external surface, 3) the thermal load for the casks and the source material, and 4) the shielding calculational uncertainty.

The activated material present in the SNF includes fuel, fission products, transuranic elements, and cladding activation products. Since there are many different radioisotopes present in the SNF, it was decided that the various sources chosen would be normalized to 1 Ci. Seven specific sources, which are representative of the myriad of sources present in the caissons, were chosen. These included ^{60}Co, ^{137}Cs, two Light-Water-Reactor (LWR) MFP sources, representative of different burnups, and three Oak Ridge Reactor (ORR) MFP sources representative of different initial enrichments and final burnups.

Point isotopic generation/depletion calculations were made to determine the mixed fission-product photon (or gamma-ray) sources. The five three-dimensional casks were reduced to (R,Z) models, and a cross-section library was chosen. Two-dimensional radiation transport calculations were made using the geometry, source, and cross-section data to determine the doses at specific points on the surface and one meter from the surface of the casks. Plots and tables of the results are presented.

Due to the voluminous data generated in a shielding analysis of this type, most of the information used to construct the final tables of results are presented in the appendices. In particular, Appendix A presents the energy dependent photon source spectra as a function of time after burnup for the one mixed fission product source; Appendix B presents the constituent isotopes comprising the one mixed fission product source at fifteen years after burnup; Appendix C presents graphical representations of the computer models used in the analysis of the five shipping casks; Appendix D presents the isodose contours for the various photon sources and casks analyzed in this report; and Appendix E presents the various code input files used in the analyses.

2.0 DESCRIPTION OF THE SHIPPING CASKS

The SNF stored in the 7827 storage facility at the SWSA site takes on many shapes and sizes. Consequently, multiple shipping casks are required for transport of these waste canisters between the storage facility and the hot cells for inspection and/or repackaging. Below is a brief description of each of the five casks identified for the movement of the SNF.

Loop Transport Carrier The Loop Transport Carrier is a lead-filled steel cask approximately 61 cm in diameter, 225 cm long, and weighs 6890 kg. The lead shielding is nominally 21 cm thick. The central cavity is a stainless steel lined cylinder approximately 14.5 cm in diameter and 175 cm long. Loading can be accomplished through either a sliding door on the bottom or a flanged gasketed plug on the top. The cask can be handled in either the normal horizontal position using the lifting ears or in a vertical position using the trunnions. The Loop Transport Carrier identification number is 8S16-80, and the reference engineering drawing number is E-35362.

In-Pile Loop LITR HB-2 Carrier The In-Pile Loop LITR HB-2 Carrier is a lead filled stainless steel cask approximately 54 cm in diameter, 282 cm long, and weighs 6140 kg. The lead shielding is nominally 15 cm thick. The cylindrical central cavity is approximately 21 cm in diameter, 243 cm long, and is lined with stainless steel (Type 347). Loading can be accomplished through a set of interlocking double doors on one end or a single sliding door on the other end. The cask can be handled in either the horizontal or vertical position using lifting eyes on the top or side. The In-Pile Loop LITR HB-2 Carrier identification number is 6S14-55, and the reference engineering drawing number is E-23286.

This carrier is similar to the In-Pile Loop ORR-HN-1 Carrier (identification number 7S19-73 and reference engineering drawing number E-28066), and the LITR In-Pile Loop Carrier (identification number 6S13-54 and reference engineering drawing number E-16590). The major differences are that the ORR-HN-1 Carrier utilizes approximately 19 cm of lead shielding instead of the 15 cm on the LITR HB-2 Carrier, and the LITR In-Pile Carrier has a smaller central cavity size (19 cm in diameter instead of the 21 cm on the LITR HB-2 Carrier).

6.5-Inch HRLEL Carrier The 6.5-Inch HRLEL Carrier is a lead filled cylindrical stainless steel cask approximately 58 cm in diameter and 130 cm long welded to a 61-cm-wide by 68-cm-deep by 70-cm-high lead filled stainless steel rectangular prism. The lead shielding is nominally 20 cm thick and the total cask weighs approximately 5900 kg. The central cavity is a stainless steel lined cylinder approximately 18 cm in diameter and 102 cm long. Loading can be accomplished through either a petcock door located in the lower rectangular portion of the cask or a flanged plug on the cylindrical top portion of the cask. The cask can be handled using the trunnions either on the two ends or in the center along each side of the cask. The carrier can be sealed on both ends by installation of 2.54-cm-thick aluminum gasketed end plates. The 6.5-Inch. HRLEL Carrier identification number is 8S15-159, and the reference engineering drawing number is E-44010.

HFIR Hot Scrap Shipping Cask The HFIR Hot Scrap Shipping Cask is a modification of the OD-2 LITR Fuel Element Carrier originally designed to be loaded from the top. The OD-2 cask was modified (and renamed) to be loaded from the bottom and used for transfers at the SWSA site. The Hot Scrap Cask is a lead-filled cylindrical stainless steel container approximately 80 cm in diameter, 149 cm in length, and weighs 6700 kg. The cask sits on a rectangular base plate 122 cm by 132 cm and is designed to be transported vertically. The lead shielding is nominally 21-cm-thick, and the central cavity is a stainless-steel-lined cylinder 31.75 cm in diameter and 93 cm in length. A stainless steel basket approximately 30.50 cm in diameter and 87 cm in length can be inserted into the cavity for the transport of ORR type fuel elements. Loading can be accomplished through either a sliding door on the bottom or a flanged plug on the top. The cask is handled with two trunnions located on the sides 180 degrees apart. The HFIR Hot Scrap Shipping Cask identification number is 9S15-135, and the reference engineering drawing number is D-37780.

10-Inch ORR Experiment Removal Shield The 10-Inch ORR Experiment Removal Shield cask is a multisectional lead filled stainless steel cask composed of four segments. One segment is approximately 74 cm in diameter, 212 cm in length, and contains 20-cm-thick lead shielding. This segment (referred to as the heavy shielded segment) also includes a 20-cm-thick lead-filled stainless steel sliding door for loading the cask. There are two more segments, each approximately 63.5 cm in diameter and 122 cm in length, which contain 14.6-cm-thick lead shielding. These two segments are referred to as the light shielded segments. Finally, there is one more segment approximately 63.5 cm in diameter and 22 cm in length which contains 14.6-cm-thick lead shielding. This section also contains a 14.6-cm-thick lead-filled stainless steel sliding door and is referred to as the light shielded door assembly. In transport operations, this cask may be used in multiple configurations. However, for the purposes of the SNF transfer sequence, the cask will be bolted together in the longest configuration (i.e., the heavy section, two light sections, and the light door) resulting in a total cask weight of 16,750 kg. In this configuration, the central cavity is a stainless steel lined cylinder approximately 27 cm in diameter and 430 cm in length. Loading access is accomplished through the heavy shielded and/or light shielded doors located on the two ends of the cask. Handling of the cask is accomplished through the use of six trunnions located along each side of the cask with the cask normally positioned in the horizontal position. The 10-Inch ORR Experiment Removal Shield identification number is 9S37-175, and the reference engineering drawing is D-25990.

3.0 DESCRIPTION OF THE CROSS SECTIONS

The photon multi-energy-group (commonly called multigroup) transport cross-section set from the VELM[1] 61-neutron, 23-photon library (VELM61) was used. The name of the library is an acronym for VITAMIN-E Liquid Metal (VELM). The neutron and photon energy group structure (Table 1 shows the photon group structure) is a subset of the VITAMIN-E[2] group structure, and the cross sections were collapsed from the VITAMIN-E library. Although the libraries were specifically designed for sodium-cooled reactor shield analysis, the photon interaction data is general enough for most other purposes.

Table 1. VELM Photon Energy-Group Structure

Group	Top Energy (MeV)	Group	Top Energy (MeV)
1	1.40E7	13	1.00E6
2	1.00E7	14	7.00E5
3	8.00E6	15	6.00E5
4	7.50E6	16	5.10E5
5	7.00E6	17	4.00E5
6	6.00E6	18	3.00E5
7	5.00E6	19	1.50E5
8	4.00E6	20	1.00E5
9	3.00E6	21	7.00E4
10	2.50E6	22	4.50E4
11	2.00E6	23	2.00E4
12	1.50E6		1.00E4*

* Bottom of energy-group 23.

The five shipping casks designated for the transport of the SNF are comprised of three basic materials: stainless steel, lead, and mild steel. While there were several different steels used in the construction of the casks, for the purposes of the shielding analyses, AISI Type 347 was chosen as the stainless steel, and SAE Type 1020 was chosen for the mild steel. The small differences in the elemental compositions of the other steels utilized in the casks' construction will cause negligible effects on the radiation transport analyses. The composition of the casks' materials used in the radiation shielding analysis were mixed using the GIP: Group-Organized Cross Section Input Program[3] and are presented in Table 2.

Table 2. Composition of Materials Used in the Radiation Shielding Analysis of the Spent Nuclear Fuel Shipping Casks.

Element	Material Composition (atoms/barn·cm)				
	Dry Air	Steel AISI 347	Lead	Steel SAE 1020	Aluminum
Carbon		3.19E-04		7.88E-04	
Nitrogen	3.98E-05[a]				
Oxygen	1.07E-05				
Aluminum					6.03E-02
Silicon		1.71E-03		4.21E-04	
Argon	2.37E-07				
Chromium		1.66E-02			
Manganese		1.74E-03		3.88E-04	
Iron		5.91E-02		8.40E-02	
Nickel		8.16E-03			
Lead			3.30E-02		
ρ(g/cm^3)	1.23E-03	7.95E+00	1.13E+01	7.86E+00	2.70E+00

[a]Read as 3.98×10^{-5}.

Elemental KERMA (Kinetic Energy Released in Material) factors, used to determine the heating rates, were pulled from the VELM library using the PAL module of the AMPX[4] code system. The elements making up the major materials of the casks were C, Al, Si, Cr, Mn, Fe, Ni, and Pb.

The KERMA factors from PAL were then processed through the AMP[5] code to change the units from (MeV.b)/(photon.atom) to (W.s)/(photon.cm), and to place the KERMA data in cross-section format.

The cross-section data for the point isotopic generation/depletion calculations were taken from the libraries[6] produced in support for major revisions to the current Nuclear Regulatory Commission decay heat rate guide.

4.0 DESCRIPTION OF THE RADIATION SOURCES

Table 3 contains those radioisotopes which form the bulk of the activity in the SNF (from the SNF Database[7]). After all the photons released from either each of these or from their daughters had been examined, it was decided to use the ^{60}Co, ^{137}Cs, and the MFP as the major sources in the calculations.

Table 3. Radioisotopes Forming Bulk of SNF

Radioisotope	Max Ci per SNF Package
MFP	10,000
^{60}Co	113,000
^{90}Sr	70,000
^{137}Cs	3,800
^{151}Sm	1,200
^{152}Eu	200
^{154}Eu	16,000
^{155}Eu	10
^{226}Ra	1
^{232}Th	<< 1
^{233}U	< 1
^{235}U	<< 1
^{237}Np	<< 1
^{238}U	<< 1
^{239}Pu	16
^{240}Pu	29
^{241}Pu	1,344
^{241}Am	2
^{244}Cm	<< 1
^{252}Cf	<< 1

Seven primary photon sources were developed for the casks radiation transport calculations. These sources were all normalized to 1Ci. Two of the sources were ^{60}Co and ^{137}Cs; and, because of the known photon lines, no depletion code calculation was necessary to determine the number of photons emitted per curie. [NOTE: The source strength for ^{137}Cs required an adjustment to conserve energy because the midpoint of the VELM61 library energy bin is 0.65 MeV and the energy of the ^{137}Cs emitted photon is 0.662 MeV with an associated yield of 92%. Therefore, to get the proper normalization, the number of photons per curie is multiplied by the yield, and the ratio of the photon emitted energy divided by the VELM61 energy group average energy.] Table 4 shows the source strength and energy group for these two sources.

Table 4. Energy Group and Source Strength for ^{60}Co and ^{137}Cs

Source	Energy Group	Strength (Photons/Ci)
^{60}Co	12	7.400E+10
^{137}Cs	14	3.467E+10

The other five photon sources resulted from mixed-fission products (MFP) and required point isotopic generation/depletion calculations be made with the ORIGEN-S[8] code.

Two of the five MFP photon sources were generated from Pressurized Water Reactor (PWR) data taken from Tables 3.11 and A.4 of Ref. 5. One source was generated from a burnup of 25 megawatt days per kilogram of uranium (2.4% enrichment), to be noted symbolically as 25 MWd/kgU and a specific power of 18 kW/kgU; the second source was generated from a burnup of 50 MWd/kgU (4.2% enrichment) and a specific power of 40kW/kgU.

The final three MFP photon sources were generated from three representative miniature fuel plates irradiated during the Department of Energy's (DOE) Reduced Enrichment Research and Test Reactor[9] (RERTR) Program which began in 1978. The fuel plates were irradiated in a special test facility, designated as High-Uranium-Loaded Fuel Element Development (HFED), in the ORR core during the period of 1980 through 1987. The pertinent attributes of the miniplates were taken from Ref. 9 and are listed in Table 5.

Table 5. Three RERTR Program Miniplate Attributes

Module No.	Slot No.	Fuel Type	Enrichment (Wt% ^{235}U)	U Loading (g)	Irradiation Time (FPD)	^{235}U Depletion (At. %)
1	1	UAl_x	40.24	5.470	470	94
5	10	U_3O_8	93.21	1.553	268	80
23	6	U_6Fe	19.84	18.390	91	27

FPD = Full Power Days

The ORIGEN-S cross-section data were also taken from libraries generated during the production of the work reported in Ref. 6. Although this data only applied to the PWRs, several test calculations indicated that it could also be applied to the ORR miniplates with little error. This was because the photon sources were being normalized to 1 Ci, and the spectra for the out years (15 years and beyond) did not show large changes when normalized in this manner.

The energy-dependent photon source spectra as a function of time after burnup for one of the five MFP sources are presented in Appendix A, and the constituent isotopes comprising one MFP source at fifteen years after burnup are given in Appendix B.

5.0 DESCRIPTION OF CALCULATIONAL MODELS

The engineering reference drawings for the five SNF casks described in Section 2.0 were utilized to design cylindrical r-z models of the casks for analysis in the DORT[10] two-dimensional radiation transport code system. Any engineering details which might contribute to a radiation streaming path were included in the calculational models to analyze their effect. Typical radial and axial mesh sizes varied from 0.5 to 1.0 cm in thickness resulting in transport models with between 43 and 64 radial intervals and between 243 and 641 axial intervals depending on the size of the cask. The casks models utilized a 240 direction symmetric quadrature set, a P_5 Legendre expansion of the cross sections, and the VELM61 [84 energy group (61 neutron, 23 gamma)] cross-section library. The materials listed in Table 2 were mapped to the radial and axial mesh to generate the DORT calculational model. The source regions for each cask were modeled as air in the DORT calculations due to the lack of information on the material composition and physical description of the SNF canisters to be transported. Detailed graphical representations of the DORT calculational models are shown in Appendix C. Expanded views of the loading doors, and end plugs are also included in Appendix C to indicate the detail associated with the calculational models. Penetrations in the sides of the shipping casks (e.g., view ports, light windows, etc.), were not included in the transport calculation models because, for the movement of the SNF, they would be plugged with lead-filled plugs of thicknesses equivalent to the cask wall thickness and would not result in measurable radiation streaming paths.

6.0 DESCRIPTION OF CALCULATIONAL METHOD

The flow diagram for the SNF shipping casks shielding analyses is given in Figure 1. The generation of the cross-section data for the ORIGEN-S and DORT codes was discussed in Section 3.0 and the calculation of the SNF energy dependent source spectra for input into DORT was discussed in Section 4.0.

The principal workhorse in the calculational sequence presented in Figure 1 is the DORT two-dimensional discrete-ordinates radiation transport code. DORT is primarily designed to solve large neutron and photon transport problems using the method of discrete ordinates. Most DORT problems deal with the calculation of radiation resulting from a given extraneous source, i.e., "fixed-source" problems. If such a system has fissile material and is subcritical, the multiplication can be calculated. The code also has K_{eff} capability and various types of searches. The directional quadrature set can be chosen from an arbitrary number of input sets. The choice can vary with spatial option and with energy group. This flexibility has proven quite effective in concentrating computer effort in areas needing attention, such as streaming gaps. Biased direction sets can be used when streaming is primarily in the upward/downward/horizontal directions. A variety of options allow sources to be specified at internal or external boundaries, distributed by space and energy, or determined from an input fluence guess. "First-collision-source" data (actually an analytical first-flight scattering source) can be accommodated. Output files for an "analytical-last-flight" integration can be obtained. These features provide increased accuracy when dealing with out-of-system or localized sources or detector locations. Both one-dimensional (1-D) and 2-D geometries can be treated. Discrete-ordinates geometries include 1-D plane or slab and 2-D X-Z, R-Theta, or R-Z. A powerful slab reflection/transmission feature is available. A variety of acceleration options are available. Extensive use of input options and output edits give the user very direct control over the iteration process. While this places a burden of decision-making on the user, it is essential to the solution of large and difficult problems. Default and recommended values assist the uninitiated in solving problems without much prior use of the code. Output source information to be used in coupling to other problems can be obtained.

Utilizing the macroscopic cross-section data generated in GIP, the SNF energy dependent source spectra generated in ORIGEN-S, and the calculational model information discussed in Section 5.0, the DORT code was executed to generate the requisite output files for the shielding analyses of the shipping casks. In particular, DORT generates a scalar flux file which is reduced to the more manageable Legendre P_0 flux component using the utility program RTFLUM: A Module For Converting, Expanding, And Editing Standard Data Files.[3] This flux file is utilized in the ISOPLOT module of the DOGS[11] code system to generate isodose contours for the shipping casks. Analysis of these isodose contours indicate potential streaming paths, dose levels within the shipping casks, and areas of maximum dose. DORT also generates a distributed source file for input into the FALSTF[12] code system. FALSTF uses an analytical-last-flight integration technique to obtain the dose at selected detector locations on the surface of the shipping casks and at one meter from the surface of the casks. In both the ISOPLOT and FALSTF codes, the ANSI[13] dose response function is used to determine the calculated dose rates per curie of source. Finally, DORT utilizes the KERMA factor data to generate the gamma-ray heating rates for the various SNF source/shipping cask combinations. Appendix E presents the listings of the various code input files used in the analyses of the different shipping cask.

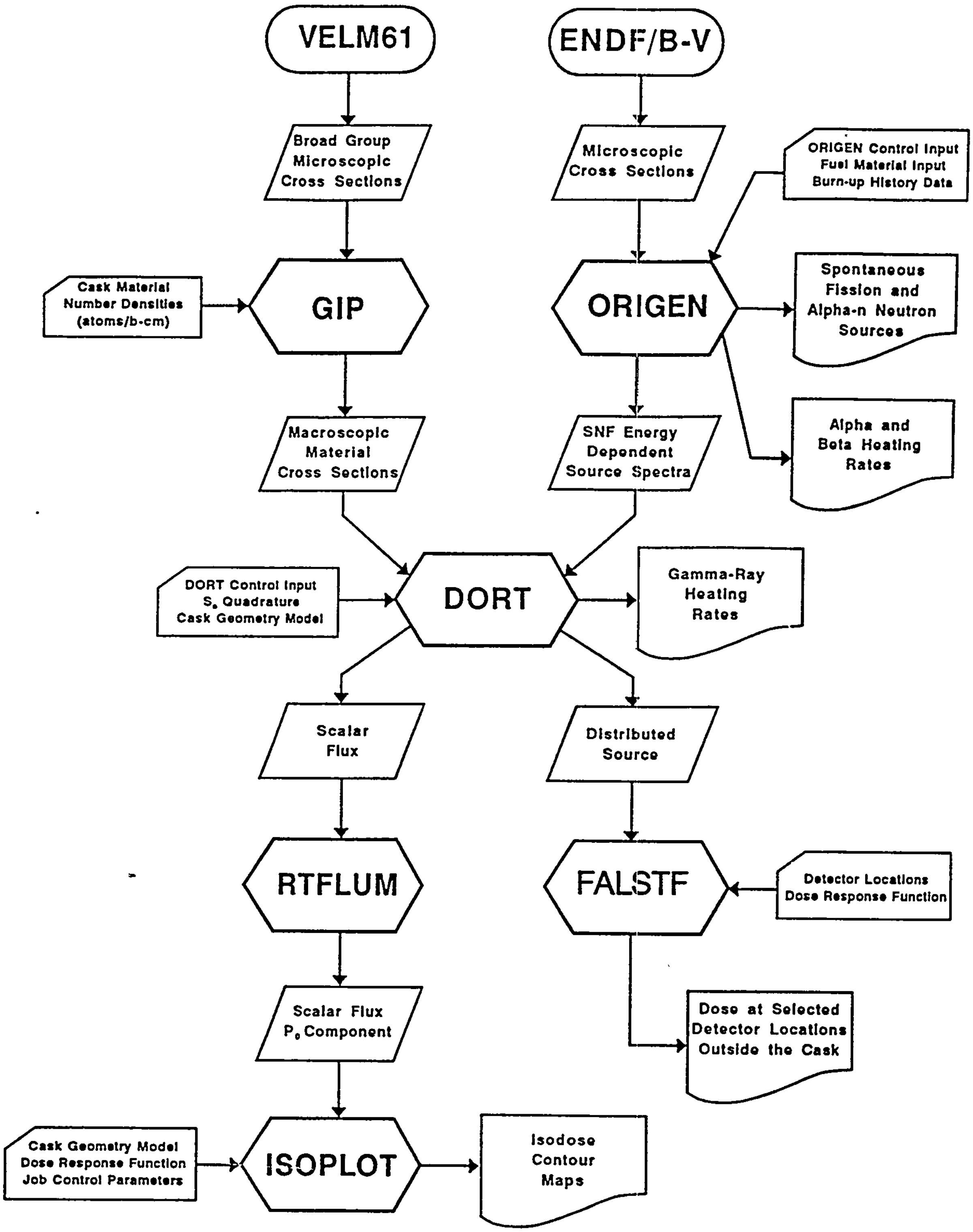

Figure 1. Flow Diagram of the SNF Shipping Casks Shielding Analysis.

7.0 RESULTS

Two of the goals associated with this shielding analysis were to determine 1) the shielding characteristics and any radiation streaming paths from inside the casks to the external surface, and 2) the thermal load for the casks and the source material. With respect to these two goals, the transportation plan specifies a dose rate of 200 mrem/hour on the cask surface and 10 mrem/hour at one meter from the cask surface. With respect to the thermal load, the transportation plan specifies a nominal limit of 1 kw total energy in the cask and source material.

To determine the total nuclear heating from the cask and the spent nuclear fuel materials within the cask, the contributions from alpha, beta, and photons had to be calculated. The alpha and beta heating rates were obtained from the ORIGEN-S calculations and are given in Table 6. Since ORIGEN-S employs a point isotopic generation/depletion calculation, these heating rates are geometry independent and a function of the source only. The photon heating rates were calculated using the DORT transport code and are given in Table 7. Because DORT performs a full radiation transport calculation and utilizes information about both the source and geometry, the photon (or gamma-ray) heating rates are calculated for each source/cask combination. In viewing the results presented in Table 7, it is apparent that there is virtually no sensitivity to the cask geometry since the photon heating rates for a given source are within one percent of each other. An average value for a given source could be applied to all of the five casks without introducing significant error.

Table 6. Alpha and Beta Heating Rates Per Curie (W/Ci) by Source Type

Source	Heating Rate (W/Ci)
Co-60	5.77E-4
18kW/kgU, 25MWd/kgU	2.36E-3
40kW/kgU, 50MWd/kgU	2.70E-3
Cs-137	1.02E-3
ORR MFP, 20% ^{235}U	2.06E-3
ORR MFP, 40% ^{235}U	3.33E-3
ORR MFP, 93% ^{235}U	2.75E-3

To determine the shielding characteristics and any radiation streaming paths from inside the casks to the external surface, the DORT scalar fluxes were folded with the ANSI dose response function and plotted using the ISOPLOT module of the DOGS code system. These isodose contours are presented in Appendix D for each of the different shipping-cask/SNF-source combinations. Visual analyses of these isodose contour plots indicate the complete dose profile for the cask, the calculated dose levels on the surface of the cask, and the potential streaming paths or areas of maximum dose on the surface of the

Table 7. Gamma-Ray Heating Rates for the Designated Spent Nuclear Fuel Shipping Cask to be Used to Transfer Radioactive Waste from the SWSA Area Sites, Building 7827 to Building 3525 and for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Designated Spent Nuclear Fuel Shipping Cask	Gamma-Ray Heating Rates[a] per One Curie of Source						
	^{60}Co	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	^{137}Cs	ORR MFP 20% ^{235}U	ORR MFP 40% ^{235}U	ORR MFP 93% ^{235}U
Loop Transport Carrier	1.47000E-02	8.55782E-04	9.18118E-04	3.56270E-03	9.39623E-04	1.05281E-03	1.05380E-03
LITR HB-2 In-Pile Loop Carrier	1.46908E-02	8.55170E-04	9.17421E-04	3.56028E-03	9.38938E-04	1.05203E-03	1.05304E-03
6.5 Inch HRLEL Carrier	1.47477E-02	8.60125E-04	9.22754E-04	3.57809E-03	9.44663E-04	1.05832E-03	1.05939E-03
HFIR Hot Scrap Carrier	1.47426E-02	8.59807E-04	9.22440E-04	3.57761E-03	9.44266E-04	1.05791E-03	1.05898E-03
10 Inch Expt. Removal Shield-ORR	1.47801E-02	8.63336E-04	9.26218E-04	3.59191E-03	9.48283E-04	1.06229E-03	1.06229E-03

[a]Gamma-Ray heating rate units are (watts)/(curie).

cask. Typically, the results show weaknesses in the cask shielding in the areas of the end plugs and loading doors, especially if there is a large cross-sectional area of stainless steel (see dose contours for the Loop Transport Carrier End Plug in Figure D-3). These areas indicate where the maximum external surface and 1 m-distance dose rates will probably occur. The isodose contours also indicate the relative magnitude (per curie) of the dose rates within the casks. One cask worth noting in particular, is the 10-Inch ORR Experiment Removal Cask (Figures D-39 to D-50). As stated in Section 2.0, this cask is a multisectional cask which can be bolted together in different combinations to accommodate different SNF transfers. The isodose contours in Appendix D indicate the stainless steel interface flanges where the various sections are bolted together present the areas of maximum dose and could be potential streaming paths.

Visual analysis of the isodose contours in Appendix D determined where to calculate the dose rates on the surface and at one meter distance from the surface of the cask in the FALSTF code. For each shipping cask, 34 different detector locations were chosen. Detectors 1 - 17 are located on the surface of the casks (technically 3.81 cm from the surface), and detectors 18 - 34 are located at 1-m distance from the surface. Graphical displays of the detector locations are given in Figures 2 through 6 for the five different shipping casks. The dose results for these detector locations are given in Tables 8 through 12 for each of the five shipping casks and all seven sources analyzed. The isodose contour results in Appendix D and the FALSTF results in Tables 8 - 12 are presented on a per-curie basis so that these data can be readily applied to the myriad of sources at the storage facility 7827 in the SWSA. Typically, for a given cask, the maximum dose rate occurred at the same detector position regardless of the SNF source. Although the absolute magnitude of the dose rate changed, the location at which it occurred remained constant. The major exception to this result is the ^{137}Cs results which are governed by a lower average energy gamma-ray than the ^{60}Co or various MFP sources. Also, the location of the maximum dose rate 1 m from the surface did not always correspond to the detector location in the general vicinity of the maximum dose rate on the cask surface. The maximum surface dose rates appear to be more affected by a local perturbation in the cask shielding (i.e., end plug, stainless steel spacer, etc.), whereas the maximum dose rate at one meter from the surface appears to be more affected by the geometric and material attenuation of the shipping cask relative to the detector location.

Figure 7, which shows the activity per gram of uranium of the MFP sources as a function of decay time, was created to aid in determining the MFP curie strength after irradiation. Rapid decay occurs in the first five years after irradiation. The actual source activity (Ci) for any of the five MFP sources can be determined after 5-40 years of decay if the decay time and the initial mass of uranium is known in the following way: the MFP source is chosen; the activity per initial gram of uranium is read from the figure using the chosen MFP source and the decay time; and the initial loading (grams of uranium) is multiplied by the activity per initial gram of uranium.

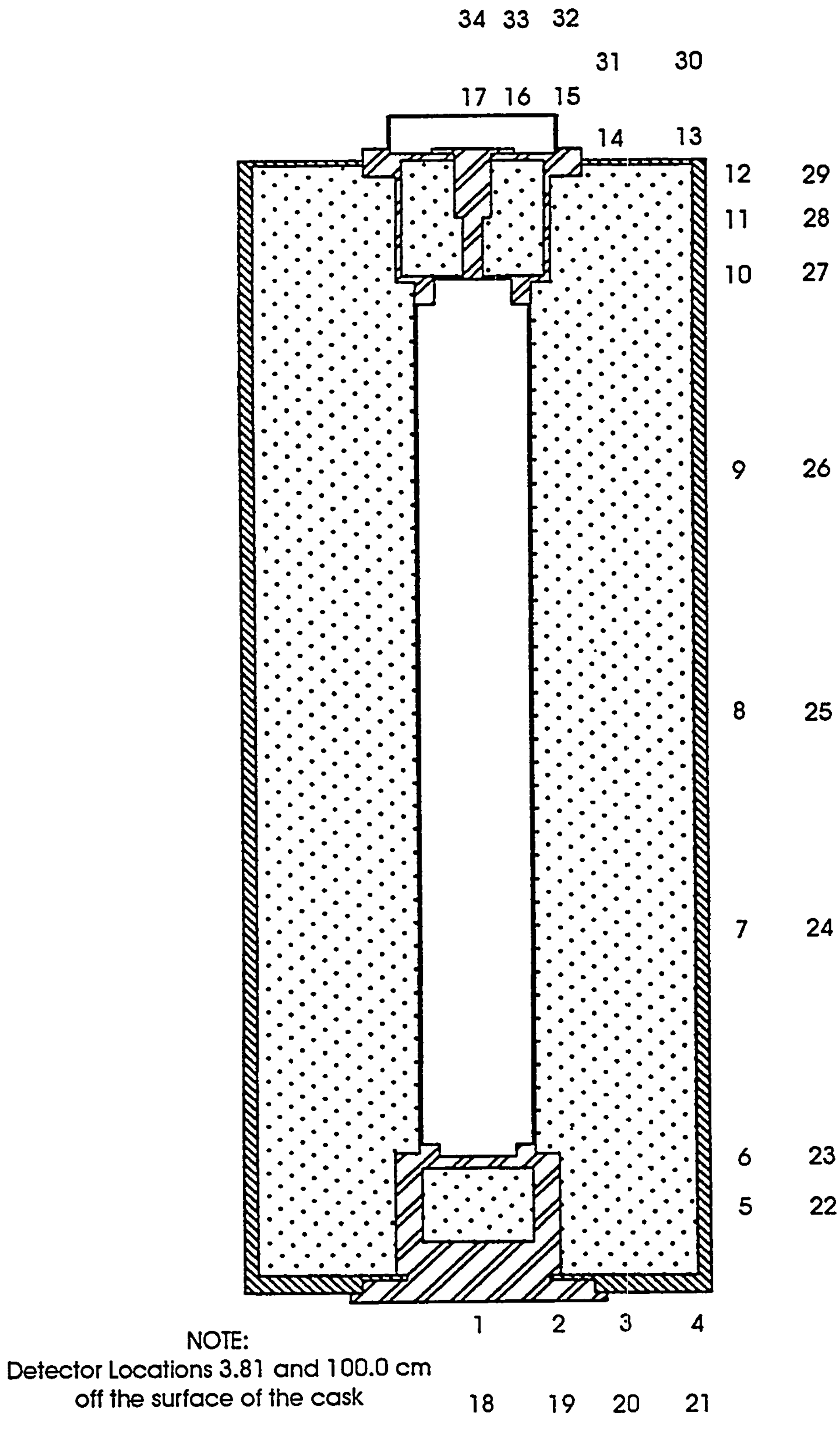

Figure 2. Detector Locations for the Surface and One Meter Distance Dose Rates Used in the Loop Transport Carrier SNF Shipping Cask Shielding Analysis.

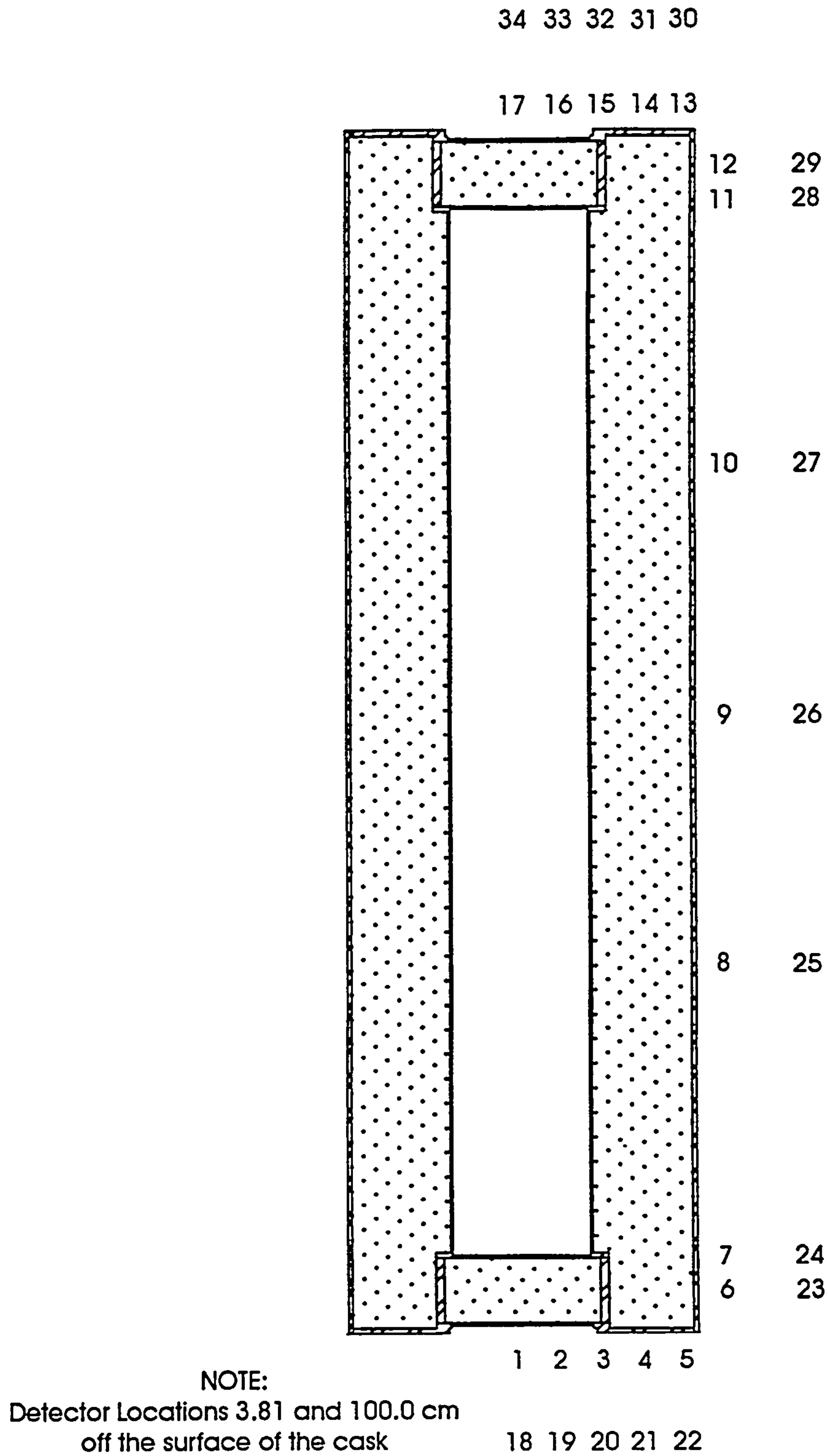

Figure 3. Detector Locations for the Surface and One Meter Distance Dose Rates Used in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask Shielding Analysis.

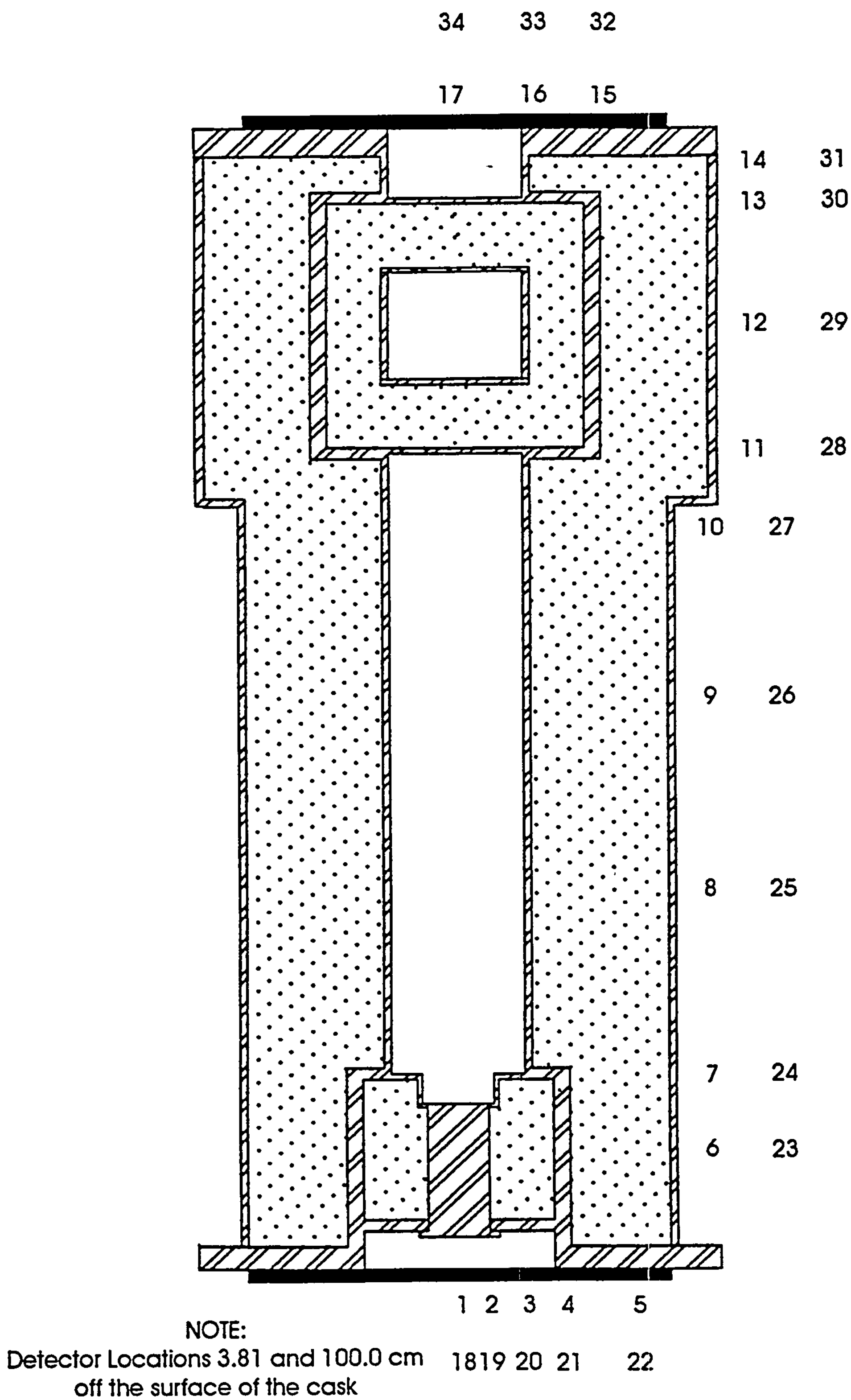

Figure 4. Detector Locations for the Surface and One Meter Distance Dose Rates Used in the 6.5 Inch HRLEL Carrier SNF Shipping Cask Shielding Analysis.

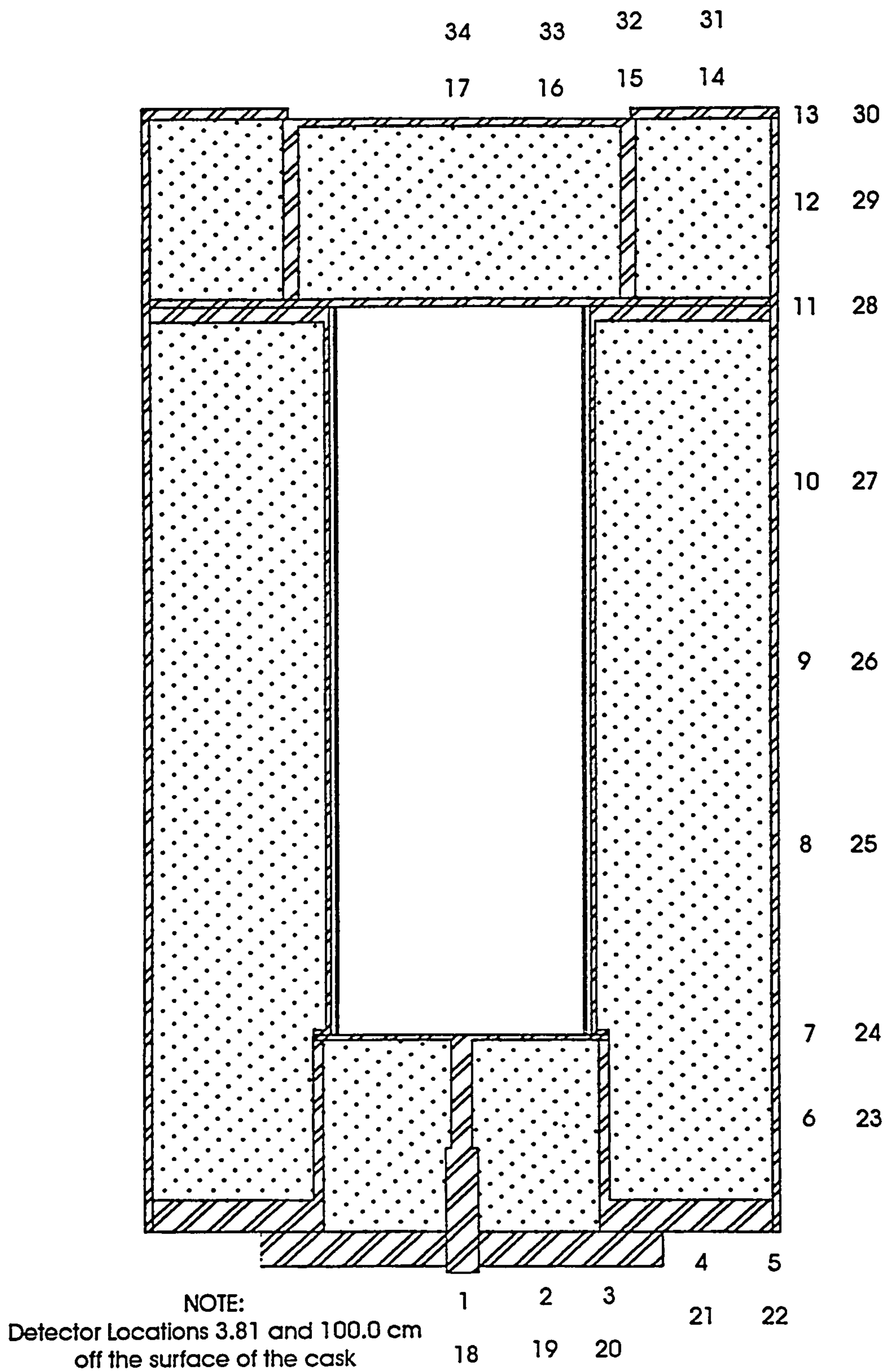

Figure 5. Detector Locations for the Surface and One Meter Distance Dose Rates Used in the HIFR Hot Scrap Carrier SNF Shipping Cask Shielding Analysis.

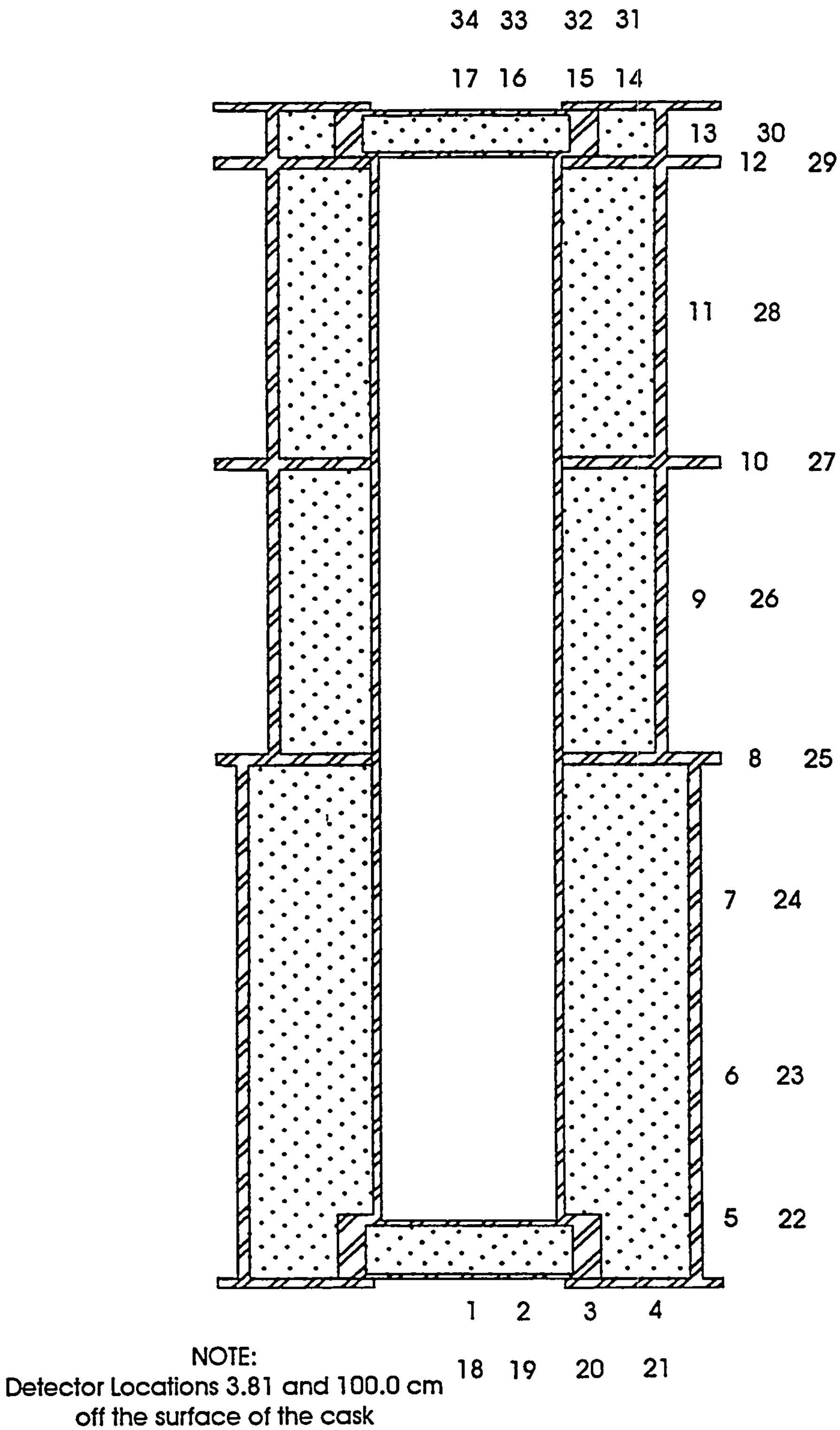

Figure 6. Detector Locations for the Surface and One Meter Distance Dose Rates Used in the 10 Inch ORR Experiment Removal Shield SNF Shipping Cask Shielding Analysis.

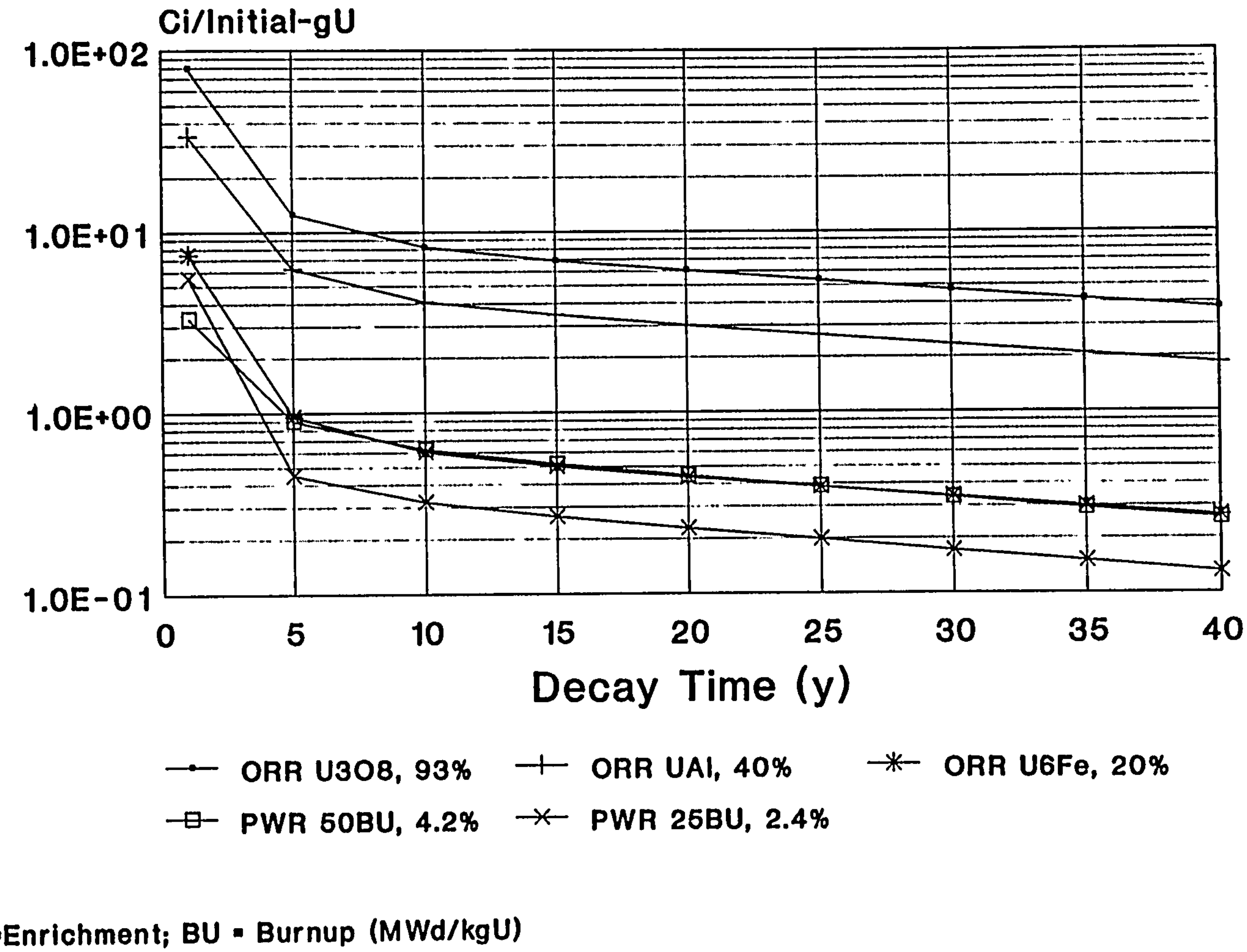

Figure 7. Activity Per Initial Gram of Uranium Loading Versus Decay Time for the Five MFP Sources.

Table 8. Gamma-Ray Dose Rates at Selected Detector Positions 3.81 cm and 1 m Away From the Surface of the Loop Transport Carrier Spent Nuclear Fuel Shipping Cask for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Detector Number	Detector Coordinates[a]		Gamma-Ray Dose Rates[b] per One Curie of Source						
	Radius (cm)	Height (cm)	Co-60	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	Cs-137	ORR MFP 20% U-235	ORR MFP 40% U-235	ORR MFP 93% U-235
1	0.00000E+0	-3.81000E+00	4.05125E-06	1.26250E-08	1.77616E-08	2.33341E-09	5.54909E-09	1.74474E-08	1.73566E-08
2	1.00000E+0	-3.81000E+00	4.08654E-06	1.27778E-08	1.79378E-08	2.96010E-09	5.70075E-09	1.77044E-08	1.76017E-08
3	2.00000E+0	-3.81000E+00	7.24025E-07	2.22777E-09	3.14759E-09	2.07885E-10	9.51233E-10	3.07421E-09	3.06059E-09
4	3.00000E+0	-3.81000E+00	1.65499E-07	5.01590E-10	7.08783E-10	4.78992E-11	2.13598E-10	6.92712E-10	6.89526E-10
5	3.43000E+01	2.00000E+01	3.00413E-07	1.01537E-09	1.43451E-09	5.79054E-14	4.27065E-10	1.38310E-09	1.37975E-09
6	3.43000E+01	3.00000E+01	1.51192E-06	4.91673E-09	6.96483E-09	3.51513E-13	2.05743E-09	6.71162E-09	6.69931E-09
7	3.43000E+01	7.00000E+01	4.44997E-06	1.43435E-08	2.03164E-08	1.16470E-12	5.99486E-09	1.95757E-08	1.95421E-08
8	3.43000E+01	1.20000E+02	4.45740E-06	1.43838E-08	2.03735E-08	1.16676E-12	6.01107E-09	1.96277E-08	1.95965E-08
9	3.43000E+01	1.70000E+02	4.44260E-06	1.43152E-08	2.02756E-08	1.16379E-12	5.98237E-09	1.95383E-08	1.95070E-08
10	3.43000E+01	2.06000E+02	1.17960E-06	3.86912E-09	5.47717E-09	2.37913E-13	1.62217E-09	5.27980E-09	5.27070E-09
11	3.43000E+01	2.15000E+02	2.31835E-07	7.94461E-10	1.12223E-09	4.65495E-14	3.34958E-10	1.08258E-09	1.08128E-09
12	3.43000E+01	2.25000E+02	2.81084E-08	9.98138E-11	1.40010E-10	3.60134E-13	4.21173E-11	1.35267E-10	1.34874E-10
13	3.00000E+01	2.33060E+02	6.58017E-08	2.07839E-10	2.92025E-10	4.14977E-11	9.17026E-11	2.85717E-10	2.84502E-10
14	1.50000E+01	2.33060E+02	1.31496E-06	4.10853E-09	5.80057E-09	3.88920E-10	1.75567E-09	5.63756E-09	5.61813E-09
15	1.00000E+01	2.42900E+02	2.63444E-06	8.58751E-09	1.19497E-08	3.32065E-09	4.02766E-09	1.18385E-08	1.17719E-08
16	5.00000E+00	2.42900E+02	6.81061E-06	2.24639E-08	3.10381E-08	1.19502E-08	1.09800E-08	3.10345E-08	3.08308E-08
17	0.00000E+00	2.42900E+02	1.67453E-05	5.91133E-08	8.05015E-08	4.71877E-08	3.12047E-08	8.13579E-08	8.07774E-08
18	0.00000E+0	-1.00000E+02	2.58104E-07	8.19731E-10	1.15270E-09	1.52002E-10	3.61960E-10	1.13352E-09	1.12767E-09
19	1.00000E+0	-1.00000E+02	2.51326E-07	7.97187E-10	1.12063E-09	1.54351E-10	3.52771E-10	1.10265E-09	1.09684E-09
20	2.00000E+0	-1.00000E+02	2.37366E-07	7.53546E-10	1.05873E-09	1.54132E-10	3.34586E-10	1.04243E-09	1.03682E-09
21	3.00000E+0	-1.00000E+02	1.91145E-07	6.02271E-10	8.47190E-10	1.10064E-10	2.65359E-10	8.33171E-10	8.28756E-10
22	1.30490E+02	2.00000E+01	3.92950E-07	1.27281E-09	1.80263E-09	1.76645E-13	5.32452E-10	1.73679E-09	1.73407E-09
23	1.30490E+02	3.00000E+01	4.89249E-07	1.58114E-09	2.23943E-09	1.38660E-13	6.61139E-10	2.15764E-09	2.15421E-09
24	1.30490E+02	7.00000E+01	8.29445E-07	2.67245E-09	3.78538E-09	2.57307E-13	1.11682E-09	3.64716E-09	3.64124E-09
25	1.30490E+02	1.20000E+02	9.53683E-07	3.07788E-09	4.35950E-09	2.81956E-13	1.28667E-09	4.20022E-09	4.19348E-09
26	1.30490E+02	1.70000E+02	7.93055E-07	2.55504E-09	3.61908E-09	2.51289E-13	1.06777E-09	3.48694E-09	3.48129E-09
27	1.30490E+02	2.06000E+02	4.72114E-07	1.52680E-09	2.16236E-09	1.17941E-12	6.38663E-10	2.08347E-09	2.08019E-09
28	1.30490E+02	2.15000E+02	3.85767E-07	1.25031E-09	1.77067E-09	1.12067E-12	5.23247E-10	1.70606E-09	1.70343E-09
29	1.30490E+02	2.25000E+02	2.99290E-07	9.72596E-10	1.37726E-09	9.60857E-13	4.07235E-10	1.32702E-09	1.32501E-09
30	3.00000E+01	3.29250E+02	1.94090E-07	6.31825E-10	8.81084E-10	2.15650E-10	2.92641E-10	8.70491E-10	8.65990E-10
31	1.50000E+01	3.29250E+02	3.86587E-07	1.29898E-09	1.79554E-09	6.67153E-10	6.33550E-10	1.79034E-09	1.77960E-09
32	1.00000E+01	3.39090E+02	4.87271E-07	1.70181E-09	2.33205E-09	1.14827E-09	8.69989E-10	2.34137E-09	2.32628E-09
33	5.00000E+00	3.39090E+02	7.03506E-07	2.53587E-09	3.45158E-09	2.02377E-09	1.34209E-09	3.48231E-09	3.45897E-09
34	0.00000E+00	3.39090E+02	7.94466E-07	2.89044E-09	3.92752E-09	2.39343E-09	1.54269E-09	3.96652E-09	3.93984E-09

[a]Detector coordinates are relative to DORT geometry model.
[b]Gamma-Ray dose units are (rem/hour)/(curie).

Table 9. Gamma-Ray Dose Rates at Selected Detector Positions 3.81 cm and 1 m Away From the Surface of the In-Pile Loop LITR HB-2 Carrier Spent Nuclear Fuel Shipping Cask for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Detector Number	Detector Coordinates[a]		Gamma-Ray Dose Rates[b] per One Curie of Source						
	Radius (cm)	Height (cm)	Co-60	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	Cs-137	ORR MFP 20% U-235	ORR MFP 40% U-235	ORR MFP 93% U-235
1	0.00000E+0	-3.81000E+00	3.35943E-04	9.22786E-07	1.31173E-06	1.80222E-08	3.75330E-07	1.27483E-06	1.26894E-06
2	6.00000E+0	-3.81000E+00	3.05943E-04	8.42923E-07	1.19771E-06	2.31747E-08	3.43982E-07	1.16477E-06	1.15931E-06
3	1.20000E+0	-3.81000E+00	1.99995E-04	5.65210E-07	7.99338E-07	6.79031E-08	2.38767E-07	7.82523E-07	7.78351E-07
4	1.80000E+0	-3.81000E+00	4.78921E-05	1.35043E-07	1.91643E-07	6.14076E-09	5.57000E-08	1.86696E-07	1.85809E-07
5	2.40000E+0	-3.81000E+00	8.92007E-06	2.56193E-08	3.63427E-08	1.12358E-09	1.06063E-08	3.53775E-08	3.52204E-08
6	3.06400E+01	9.00000E+00	2.00006E-05	5.67722E-08	8.06595E-08	2.58524E-10	2.31582E-08	7.81530E-08	7.78536E-08
7	3.06400E+01	1.80000E+01	8.28306E-05	2.30268E-07	3.27336E-07	1.53614E-09	9.35404E-08	3.17557E-07	3.16228E-07
8	3.06400E+01	6.00000E+01	1.67406E-04	4.65977E-07	6.62509E-07	2.23585E-09	1.89196E-07	6.42310E-07	6.39656E-07
9	3.06400E+01	1.40000E+02	1.67345E-04	4.65633E-07	6.62020E-07	2.23690E-09	1.89091E-07	6.41808E-07	6.39169E-07
10	3.06400E+01	2.20000E+02	1.67437E-04	4.66053E-07	6.62622E-07	2.23571E-09	1.89228E-07	6.42419E-07	6.39771E-07
11	3.06400E+01	2.64000E+02	8.26655E-05	2.29811E-07	3.26692E-07	1.53341E-09	9.33580E-08	3.16932E-07	3.15607E-07
12	3.06400E+01	2.73000E+02	1.99136E-05	5.65284E-08	8.03169E-08	2.57306E-10	2.30593E-08	7.78185E-08	7.75223E-08
13	2.40000E+01	2.85790E+02	8.92007E-06	2.56194E-08	3.63428E-08	1.12358E-09	1.06063E-08	3.53776E-08	3.52206E-08
14	1.80000E+01	2.85790E+02	4.78919E-05	1.35043E-07	1.91643E-07	6.14076E-09	5.56998E-08	1.86696E-07	1.85809E-07
15	1.20000E+01	2.85790E+02	1.99995E-04	5.65208E-07	7.99336E-07	6.79027E-08	2.38766E-07	7.82520E-07	7.78348E-07
16	6.00000E+00	2.85790E+02	3.05942E-04	8.42919E-07	1.19771E-06	2.31748E-08	3.43980E-07	1.16477E-06	1.15930E-06
17	0.00000E+00	2.85790E+02	3.35942E-04	9.22782E-07	1.31173E-06	1.80222E-08	3.75328E-07	1.27482E-06	1.26894E-06
18	0.00000E+0	-1.00000E+02	2.45388E-05	6.86605E-08	9.74375E-08	3.30409E-09	2.83042E-08	9.49286E-08	9.44759E-08
19	6.00000E+0	-1.00000E+02	2.42730E-05	6.80454E-08	9.65251E-08	3.79076E-09	2.81286E-08	9.40691E-08	9.36190E-08
20	1.20000E+0	-1.00000E+02	2.33701E-05	6.57798E-08	9.32286E-08	4.77186E-09	2.73586E-08	9.09315E-08	9.04911E-08
21	1.80000E+0	-1.00000E+02	2.01119E-05	5.66036E-08	8.01934E-08	4.57924E-09	2.36034E-08	7.82624E-08	7.78769E-08
22	2.40000E+0	-1.00000E+02	1.66834E-05	4.67541E-08	6.62799E-08	3.29406E-09	1.94164E-08	6.46663E-08	6.43460E-08
23	1.26830E+02	9.00000E+00	1.54296E-05	4.30265E-08	6.11678E-08	2.11464E-10	1.74796E-08	5.92952E-08	5.90535E-08
24	1.26830E+02	1.80000E+01	1.84773E-05	5.14496E-08	7.31455E-08	2.65748E-10	2.08965E-08	7.09166E-08	7.06248E-08
25	1.26830E+02	6.00000E+01	3.04513E-05	8.46083E-08	1.20295E-07	4.52412E-10	3.43492E-08	1.16649E-07	1.16163E-07
26	1.26830E+02	1.40000E+02	3.60334E-05	1.00309E-07	1.42611E-07	5.00251E-10	4.07350E-08	1.38261E-07	1.37693E-07
27	1.26830E+02	2.20000E+02	3.08322E-05	8.56704E-08	1.21806E-07	4.56900E-10	3.47806E-08	1.18112E-07	1.17621E-07
28	1.26830E+02	2.64000E+02	1.84703E-05	5.14310E-08	7.31192E-08	2.65632E-10	2.08891E-08	7.08909E-08	7.05994E-08
29	1.26830E+02	2.73000E+02	1.54228E-05	4.30082E-08	6.11419E-08	2.11354E-10	1.74724E-08	5.92700E-08	5.90286E-08
30	2.40000E+01	3.81980E+02	1.66833E-05	4.67539E-08	6.62796E-08	3.29404E-09	1.94163E-08	6.46660E-08	6.43457E-08
31	1.80000E+01	3.81980E+02	2.01118E-05	5.66034E-08	8.01930E-08	4.57921E-09	2.36032E-08	7.82620E-08	7.78765E-08
32	1.20000E+01	3.81980E+02	2.33699E-05	6.57795E-08	9.32282E-08	4.77183E-09	2.73584E-08	9.09310E-08	9.04906E-08
33	6.00000E+00	3.81980E+02	2.42729E-05	6.80450E-08	9.65247E-08	3.79074E-09	2.81284E-08	9.40686E-08	9.36186E-08
34	0.00000E+00	3.81980E+02	2.45387E-05	6.86602E-08	9.74371E-08	3.30407E-09	2.83041E-08	9.49281E-08	9.44755E-08

[a]Detector coordinates are relative to DORT geometry model.
[b]Gamma-Ray dose units are (rem/hour)/(curie).

Table 10. Gamma-Ray Dose Rates at Selected Detector Positions 3.81 cm and 1 m Away From the Surface of the 6.5 Inch HRLEL Carrier Spent Nuclear Fuel Shipping Cask for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Detector Number	Detector Coordinates[a]		Gamma-Ray Dose Rates[b] per One Curie of Source						
	Radius (cm)	Height (cm)	Co-60	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	Cs-137	ORR MFP 20% U-235	ORR MFP 40% U-235	ORR MFP 93% U-235
1	0.00000E+00	-3.81000E+00	3.94209E-04	1.77928E-06	2.29810E-06	3.10675E-06	1.18436E-06	2.42343E-06	2.39979E-06
2	3.00000E+00	-3.81000E+00	3.57054E-04	1.60661E-06	2.07618E-06	2.79089E-06	1.06734E-06	2.18877E-06	2.16742E-06
3	9.00000E+00	-3.81000E+00	1.36824E-04	5.88377E-07	7.65898E-07	9.50529E-07	3.80308E-07	8.04407E-07	7.96543E-07
4	1.40000E+01	-3.81000E+00	5.23141E-05	2.22784E-07	2.90388E-07	3.54986E-07	1.43172E-07	3.04626E-07	3.01656E-07
5	2.50000E+01	-3.81000E+00	3.74095E-06	1.75391E-08	2.24757E-08	3.31199E-08	1.20023E-08	2.38253E-08	2.35981E-08
6	3.30200E+01	2.00000E+01	2.19434E-06	6.74266E-09	9.53221E-09	1.27761E-11	2.78909E-09	9.22275E-09	9.19117E-09
7	3.30200E+01	3.50000E+01	2.17129E-05	6.41927E-08	9.10850E-08	1.39826E-10	2.63899E-08	8.80461E-08	8.77758E-08
8	3.30200E+01	7.50000E+01	3.58875E-05	1.08078E-07	1.53326E-07	4.77746E-11	4.45415E-08	1.47953E-07	1.47561E-07
9	3.30200E+01	1.10000E+02	3.58362E-05	1.07951E-07	1.53154E-07	4.77844E-11	4.44994E-08	1.47823E-07	1.47419E-07
10	3.30200E+01	1.30000E+02	3.16396E-05	9.48612E-08	1.34587E-07	4.54167E-11	3.90879E-08	1.29881E-07	1.29553E-07
11	3.87400E+01	1.41000E+02	1.19541E-06	3.86404E-09	5.47361E-09	1.68612E-12	1.61974E-09	5.28366E-09	5.27547E-09
12	3.87400E+01	1.62000E+02	3.79460E-08	1.30320E-10	1.84907E-10	2.42446E-14	5.51208E-11	1.78498E-10	1.78110E-10
13	3.87400E+01	1.84000E+02	8.21457E-10	2.69950E-12	3.82326E-12	3.50462E-15	1.13814E-12	3.70367E-12	3.69928E-12
14	3.87400E+01	1.90000E+02	4.16525E-10	1.35261E-12	1.91582E-12	2.66436E-15	5.69403E-13	1.85685E-12	1.85447E-12
15	2.00000E+01	2.02210E+02	1.74806E-08	5.77096E-11	8.17160E-11	1.51809E-15	2.42308E-11	7.86831E-11	7.85789E-11
16	1.00000E+01	2.02210E+02	5.98642E-07	2.01390E-09	2.84999E-09	8.37134E-14	8.48741E-10	2.74514E-09	2.74159E-09
17	0.00000E+00	2.02210E+02	1.31988E-06	4.43271E-09	6.27323E-09	2.80601E-13	1.86728E-09	6.04217E-09	6.03447E-09
18	0.00000E+00	-1.00000E+02	1.73441E-05	7.55561E-08	9.83230E-08	1.21879E-07	4.88201E-08	1.02918E-07	1.01973E-07
19	3.00000E+00	-1.00000E+02	1.71236E-05	7.46676E-08	9.71472E-08	1.20714E-07	4.82849E-08	1.01707E-07	1.00771E-07
20	9.00000E+00	-1.00000E+02	1.46794E-05	6.37276E-08	8.29635E-08	1.02430E-07	4.11218E-08	8.68659E-08	8.60609E-08
21	1.40000E+01	-1.00000E+02	1.18299E-05	5.08085E-08	6.62557E-08	8.02751E-08	3.25809E-08	6.93452E-08	6.86975E-08
22	2.50000E+01	-1.00000E+02	7.61162E-06	3.19841E-08	4.18477E-08	4.87821E-08	2.02510E-08	4.37613E-08	4.33465E-08
23	1.29210E+02	2.00000E+01	3.01651E-06	9.08507E-09	1.28889E-08	9.08578E-12	3.74607E-09	1.24410E-08	1.24088E-08
24	1.29210E+02	3.50000E+01	4.08397E-06	1.22671E-08	1.74045E-08	1.01546E-11	5.05521E-09	1.67988E-08	1.67550E-08
25	1.29210E+02	7.50000E+01	6.17273E-06	1.85049E-08	2.62564E-08	1.06369E-11	7.62259E-09	2.53389E-08	2.52729E-08
26	1.29210E+02	1.10000E+02	5.63233E-06	1.69147E-08	2.39993E-08	9.41508E-12	6.97024E-09	2.31591E-08	2.30994E-08
27	1.29210E+02	1.30000E+02	4.14068E-06	1.24766E-08	1.77010E-08	6.19321E-12	5.14478E-09	1.70798E-08	1.70365E-08
28	1.34930E+02	1.41000E+02	3.04849E-06	9.21628E-09	1.30744E-08	3.97217E-12	3.80286E-09	1.26145E-08	1.25831E-08
29	1.34930E+02	1.62000E+02	1.61935E-06	4.93689E-09	7.00210E-09	1.37614E-12	2.04035E-09	6.75456E-09	6.73848E-09
30	1.34930E+02	1.84000E+02	7.51365E-07	2.30130E-09	3.26357E-09	4.51042E-13	9.51872E-10	3.14810E-09	3.14078E-09
31	1.34930E+02	1.90000E+02	6.10532E-07	1.86945E-09	2.65114E-09	3.57450E-13	7.73182E-10	2.55741E-09	2.55146E-09
32	2.00000E+01	2.98400E+02	6.27837E-08	2.15400E-10	3.04701E-10	1.73934E-14	9.11097E-11	2.93505E-10	2.93173E-10
33	1.00000E+01	2.98400E+02	1.03670E-07	3.63315E-10	5.13721E-10	4.21982E-14	1.54241E-10	4.94794E-10	4.94346E-10
34	0.00000E+00	2.98400E+02	1.09517E-07	3.83497E-10	5.42267E-10	4.56218E-14	1.62786E-10	5.22293E-10	5.21815E-10

[a]Detector coordinates are relative to DORT geometry model.
[b]Gamma-Ray dose units are (rem/hour)/(curie).

Table 11. Gamma-Ray Dose Rates at Selected Detector Positions 3.81 cm and 1 m Away From the Surface of the HFIR Hot Scrap and Spent Nuclear Fuel Shipping Cask for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Detector Number	Detector Coordinates[a]		Gamma-Ray Dose Rates[b] per One Curie of Source						
	Radius (cm)	Height (cm)	^{60}Co	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	^{137}Cs	ORR MFP 20% ^{235}U	ORR MFP 40% ^{235}U	ORR MFP 93% ^{235}U
1	0.00000E+00	-3.81000E+00	2.33952E-06	7.69303E-09	1.07656E-08	2.03302E-09	3.49447E-09	1.06010E-08	1.05508E-08
2	9.00000E+00	-2.86000E+00	6.98577E-07	2.40801E-09	3.39480E-09	1.76782E-10	1.04283E-09	3.29270E-09	3.28654E-09
3	1.80000E+01	-2.86000E+00	8.07562E-07	2.61450E-09	3.69893E-09	8.16835E-11	1.10533E-09	3.58410E-09	3.57478E-09
4	2.80000E+01	-2.86000E+00	4.87254E-07	1.61992E-09	2.29277E-09	6.56894E-12	6.82245E-10	2.21238E-09	2.20838E-09
5	3.80000E+01	-2.86000E+00	1.79078E-07	5.88129E-10	8.32590E-10	2.10165E-12	2.47074E-10	8.03122E-10	8.01637E-10
6	4.38200E+01	1.60000E+01	1.61950E-07	5.71091E-10	8.07689E-10	1.09546E-13	2.42850E-10	7.78036E-10	7.77531E-10
7	4.38200E+01	3.10000E+01	1.83374E-06	6.04930E-09	8.56576E-09	6.46230E-13	2.54084E-09	8.25169E-09	8.23777E-09
8	4.38200E+01	5.40000E+01	3.60398E-06	1.18520E-08	1.67787E-08	2.48379E-12	4.97231E-09	1.61680E-08	1.61438E-08
9	4.38200E+01	7.70000E+01	3.71443E-06	1.22531E-08	1.73467E-08	1.76057E-11	5.14508E-09	1.67125E-08	1.66893E-08
10	4.38200E+01	1.00000E+02	3.68462E-06	1.21529E-08	1.71817E-08	3.23702E-10	5.14196E-09	1.65809E-08	1.65546E-08
11	4.38200E+01	1.23000E+02	5.12732E-05	1.99963E-07	2.65249E-07	2.57702E-07	1.19622E-07	2.75147E-07	2.72594E-07
12	4.38200E+01	1.34000E+02	2.36028E-06	7.98814E-09	1.10196E-08	4.25416E-09	3.91010E-09	1.09663E-08	1.09105E-08
13	4.38200E+01	1.45000E+02	1.91411E-07	6.79733E-10	9.31020E-10	4.30450E-10	3.43816E-10	9.32018E-10	9.26614E-10
14	3.20000E+01	1.52720E+02	2.89108E-07	9.78186E-10	1.38369E-09	2.33247E-12	4.13064E-10	1.33403E-09	1.33228E-09
15	2.12500E+01	1.52720E+02	4.19370E-06	1.30722E-08	1.85088E-08	4.26577E-10	5.48615E-09	1.79340E-08	1.78828E-08
16	1.10000E+01	1.51450E+02	6.41341E-06	2.07393E-08	2.93700E-08	1.41414E-11	8.67577E-09	2.82958E-08	2.82509E-08
17	0.00000E+00	1.51450E+02	8.21031E-06	2.63923E-08	3.73823E-08	8.19659E-12	1.10282E-08	3.60223E-08	3.59557E-08
18	0.00000E+00	-1.00000E+02	1.25505E-07	4.24985E-10	5.98004E-10	5.38811E-11	1.86421E-10	5.82272E-10	5.80594E-10
19	9.00000E+00	-9.90500E+01	1.25687E-07	4.23895E-10	5.96882E-10	4.82933E-11	1.85113E-10	5.80828E-10	5.79178E-10
20	1.80000E+01	-9.90500E+01	1.15348E-07	3.84228E-10	5.42563E-10	2.26713E-11	1.64715E-10	5.26532E-10	5.25165E-10
21	2.80000E+01	-9.90500E+01	9.95551E-08	3.31416E-10	4.68295E-10	1.45757E-11	1.41412E-10	4.53872E-10	4.52776E-10
22	3.80000E+01	-9.90500E+01	8.55284E-08	2.86716E-10	4.05234E-10	9.80159E-12	1.22130E-10	3.92308E-10	3.91445E-10
23	1.40010E+02	1.60000E+01	3.83127E-07	1.30209E-09	1.82463E-09	2.69153E-10	5.84264E-10	1.77839E-09	1.77363E-09
24	1.40010E+02	3.10000E+01	5.33494E-07	1.80540E-09	2.52946E-09	3.83503E-10	8.10890E-10	2.46641E-09	2.45961E-09
25	1.40010E+02	5.40000E+01	7.70823E-07	2.60614E-09	3.64321E-09	6.80038E-10	1.18679E-09	3.56354E-09	3.55222E-09
26	1.40010E+02	7.70000E+01	9.91316E-07	3.37773E-09	4.69556E-09	1.27434E-09	1.59109E-09	4.62698E-09	4.60810E-09
27	1.40010E+02	1.00000E+02	1.25791E-06	4.37810E-09	6.02107E-09	2.61293E-09	2.19377E-09	6.01487E-09	5.98078E-09
28	1.40010E+02	1.23000E+02	2.11686E-06	8.07131E-09	1.08174E-08	8.77957E-09	4.60486E-09	1.10777E-08	1.09905E-08
29	1.40010E+02	1.34000E+02	1.80253E-06	6.56254E-09	8.87867E-09	6.02358E-09	3.58052E-09	9.02712E-09	8.95965E-09
30	1.40010E+02	1.45000E+02	1.12676E-06	3.89465E-09	5.33585E-09	2.65477E-09	1.99259E-09	5.36384E-09	5.32851E-09
31	3.20000E+01	2.48910E+02	6.13923E-07	1.97430E-09	2.79576E-09	1.84279E-11	8.27384E-10	2.69826E-09	2.69308E-09
32	2.12500E+01	2.48910E+02	7.59203E-07	2.43609E-09	3.44945E-09	2.98062E-11	1.02136E-09	3.33009E-09	3.32353E-09
33	1.10000E+01	2.47640E+02	8.52423E-07	2.73523E-09	3.87390E-09	1.81814E-11	1.14478E-09	3.73760E-09	3.73058E-09
34	0.00000E+00	2.47640E+02	8.81912E-07	2.82948E-09	4.00765E-09	1.40253E-11	1.18356E-09	3.86582E-09	3.85868E-09

[a]Detector coordinates are relative to DORT geometry model.
[b]Gamma-Ray dose units are (rem/hour)/(curie).

Table 12. Gamma-Ray Dose Rates at Selected Detector Positions 3.81 cm and 1 m Away From the Surface of the 10 Inch ORR Experiment Removal Shield Spent Nuclear Fuel Shipping Cask for Representative Sources Stored in the SWSA Area Sites, Building 7827.

Detector Number	Detector Coordinates[a]		Gamma-Ray Dose Rates[b] per One Curie of Source							
	Radius (cm)	Height (cm)	Co-60	LWR MFP 25 MWd/kgU	LWR MFP 50 MWd/kgU	Cs-137	ORR MFP 20% U-235	ORR MFP 40% U-235	ORR MFP 93% U-235
1	0.00000E+00	0.00000E+00	4.99486E-06	1.54614E-08	2.18905E-08	4.85992E-10	6.47467E-09	2.11671E-08	2.11192E-08
2	9.00000E+00	0.00000E+00	4.52248E-06	1.40544E-08	1.98742E-08	8.37599E-10	5.94115E-09	1.92564E-08	1.92038E-08
3	1.80000E+0	-3.81000E+00	2.05460E-06	6.27199E-09	8.83646E-09	1.01609E-09	2.72748E-09	8.66584E-09	8.62479E-09
4	2.60000E+0	-3.81000E+00	6.80733E-07	2.07576E-09	2.93350E-09	1.98421E-10	8.84744E-10	2.86493E-09	2.85261E-09
5	4.06400E+01	2.70000E+01	1.93143E-06	5.78705E-09	8.20800E-09	6.97602E-11	2.39462E-09	7.93735E-09	7.91432E-09
6	4.06400E+01	8.90000E+01	2.25013E-06	7.07156E-09	1.00135E-08	1.32860E-10	2.95773E-09	9.66301E-09	9.64231E-09
7	4.06400E+01	1.51000E+02	2.30304E-06	7.30361E-09	1.03116E-08	5.18148E-10	3.10925E-09	9.98005E-09	9.95490E-09
8	4.38200E+01	2.13000E+02	2.39431E-05	8.43446E-08	1.14168E-07	7.82158E-08	4.59255E-08	1.16360E-07	1.15420E-07
9	3.55600E+01	2.73000E+02	5.98499E-05	1.74223E-07	2.45245E-07	3.31648E-08	7.55966E-08	2.39565E-07	2.38483E-07
10	4.38200E+01	3.33000E+02	3.66634E-05	1.21883E-07	1.66832E-07	8.78989E-08	6.25867E-08	1.68038E-07	1.66838E-07
11	3.55600E+01	3.93000E+02	5.95397E-05	1.72436E-07	2.43045E-07	2.86662E-08	7.42139E-08	2.37178E-07	2.36134E-07
12	4.38200E+01	4.53000E+02	2.45343E-05	8.25796E-08	1.12717E-07	6.37515E-08	4.30294E-08	1.13805E-07	1.12975E-07
13	3.55600E+01	4.65000E+02	5.15851E-05	2.25169E-07	2.91543E-07	3.84092E-07	1.48068E-07	3.05029E-07	3.02356E-07
14	2.40000E+01	4.81360E+02	1.76315E-05	5.30378E-08	7.41611E-08	1.79702E-08	2.42143E-08	7.37133E-08	7.32146E-08
15	1.80000E+01	4.81360E+02	3.45060E-05	1.04734E-07	1.46003E-07	4.11035E-08	4.85880E-08	1.44999E-07	1.44072E-07
16	9.00000E+00	4.78180E+02	9.92879E-05	2.80159E-07	3.96742E-07	2.40959E-08	1.17022E-07	3.86510E-07	3.84726E-07
17	0.00000E+00	4.78180E+02	1.13646E-04	3.17448E-07	4.50508E-07	1.47984E-08	1.30688E-07	4.38079E-07	4.36155E-07
18	0.00000E+0	-9.61900E+01	4.96810E-07	1.55793E-09	2.20357E-09	8.11260E-11	6.58447E-10	2.13678E-09	2.13067E-09
19	9.00000E+0	-9.61900E+01	4.85112E-07	1.52198E-09	2.15255E-09	8.17796E-11	6.43646E-10	2.08767E-09	2.08165E-09
20	1.80000E+0	-1.00000E+02	4.18406E-07	1.31194E-09	1.85504E-09	7.85526E-11	5.55821E-10	1.80023E-09	1.79487E-09
21	2.60000E+0	-1.00000E+02	3.44729E-07	1.07260E-09	1.51626E-09	7.50869E-11	4.55193E-10	1.47317E-09	1.46840E-09
22	1.36830E+02	2.70000E+01	5.99346E-07	2.37052E-09	3.15725E-09	2.79235E-09	1.38396E-09	3.21055E-09	3.19085E-09
23	1.36830E+02	8.90000E+01	1.10183E-06	4.25397E-09	5.68978E-09	4.69922E-09	2.43683E-09	5.76954E-09	5.73472E-09
24	1.36830E+02	1.51000E+02	2.35205E-06	8.73662E-09	1.17250E-08	9.23179E-09	4.92898E-09	1.18877E-08	1.18110E-08
25	1.40010E+02	2.13000E+02	8.80853E-06	2.99414E-08	4.07491E-08	2.44516E-08	1.57800E-08	4.09541E-08	4.06942E-08
26	1.31750E+02	2.73000E+02	1.94467E-05	7.11599E-08	9.53018E-08	7.88115E-08	4.05498E-08	9.70137E-08	9.63229E-08
27	1.40010E+02	3.33000E+02	1.54312E-05	5.11899E-08	6.99762E-08	3.77500E-08	2.63656E-08	7.00750E-08	6.96448E-08
28	1.31750E+02	3.93000E+02	1.76180E-05	6.39782E-08	8.58058E-08	6.91283E-08	3.62085E-08	8.71872E-08	8.65823E-08
29	1.40010E+02	4.53000E+02	9.02993E-06	3.10276E-08	4.20909E-08	2.72214E-08	1.66210E-08	4.24239E-08	4.21453E-08
30	1.31750E+02	4.65000E+02	9.43877E-06	3.56568E-08	4.74621E-08	4.34044E-08	2.08945E-08	4.85874E-08	4.82221E-08
31	2.40000E+01	5.77550E+02	7.22467E-06	2.09135E-08	2.94967E-08	3.35878E-09	8.98891E-09	2.88785E-08	2.87336E-08
32	1.80000E+01	5.77550E+02	8.49160E-06	2.45410E-08	3.46460E-08	3.45498E-09	1.04815E-08	3.38803E-08	3.37150E-08
33	9.00000E+00	5.74370E+02	9.86148E-06	2.84246E-08	4.01542E-08	3.65022E-09	1.20881E-08	3.92404E-08	3.90512E-08
34	0.00000E+00	5.74370E+02	1.01021E-05	2.90881E-08	4.10978E-08	3.65627E-09	1.23575E-08	4.01569E-08	3.99635E-08

[a]Detector coordinates are relative to DORT geometry model.
[b]Gamma-Ray dose units are (rem/hour)/(curie).

8.0 UNCERTAINTIES

There are several areas where the uncertainties in the computational model, source distribution, and cross section data may cause significant perturbations to the reported results. An estimate of the magnitude of these perturbations is as follows:

1) The sources are assumed to be uniformly distributed throughout the cavity of the casks and not in isolated positions within the cavity. Possible error: increase in dose of a factor of 10.

2) Due to lack of information on the composition of the source material, it is assumed to be void; thus there is no self-absorption within the source region of the computational model. Possible error: decrease of dose of a factor of 10.

3) The ORIGEN-S code is a point-depletion code; thus, it assumes that all points in the reactor see the same flux/power. Possible error: small decrease of dose.

4) The ORIGEN-S calculations assume the cross-section library is appropriate for the situation. For the two PWR cases, one-dimensional radiation transport calculations were made with a broad-group library, then were collapsed to the ORIGEN-S group structure; thus, the PWR ORIGEN-S calculations should be very good. For the ORR cases, the same PWR ORIGEN-S cross-section libraries were used; this will inherently include some uncertainty in the results. Possible error: increase in dose of a factor of 2.

5) The DORT radiation transport calculations used Legendre P_5 cross sections. Possible error: negligible increase in dose.

In consideration of the possible contributors to the calculational uncertainties listed above, the first two dealing with the source descriptions within the calculational models represent the two largest uncertainties. It should be noted that they are estimated to be equal in magnitude and may essentially negate each other for a given calculation.

9.0 EXAMPLE APPLICATIONS OF DOSE AND THERMAL HEATING DATA TABLES

The dose and heating rate data presented in Tables 6 - 12 of this report are reported on a per-curie basis, so cask and SNF source dependent expected dose and heating rates can be readily calculated for all the projected sequence of moves for storage facility 7827 in the SWSA. To demonstrate the application of the tabulated dose and heating rate data, two examples are given below.

Example 1: Transfer of container with Accountability Transfer Number (ATN) 1802 from Well 5 to Well 1. This SNF package contains sections of an H.B. Robinson fuel assembly which was estimated to contain 1,200 Ci of MFP when it was loaded into Well 5 in April 1979. The cask identified in the Transportation Plan to accommodate this move is the Loop Transport Carrier. To be conservative, assume there is no reduction in the source strength, whereas in reality, the source has decayed to a lower value (Figure 7 can be used to determine actual source strength, if desired). Furthermore, assume the source has a high burnup rate and use the LWR MFP (50 MWd/kgU) source data which will yield the higher doses and heating rates. From Table 6, the alpha and beta heating rate is determined to be 3.24 W [2.70E-3 W/Ci x 1,200 Ci}]. From Table 7, the photon heating rate is determined to be 1.10 W. Therefore, the total thermal load on the cask for this SNF package is 4.34 W. To determine the maximum dose rates on the surface and at one meter from the surface of the cask, look in Table 8 under the 50 MWd/kgU LWR MFP source column and find the maximum dose rates. For the surface dose, this occurs at detector 17, and for the one meter distance dose, this occurs at detector 25. Multiply the dose rates (per curie) from Table 8 at these two detector locations by the number of source curies to yield the maximum expected dose rate for this SNF package in this cask. This yields a surface dose rate of 9.66E-02 mrem/h and a one meter distance dose rate of 5.23E-03 mrem/h. From these dose rates and heating rates, this SNF package can safely be transported using this cask and not exceed the transportation guidelines.

In the above analysis, the MFP source strength was not decayed to the level which would be present after being stored in the well for 16 years. This represents a conservative approach and will always yield higher heating rates and dose rates than will actually occur. To be more precise, the above analysis should be repeated with the source strength corrected using Figure 7 to account for decay.

Example 2: Transfer of ATN 1340 from Well 1 to Well 26. This SNF package contains irradiated stainless steel clad with fuel removed and is estimated to contain approximately 1,000 Ci of ^{60}Co when it was loaded in the well in December 1976. The cask identified in the Transportation Plan to accommodate this move is the 6.5-Inch HRLEL Carrier. ^{60}Co has a 5.27 year half life. Assuming the package will be moved in June 1995, the source strength has decayed to 87.8 Ci [N=N0*exp((-0.693/5.27)*18.5)] where N is the source strength in June 1995, and N0 is the initial source strength back in December 1976. From Table 6, the alpha and beta heating rate is 5.066E-02 W, and from Table 7, the photon heating rate is 1.295 W. This gives a total heating rate of 1.35 W, which is well within the Transportation Plan guidelines. To obtain the maximum dose rates on the surface and at one meter from the surface, look in Table 10 under the ^{60}Co source column. Detector 1 yields the highest dose rate of 34.61 mrem/h on the surface of the cask, and Detector 18 yields the highest dose rate of 1.52 mrem/h at one meter distance from the cask surface. Again these dose rates are within the guidelines presented in the Transportation Plan.

The procedure demonstrated in the above two examples is applicable to all of the SNF packages to be transported. In those cases where there is a combination of sources (i.e., ^{60}Co and MFP) then the above analysis should be performed for each source and the results combined to obtain the total heating and dose rates.

10.0 REFERENCES

1. C. Y. Fu and D. T. Ingersoll. "VELM61 and VELM22: Multigroup Cross-Section Libraries for Sodium-Cooled Reactor Shield Analysis," ORNL/TM-10302, April 1987.

2. C. R. Weisbin, R. W. Roussin, J. Wagschal, J. E. White, and R. Q. Wright. "VITAMIN-E: An ENDF/B-V Multigroup Cross-Section Library for LMFBR Core and Shield, LWR Shield, Dosimetry and Fussion-Blanket Technology," ORNL-5505 (ENDF-274), 1979. The release by RSIC, dated August 1985, is denoted as DLC-133B.

3. W. A. Rhoades and M. B. Emmett, "DOS: The Discrete Ordinates System," ORNL/TM-8362, September 1982.

4. N. M. Greene, W. E. Ford III, L. M. Petrie, and J. W. Arwood. "AMPX-77: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Cross--Section Libraries from ENDF/B-IV and/or ENDF/B-V," ORNL/CSD/TM-283, October 1992.

5. G. C. Haynes and W. W. Engle. "AMP - Activity Manipulation Program," ORNL-CF-75-6-53, June 1975.

6. O. W. Hermann, C. V. Parks, and J. P. Renier. "Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data," NUREG/CR-5625 (ORNL-6698), September 1994.

7. J. A. Klein maintains the SNF Database at ORNL.

8. O. W. Hermann and R. M. Westfall. "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms," as described in Sect. F7 *of SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation,* NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I-III. Available from Radiation Shielding Information Center at Oak Ridge National Laboratory as CCC-545.

9. R. L. Sean. "Summary Report on the HFED Miniplate Irradiations for the RERTR Program," ORNL-6539, April 1989.

10. W. A. Rhoades and R. L. Childs, "The DORT Two-Dimensional Discrete Ordinates Transport Code,"*Nuclear Science & Engineering* 99, 1, 88-89 (May 1988).

11. D. T. Ingersoll and C. O. Slater, "DOGS - A Collection of Graphics For Support Of Discrete Ordinates Codes," ORNL/TM-7188, March 1980.

12. R. L. Childs, "The FALSTF Last-Flight Computer Program," ORNL/TM-12675, to be published.

13. ANSI/ANS-6.1.1-1977, American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors (1977).

APPENDIX A

Gamma Source Spectra

Table A.1 Gamma Source Spectra (gammas/s.Ci), VELM 23 Grp, 25MWd/kgU, 18kW/kgU, Continuous Operation = 1388.9d

Energy Interval (MeV)		Decay Period 1 Y	5 Y	10 Y	15 Y	20 Y	25 Y	30 Y	35 Y	40 Y	45 Y
1.00E-02	2.00E-02	3.65E+09	1.83E+09	1.64E+09	1.72E+09	1.79E+09	1.85E+09	1.90E+09	1.95E+09	2.01E+09	2.05E+09
2.00E-02	4.50E-02	4.50E+09	2.38E+09	2.12E+09	2.15E+09	2.18E+09	2.21E+09	2.24E+09	2.27E+09	2.30E+09	2.32E+09
4.50E-02	7.00E-02	1.78E+09	8.74E+08	8.03E+08	8.70E+08	9.33E+08	9.94E+08	1.06E+09	1.13E+09	1.20E+09	1.27E+09
7.00E-02	1.00E-01	1.42E+09	6.29E+08	5.13E+08	5.16E+08	5.20E+08	5.24E+08	5.31E+08	5.35E+08	5.42E+08	5.46E+08
1.00E-01	1.50E-01	1.87E+09	7.10E+08	5.45E+08	5.22E+08	5.03E+08	4.88E+08	4.78E+08	4.69E+08	4.66E+08	4.61E+08
1.50E-01	3.00E-01	1.29E+09	5.40E+08	4.34E+08	4.43E+08	4.50E+08	4.55E+08	4.60E+08	4.63E+08	4.68E+08	4.69E+08
3.00E-01	4.00E-01	4.87E+08	1.81E+08	1.37E+08	1.41E+08	1.45E+08	1.48E+08	1.51E+08	1.52E+08	1.54E+08	1.55E+08
4.00E-01	5.10E-01	9.13E+08	3.00E+08	1.14E+08	9.24E+07	8.81E+07	8.74E+07	8.81E+07	8.86E+07	8.96E+07	8.99E+07
5.10E-01	6.00E-01	8.67E+08	4.80E+08	1.36E+08	5.85E+07	3.84E+07	3.16E+07	2.84E+07	2.62E+07	2.48E+07	2.36E+07
6.00E-01	7.00E-01	3.68E+09	6.49E+09	6.76E+09	6.96E+09	7.19E+09	7.38E+09	7.58E+09	7.73E+09	7.91E+09	8.01E+09
7.00E-01	1.00E+00	2.65E+09	1.43E+09	5.27E+08	2.52E+08	1.66E+08	1.29E+08	1.06E+08	8.97E+07	7.77E+07	6.81E+07
1.00E+00	1.50E+00	3.33E+08	3.05E+08	2.10E+08	1.59E+08	1.24E+08	9.82E+07	7.86E+07	6.30E+07	5.14E+07	4.21E+07
1.50E+00	2.00E+00	4.03E+07	1.41E+07	7.85E+06	6.36E+06	5.20E+06	4.26E+06	3.54E+06	2.97E+06	2.54E+06	2.19E+06
2.00E+00	2.50E+00	5.66E+07	6.54E+06	1.77E+05	2.25E+04	1.89E+04	1.91E+04	1.95E+04	1.97E+04	2.00E+04	2.01E+04
2.50E+00	3.00E+00	9.84E+05	2.16E+05	1.11E+04	1.93E+03	1.79E+03	1.97E+03	2.17E+03	2.36E+03	2.58E+03	2.79E+03
3.00E+00	4.00E+00	1.19E+05	2.69E+04	1.29E+03	8.08E+01	3.19E+01	2.90E+01	2.80E+01	2.69E+01	2.60E+01	2.50E+01
4.00E+00	5.00E+00	4.24E+00	8.83E+00	1.03E+01	1.04E+01	1.01E+01	9.75E+00	9.42E+00	9.06E+00	8.76E+00	8.43E+00
5.00E+00	6.00E+00	1.43E+00	2.98E+00	3.48E+00	3.49E+00	3.40E+00	3.28E+00	3.17E+00	3.05E+00	2.95E+00	2.83E+00
6.00E+00	7.00E+00	4.81E-01	1.00E+00	1.17E+00	1.18E+00	1.15E+00	1.11E+00	1.07E+00	1.03E+00	9.91E-01	9.53E-01
7.00E+00	7.50E+00	1.03E-01	2.15E-01	2.52E-01	2.53E-01	2.46E-01	2.38E-01	2.29E-01	2.20E-01	2.13E-01	2.05E-01
7.50E+00	8.00E+00	6.00E-02	1.25E-01	1.46E-01	1.46E-01	1.43E-01	1.38E-01	1.33E-01	1.28E-01	1.23E-01	1.19E-01
8.00E+00	1.00E+01	7.08E-02	1.48E-01	1.73E-01	1.73E-01	1.68E-01	1.63E-01	1.57E-01	1.51E-01	1.46E-01	1.40E-01
1.00E+01	1.40E+01	3.36E-03	6.99E-03	8.18E-03	8.19E-03	7.98E-03	7.70E-03	7.43E-03	7.14E-03	6.89E-03	6.62E-03
Totals		2.35E+10	1.62E+10	1.40E+10	1.39E+10	1.41E+10	1.44E+10	1.47E+10	1.50E+10	1.53E+10	1.55E+10

Table A.2 Gamma Source Spectra (gammas/s.Ci), VELM 23 Grp, 50MWd/kgU, 40kW/kgU, Continuous Operation = 1250d

		Decay Period							
Energy Interval (MeV)		1 Y	5 Y	10 Y	15 Y	20 Y	25 Y	30 Y	35 Y
1.00E-02	2.00E-02	3.76E+09	1.95E+09	1.73E+09	1.81E+09	1.87E+09	1.92E+09	1.97E+09	2.02E+09
2.00E-02	4.50E-02	4.63E+09	2.56E+09	2.25E+09	2.26E+09	2.27E+09	2.29E+09	2.31E+09	2.33E+09
4.50E-02	7.00E-02	1.84E+09	9.24E+08	8.27E+08	8.81E+08	9.32E+08	9.83E+08	1.04E+09	1.09E+09
7.00E-02	1.00E-01	1.47E+09	6.93E+08	5.54E+08	5.45E+08	5.42E+08	5.43E+08	5.46E+08	5.50E+08
1.00E-01	1.50E-01	1.95E+09	8.26E+08	6.39E+08	5.95E+08	5.60E+08	5.33E+08	5.14E+08	4.99E+08
1.50E-01	3.00E-01	1.32E+09	5.81E+08	4.61E+08	4.66E+08	4.70E+08	4.73E+08	4.76E+08	4.78E+08
3.00E-01	4.00E-01	5.00E+08	1.91E+08	1.42E+08	1.46E+08	1.49E+08	1.52E+08	1.54E+08	1.56E+08
4.00E-01	5.10E-01	9.57E+08	3.37E+08	1.24E+08	9.71E+07	9.15E+07	9.02E+07	9.05E+07	9.09E+07
5.10E-01	6.00E-01	1.10E+09	7.25E+08	2.09E+08	8.13E+07	4.85E+07	3.78E+07	3.28E+07	2.97E+07
6.00E-01	7.00E-01	4.40E+09	7.40E+09	7.20E+09	7.23E+09	7.40E+09	7.58E+09	7.77E+09	7.92E+09
7.00E-01	1.00E+00	3.47E+09	2.32E+09	8.35E+08	3.71E+08	2.31E+08	1.73E+08	1.39E+08	1.14E+08
1.00E+00	1.50E+00	4.19E+08	4.44E+08	3.07E+08	2.28E+08	1.76E+08	1.38E+08	1.09E+08	8.60E+07
1.50E+00	2.00E+00	4.34E+07	1.79E+07	1.10E+07	8.85E+06	7.14E+06	5.76E+06	4.68E+06	3.85E+06
2.00E+00	2.50E+00	5.81E+07	7.23E+06	1.99E+05	2.37E+04	1.95E+04	1.97E+04	2.00E+04	2.03E+04
2.50E+00	3.00E+00	1.03E+06	2.43E+05	1.43E+04	4.33E+03	4.50E+03	4.98E+03	5.46E+03	5.95E+03
3.00E+00	4.00E+00	1.25E+05	3.02E+04	1.55E+03	1.73E+02	1.14E+02	1.07E+02	1.03E+02	9.78E+01
4.00E+00	5.00E+00	1.18E+01	3.31E+01	3.93E+01	3.91E+01	3.78E+01	3.62E+01	3.46E+01	3.30E+01
5.00E+00	6.00E+00	3.98E+00	1.11E+01	1.32E+01	1.32E+01	1.27E+01	1.22E+01	1.17E+01	1.11E+01
6.00E+00	7.00E+00	1.34E+00	3.75E+00	4.46E+00	4.44E+00	4.29E+00	4.11E+00	3.93E+00	3.74E+00
7.00E+00	7.50E+00	2.88E-01	8.07E-01	9.58E-01	9.54E-01	9.23E-01	8.84E-01	8.45E-01	8.05E-01
7.50E+00	8.00E+00	1.67E-01	4.68E-01	5.56E-01	5.53E-01	5.35E-01	5.12E-01	4.90E-01	4.67E-01
8.00E+00	1.00E+01	1.97E-01	5.52E-01	6.56E-01	6.53E-01	6.32E-01	6.05E-01	5.79E-01	5.51E-01
1.00E+01	1.40E+01	9.36E-03	2.62E-02	3.11E-02	3.10E-02	2.99E-02	2.87E-02	2.74E-02	2.61E-02
Totals		2.59E+10	1.90E+10	1.53E+10	1.47E+10	1.47E+10	1.49E+10	1.51E+10	1.54E+10

Table A.3 Gamma Source Spectra (gammas/s.Ci), VELM 23 Grp. HFED UAl, Module 1, Slot 1, 40.24% Enrichment, 94% Depleted, 7.65E-4 MW/gU

		Decay Period									
Energy Interval (MeV)		1Y	5Y	10Y	15Y	20Y	25Y	30Y	35Y	40Y	45Y
1.00E-02	2.00E-02	4.01E+09	2.59E+09	2.41E+09	2.46E+09	2.49E+09	2.50E+09	2.51E+09	2.51E+09	2.51E+09	2.51E+09
2.00E-02	4.50E-02	5.17E+09	3.19E+09	2.87E+09	2.86E+09	2.84E+09	2.83E+09	2.81E+09	2.79E+09	2.77E+09	2.77E+09
4.50E-02	7.00E-02	1.94E+09	1.17E+09	1.06E+09	1.07E+09	1.08E+09	1.08E+09	1.08E+09	1.08E+09	1.08E+09	1.08E+09
7.00E-02	1.00E-01	1.61E+09	8.85E+08	7.46E+08	7.37E+08	7.28E+08	7.22E+08	7.18E+08	7.13E+08	7.08E+08	7.06E+08
1.00E-01	1.50E-01	2.35E+09	1.03E+09	7.75E+08	7.33E+08	6.95E+08	6.65E+08	6.41E+08	6.21E+08	6.06E+08	5.95E+08
1.50E-01	3.00E-01	1.37E+09	7.39E+08	6.34E+08	6.40E+08	6.38E+08	6.35E+08	6.30E+08	6.25E+08	6.20E+08	6.16E+08
3.00E-01	4.00E-01	5.16E+08	2.47E+08	2.02E+08	2.07E+08	2.08E+08	2.09E+08	2.09E+08	2.08E+08	2.07E+08	2.06E+08
4.00E-01	5.10E-01	7.04E+08	3.63E+08	1.65E+08	1.33E+08	1.26E+08	1.23E+08	1.22E+08	1.21E+08	1.20E+08	1.20E+08
5.10E-01	6.00E-01	1.22E+09	1.45E+09	4.35E+08	1.35E+08	6.38E+07	4.52E+07	3.85E+07	3.50E+07	3.26E+07	3.09E+07
6.00E-01	7.00E-01	5.07E+09	1.04E+10	8.74E+09	8.06E+09	7.98E+09	8.02E+09	8.07E+09	8.10E+09	8.12E+09	8.16E+09
7.00E-01	1.00E+00	5.69E+09	5.03E+09	1.63E+09	5.37E+08	2.60E+08	1.75E+08	1.37E+08	1.14E+08	9.75E+07	8.55E+07
1.00E+00	1.50E+00	4.23E+08	5.84E+08	3.37E+08	2.20E+08	1.61E+08	1.24E+08	9.75E+07	7.74E+07	6.23E+07	5.10E+07
1.50E+00	2.00E+00	3.84E+07	1.71E+07	1.03E+07	8.35E+06	6.74E+06	5.47E+06	4.49E+06	3.74E+06	3.16E+06	2.74E+06
2.00E+00	2.50E+00	8.01E+07	1.32E+07	3.07E+05	3.27E+04	2.75E+04	2.74E+04	2.74E+04	2.73E+04	2.72E+04	2.71E+04
2.50E+00	3.00E+00	5.40E+05	1.82E+05	1.90E+04	1.41E+04	1.59E+04	1.75E+04	1.89E+04	2.03E+04	2.17E+04	2.33E+04
3.00E+00	4.00E+00	6.01E+04	2.15E+04	1.28E+03	2.26E+02	1.73E+02	1.61E+02	1.53E+02	1.45E+02	1.38E+02	1.32E+02
4.00E+00	5.00E+00	1.99E+01	6.60E+01	6.79E+01	6.20E+01	5.78E+01	5.45E+01	5.16E+01	4.89E+01	4.65E+01	4.45E+01
5.00E+00	6.00E+00	6.71E+00	2.22E+01	2.29E+01	2.09E+01	1.95E+01	1.84E+01	1.74E+01	1.65E+01	1.57E+01	1.50E+01
6.00E+00	7.00E+00	2.26E+00	7.49E+00	7.70E+00	7.04E+00	6.56E+00	6.18E+00	5.85E+00	5.55E+00	5.27E+00	5.05E+00
7.00E+00	7.50E+00	4.86E-01	1.61E+00	1.66E+00	1.51E+00	1.41E+00	1.33E+00	1.26E+00	1.19E+00	1.13E+00	1.08E+00
7.50E+00	8.00E+00	2.82E-01	9.34E-01	9.60E-01	8.78E-01	8.17E-01	7.70E-01	7.29E-01	6.91E-01	6.57E-01	6.29E-01
8.00E+00	1.00E+01	3.33E-01	1.10E+00	1.13E+00	1.04E+00	9.65E-01	9.10E-01	8.62E-01	8.17E-01	7.76E-01	7.43E-01
1.00E+01	1.40E+01	1.58E-02	5.23E-02	5.38E-02	4.91E-02	4.57E-02	4.31E-02	4.08E-02	3.87E-02	3.68E-02	3.52E-02
Totals		3.02E+10	2.78E+10	2.00E+10	1.78E+10	1.73E+10	1.71E+10	1.71E+10	1.70E+10	1.69E+10	1.69E+10

Table A.4 Gamma Source Spectra (gammas/s.Ci), VELM 23 Grp. HFED U3O8, Module 5, Slot 10, 93.21% Enrichment, 80% Depleted, 2.65E-3 MW/gU

Energy Interval (MeV)		Decay Period 1Y	5Y	10Y	15Y	20Y	25Y	30Y	35Y	40Y	45Y
1.00E-02	2.00E-02	3.95E+09	2.66E+09	2.51E+09	2.57E+09	2.58E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.58E+09
2.00E-02	4.50E-02	5.21E+09	3.35E+09	3.01E+09	3.02E+09	3.00E+09	2.97E+09	2.96E+09	2.94E+09	2.92E+09	2.91E+09
4.50E-02	7.00E-02	1.91E+09	1.23E+09	1.13E+09	1.15E+09	1.15E+09	1.14E+09	1.14E+09	1.13E+09	1.13E+09	1.12E+09
7.00E-02	1.00E-01	1.60E+09	9.32E+08	7.97E+08	7.93E+08	7.83E+08	7.75E+08	7.70E+08	7.65E+08	7.60E+08	7.55E+08
1.00E-01	1.50E-01	2.45E+09	1.12E+09	8.17E+08	7.78E+08	7.39E+08	7.07E+08	6.83E+08	6.64E+08	6.48E+08	6.35E+08
1.50E-01	3.00E-01	1.34E+09	7.73E+08	6.82E+08	6.92E+08	6.89E+08	6.84E+08	6.79E+08	6.74E+08	6.68E+08	6.63E+08
3.00E-01	4.00E-01	4.99E+08	2.59E+08	2.19E+08	2.25E+08	2.26E+08	2.26E+08	2.26E+08	2.25E+08	2.24E+08	2.23E+08
4.00E-01	5.10E-01	5.26E+08	3.10E+08	1.68E+08	1.43E+08	1.36E+08	1.33E+08	1.32E+08	1.31E+08	1.30E+08	1.29E+08
5.10E-01	6.00E-01	8.70E+08	1.27E+09	3.95E+08	1.28E+08	6.41E+07	4.69E+07	4.06E+07	3.72E+07	3.48E+07	3.30E+07
6.00E-01	7.00E-01	3.93E+09	9.87E+09	8.59E+09	8.03E+09	7.95E+09	7.97E+09	8.02E+09	8.06E+09	8.08E+09	8.10E+09
7.00E-01	1.00E+00	6.12E+09	4.52E+09	1.49E+09	5.09E+08	2.56E+08	1.77E+08	1.40E+08	1.18E+08	1.01E+08	8.91E+07
1.00E+00	1.50E+00	3.28E+08	5.43E+08	3.28E+08	2.18E+08	1.61E+08	1.24E+08	9.80E+07	7.83E+07	6.33E+07	5.20E+07
1.50E+00	2.00E+00	3.30E+07	1.63E+07	1.04E+07	8.45E+06	6.83E+06	5.55E+06	4.58E+06	3.84E+06	3.27E+06	2.84E+06
2.00E+00	2.50E+00	8.62E+07	1.61E+07	3.39E+05	3.43E+04	2.95E+04	2.94E+04	2.94E+04	2.94E+04	2.92E+04	2.91E+04
2.50E+00	3.00E+00	2.75E+05	9.98E+04	1.08E+04	8.68E+03	9.81E+03	1.08E+04	1.17E+04	1.25E+04	1.34E+04	1.44E+04
3.00E+00	4.00E+00	2.54E+04	1.06E+04	5.43E+02	2.69E+01	6.38E+00	5.36E+00	5.11E+00	4.90E+00	4.71E+00	4.55E+00
4.00E+00	5.00E+00	2.99E-01	1.58E+00	1.97E+00	1.95E+00	1.87E+00	1.79E+00	1.71E+00	1.64E+00	1.57E+00	1.52E+00
5.00E+00	6.00E+00	1.01E-01	5.30E-01	6.63E-01	6.55E-01	6.28E-01	5.99E-01	5.73E-01	5.49E-01	5.26E-01	5.07E-01
6.00E+00	7.00E+00	3.38E-02	1.78E-01	2.23E-01	2.20E-01	2.11E-01	2.01E-01	1.92E-01	1.84E-01	1.76E-01	1.70E-01
7.00E+00	7.50E+00	7.26E-03	3.82E-02	4.78E-02	4.72E-02	4.52E-02	4.31E-02	4.12E-02	3.94E-02	3.77E-02	3.63E-02
7.50E+00	8.00E+00	4.21E-03	2.21E-02	2.77E-02	2.74E-02	2.62E-02	2.50E-02	2.38E-02	2.28E-02	2.18E-02	2.10E-02
8.00E+00	1.00E+01	4.96E-03	2.61E-02	3.27E-02	3.23E-02	3.09E-02	2.94E-02	2.81E-02	2.69E-02	2.57E-02	2.47E-02
1.00E+01	1.40E+01	2.35E-04	1.24E-03	1.55E-03	1.53E-03	1.46E-03	1.39E-03	1.33E-03	1.27E-03	1.21E-03	1.17E-03
Totals		2.88E+10	2.69E+10	2.01E+10	1.83E+10	1.77E+10	1.76E+10	1.75E+10	1.74E+10	1.73E+10	1.73E+10

Table A.5 Gamma Source Spectra (gammas/s.Ci),VELM 23 Grp. HFED U6Fe, Module 23, Slot 6, 19.84% Enrichment, 27% Depleted, 5.59E-02 MW/gU

		Decay Period									
Energy Interval (MeV)		1Y	5Y	10Y	15Y	20Y	25Y	30Y	35Y	40Y	45Y
1.00E-02	2.00E-02	3.78E+09	2.55E+09	2.38E+09	2.48E+09	2.51E+09	2.53E+09	2.52E+09	2.53E+09	2.52E+09	2.52E+09
2.00E-02	4.50E-02	4.92E+09	3.16E+09	2.82E+09	2.92E+09	2.95E+09	2.96E+09	2.96E+09	2.96E+09	2.95E+09	2.95E+09
4.50E-02	7.00E-02	1.82E+09	1.18E+09	1.08E+09	1.13E+09	1.15E+09	1.15E+09	1.15E+09	1.16E+09	1.16E+09	1.16E+09
7.00E-02	1.00E-01	1.51E+09	8.75E+08	7.40E+08	7.68E+08	7.74E+08	7.77E+08	7.74E+08	7.74E+08	7.70E+08	7.69E+08
1.00E-01	1.50E-01	2.31E+09	9.75E+08	6.36E+08	6.48E+08	6.47E+08	6.43E+08	6.37E+08	6.34E+08	6.28E+08	6.25E+08
1.50E-01	3.00E-01	1.28E+09	7.49E+08	6.39E+08	6.67E+08	6.75E+08	6.78E+08	6.76E+08	6.76E+08	6.73E+08	6.71E+08
3.00E-01	4.00E-01	4.80E+08	2.64E+08	2.14E+08	2.23E+08	2.27E+08	2.28E+08	2.28E+08	2.28E+08	2.27E+08	2.26E+08
4.00E-01	5.10E-01	5.23E+08	2.63E+08	1.47E+08	1.36E+08	1.34E+08	1.33E+08	1.32E+08	1.32E+08	1.31E+08	1.31E+08
5.10E-01	6.00E-01	2.35E+08	2.42E+08	8.42E+07	4.62E+07	3.67E+07	3.37E+07	3.22E+07	3.13E+07	3.06E+07	3.01E+07
6.00E-01	7.00E-01	1.36E+09	5.84E+09	7.46E+09	7.86E+09	8.02E+09	8.13E+09	8.18E+09	8.25E+09	8.28E+09	8.33E+09
7.00E-01	1.00E+00	5.65E+09	6.41E+08	2.55E+08	1.29E+08	9.39E+07	8.09E+07	7.36E+07	6.89E+07	6.51E+07	6.24E+07
1.00E+00	1.50E+00	1.32E+08	1.23E+08	7.77E+07	6.03E+07	4.96E+07	4.20E+07	3.61E+07	3.19E+07	2.85E+07	2.60E+07
1.50E+00	2.00E+00	2.98E+07	1.07E+07	3.56E+06	3.07E+06	2.74E+06	2.48E+06	2.26E+06	2.10E+06	1.97E+06	1.87E+06
2.00E+00	2.50E+00	8.22E+07	1.89E+07	4.08E+05	3.57E+04	2.97E+04	2.98E+04	2.98E+04	2.98E+04	2.97E+04	2.96E+04
2.50E+00	3.00E+00	2.79E+05	1.23E+05	6.00E+03	3.75E+02	1.80E+02	1.90E+02	2.05E+02	2.21E+02	2.37E+02	2.55E+02
3.00E+00	4.00E+00	2.64E+04	1.35E+04	7.11E+02	2.85E+01	1.28E+00	2.60E-01	2.42E-01	2.67E-01	2.94E-01	3.26E-01
4.00E+00	5.00E+00	5.66E-03	3.40E-02	5.13E-02	5.93E-02	6.58E-02	7.26E-02	7.98E-02	8.83E-02	9.74E-02	1.08E-01
5.00E+00	6.00E+00	1.90E-03	1.14E-02	1.71E-02	1.98E-02	2.19E-02	2.41E-02	2.65E-02	2.93E-02	3.23E-02	3.58E-02
6.00E+00	7.00E+00	6.36E-04	3.80E-03	5.72E-03	6.60E-03	7.30E-03	8.05E-03	8.84E-03	9.76E-03	1.08E-02	1.19E-02
7.00E+00	7.50E+00	1.36E-04	8.14E-04	1.22E-03	1.41E-03	1.56E-03	1.72E-03	1.89E-03	2.08E-03	2.30E-03	2.55E-03
7.50E+00	8.00E+00	7.89E-05	4.71E-04	7.08E-04	8.15E-04	9.02E-04	9.94E-04	1.09E-03	1.20E-03	1.33E-03	1.47E-03
8.00E+00	1.00E+01	9.29E-05	5.54E-04	8.33E-04	9.59E-04	1.06E-03	1.17E-03	1.28E-03	1.41E-03	1.56E-03	1.73E-03
1.00E+01	1.40E+01	4.39E-06	2.62E-05	3.93E-05	4.52E-05	5.00E-05	5.50E-05	6.03E-05	6.66E-05	7.34E-05	8.13E-05
Totals		2.41E+10	1.69E+10	1.65E+10	1.71E+10	1.73E+10	1.74E+10	1.74E+10	1.75E+10	1.75E+10	1.75E+10

APPENDIX B

Major Isotopic Activity (Ci) for the MFPs from the
50-MWd/kgU, 40-kW/kgU Case

Table B.1 Light Element Activity at 15-Year Decay Period
50 MWd/kgU, 40kW/kgU, U-wt% (U234=.037, U235=4.200, U236=.019, U238=95.744); Continuous Operation = 1250.00 d; Tbl A.4 ORNL-6698. Cycle 3 of 5. Clad is Zircaloy: Wt% (97.91 Zr, 1.59 Sn, 0.5 Fe). SCALE 4.2 Composition Library. See Tbl. 3.11, ORNL-6698 for composition.

Light Elements (Ci/Mg)			
Isotope	15 Yr	% Total	Running %
Sb-125	2.85E+01	5.43E+01	5.43E+01
Fe-55	1.51E+01	2.88E+01	8.30E+01
Te-125m	6.95E+01	1.32E+01	9.63E+01
Sn-121m	8.53E+01	1.62E+01	9.79E+01
Sn-121	6.62E-01	1.26E+00	9.92E+01
Co-60	1.80E-01	3.43E-01	9.95E+01
Zr-93	1.79E-01	3.41E-01	9.99E+01
Nb-93m	9.13E-02	1.74E-01	1.00E+02
Sn-119m	2.42E-02	4.61E-02	1.00E+02
Sr-90	2.61E-03	4.97E-03	1.00E+02
Y-90	2.61E-03	4.97E-03	1.00E+02
Mn-54	8.46E-04	1.61E-03	1.00E+02
Cd-113m	1.85E-05	3.52E-05	1.00E+02
Tc-99	3.42E-06	6.51E-06	1.00E+02
H-3	9.15E-08	1.74E-07	1.00E+02
Ni-63	3.49E-09	6.65E-09	1.00E+02
Nb-94	1.85E-09	3.52E-09	1.00E+02
Sn-123	6.25E-11	1.19E-10	1.00E+02
In-113m	1.11E-11	2.11E-11	1.00E+02
Sn-113	1.10E-11	2.10E-11	1.00E+02
Te-123m	1.67E-13	3.18E-13	1.00E+02
Te-127m	3.94E-17	7.50E-17	1.00E+02
Te-127	3.86E-17	7.35E-17	1.00E+02
Nb-95	2.04E-21	3.89E-21	1.00E+02
Zr-95	9.27E-22	1.77E-21	1.00E+02
Nb-95m	1.09E-23	2.08E-23	1.00E+02
Sb-124	1.57E-26	2.99E-26	1.00E+02
Y-91	1.23E-26	2.34E-26	1.00E+02
Co-58	2.82E-28	5.37E-28	1.00E+02
Dr-89	1.79E-31	3.41E-31	1.00E+02
In-114m	1.58E-31	3.01E-31	1.00E+02
Totals	5.25E+01	1.00E+02	

Table B.2 Actinide Activity at 15-Year Decay Period
50 MWd/kgU, 40kW/kgU, U-wt%(U234=.037,
U235=4.200, U236=.019,U238=95.744); Continuous
Operation = 1250.00 d; Tbl A.4 ORNL-6698. Cycle 3 of 5. Clad is Zircaloy:
Wt%(97.91 Zr, 1.59 Sn, 0.5 Fe). SCALE 4.2 Composition Library.
See Tbl 3.11, ORNL-6698 for composition.

Actinides (Ci/Mg)			
Element	15 Yr	% Total	Running %
Pu-241	1.08E+05	8.78E+01	8.78E+01
Pu-238	6.00E+03	4.88E+00	9.27E+01
Cm-244	4.19E+03	3.41E+00	9.61E+01
Am-241	3.97E+03	3.23E+00	9.93E+01
Pu-240	5.25E+02	4.27E-01	9.97E+01
Pu-239	3.99E+02	3.24E-01	1.00E+02
Np-239	5.09E+01	4.14E-02	1.00E+02
Am-243	5.09E+01	4.14E-02	1.00E+02
Cm-243	3.74E+01	3.04E-02	1.00E+02
Am-242m	1.88E+01	1.53E-02	1.00E+02
Am-242	1.87E+01	1.52E-02	1.00E+02
Cm-242	1.55E+01	1.26E-02	1.00E+02
Pu-242	3.36E+00	2.73E-03	1.00E+02
U-237	2.58E+00	2.10E-03	1.00E+02
U-234	1.39E+00	1.13E-03	1.00E+02
Cm-245	7.99E-01	6.50E-04	1.00E+02
Pa-233	6.13E-01	4.98E-04	1.00E+02
Np-237	6.13E-01	4.98E-04	1.00E+02
U-236	3.77E-01	3.07E-04	1.00E+02
Th-234	3.10E-01	2.52E-04	1.00E+02
Pa-234m	3.10E-01	2.52E-04	1.00E+02
U-238	3.10E-01	2.52E-04	1.00E+02
Cm-246	2.31E-01	1.88E-04	1.00E+02
U-232	1.57E-01	1.28E-04	1.00E+02
Pb-212	1.54E-01	1.25E-04	1.00E+02
Bi-212	1.54E-01	1.25E-04	1.00E+02
Po-216	1.54E-01	1.25E-04	1.00E+02
U-235	1.63E-02	1.33E-05	1.00E+02
Pa-234	4.03E-04	3.28E-07	1.00E+02
Cf-250	2.94E-04	2.39E-07	1.00E+02
Totals	1.23E+05		

Table B.3 Fission Product Activity at 15-Year Decay Period 50 MWd/kgU, 40kW/kgU, U-wt% (U234=.037, U235=4.200, U236=.019, U238=95.744); Continuous Operation = 1250.00 d; Tbl A.4 ORNL-6698. Cycle 3 of 5. Clad is Zircaloy: Wt%(97.91 Zr, 1.59 Sn, 0.5 Fe). SCALE 4.2 Composition Library. See Tbl 3.11, ORNL-6698 for composition.

Fission Products (Ci/Mg)			
Element	15 Yr	% Total	Running %
Cs137	1.15E+05	2.90E+01	2.90E+01
Ba137m	1.08E+05	2.72E+01	5.62E+01
Sr 90	7.72E+04	1.94E+01	7.56E+01
Y 90	7.72E+04	1.94E+01	9.51E+01
Eu154	5.92E+03	1.49E+00	9.66E+01
Kr 85	4.89E+03	1.23E+00	9.78E+01
Pm147	3.66E+03	9.22E-01	9.88E+01
Cs134	1.89E+03	4.76E-01	9.93E+01
Eu155	1.60E+03	4.03E-01	9.97E+01
Sm151	5.48E+02	1.38E-01	9.98E+01
H 3	3.11E+02	7.83E-02	9.99E+01
Sb125	2.56E+02	6.45E-02	1.00E+02
Te125m	6.26E+01	1.58E-02	1.00E+02
Ru106	2.90E+01	7.30E-03	1.00E+02
Rh106	2.90E+01	7.30E-03	1.00E+02
Cd113m	2.37E+01	5.97E-03	1.00E+02
Tc 99	1.92E+01	4.84E-03	1.00E+02
Eu152	4.09E+00	1.03E-03	1.00E+02
Sn121m	2.94E+00	7.41E-04	1.00E+02
Ce144	2.31E+00	5.82E-04	1.00E+02
Pr144	2.31E+00	5.82E-04	1.00E+02
Sn121	2.28E+00	5.74E-04	1.00E+02
Zr 93	1.74E+00	4.38E-04	1.00E+02
Pm146	1.32E+00	3.32E-04	1.00E+02
Se 79	1.00E+00	2.52E-04	1.00E+02
Nb 93m	8.96E-01	2.26E-04	1.00E+02
Sn126	8.40E-01	2.12E-04	1.00E+02
Sb126m	8.40E-01	2.12E-04	1.00E+02
Cs135	7.10E-01	1.79E-04	1.00E+02
Pd107	1.86E-01	4.69E-05	1.00E+02
Pm145	1.31E-01	3.30E-05	1.00E+02
Sb126	1.18E-01	2.97E-05	1.00E+02
Rh102	8.58E-02	2.16E-05	1.00E+02
Totals	3.97E+05		

APPENDIX C

Graphical Representations of the DORT Calculational Models Used in the Shielding Analysis of the SNF Shipping Casks

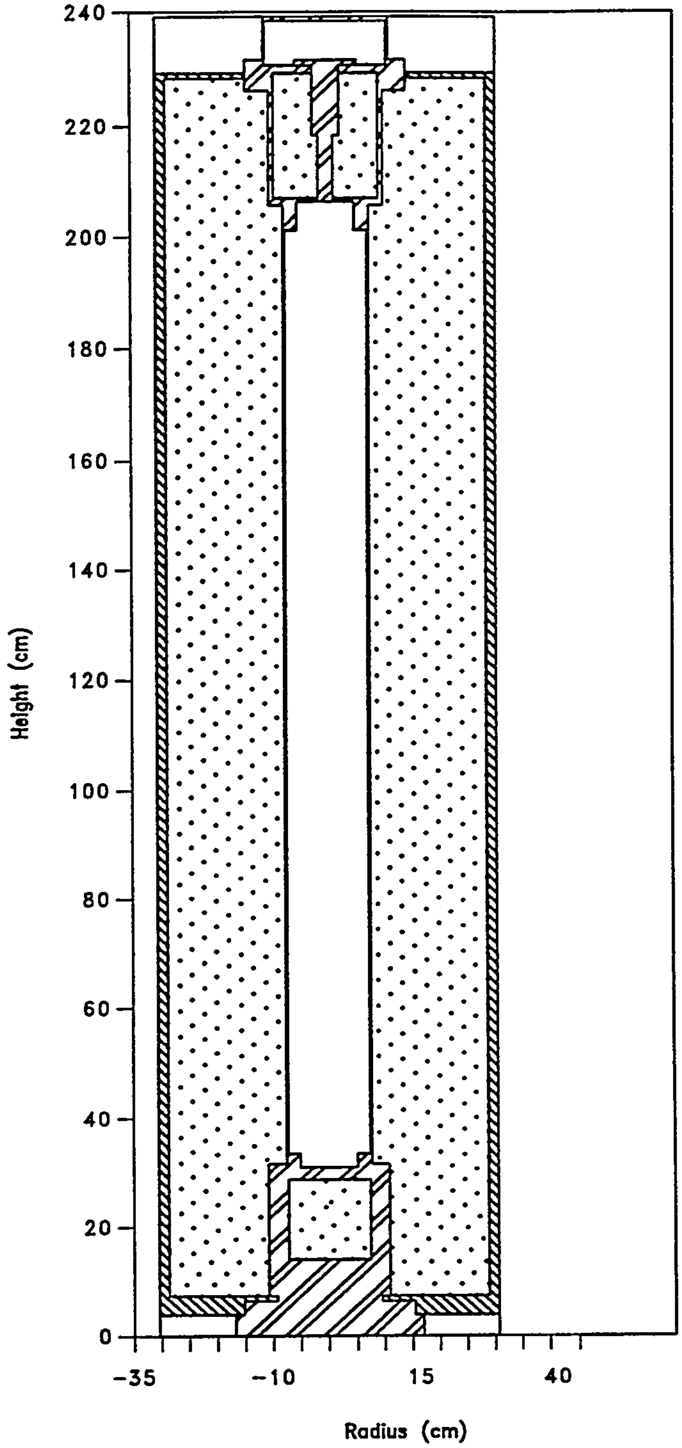

Figure C.1 DORT Calculational Model of the Loop Transport Carrier SNF Shipping Cask.

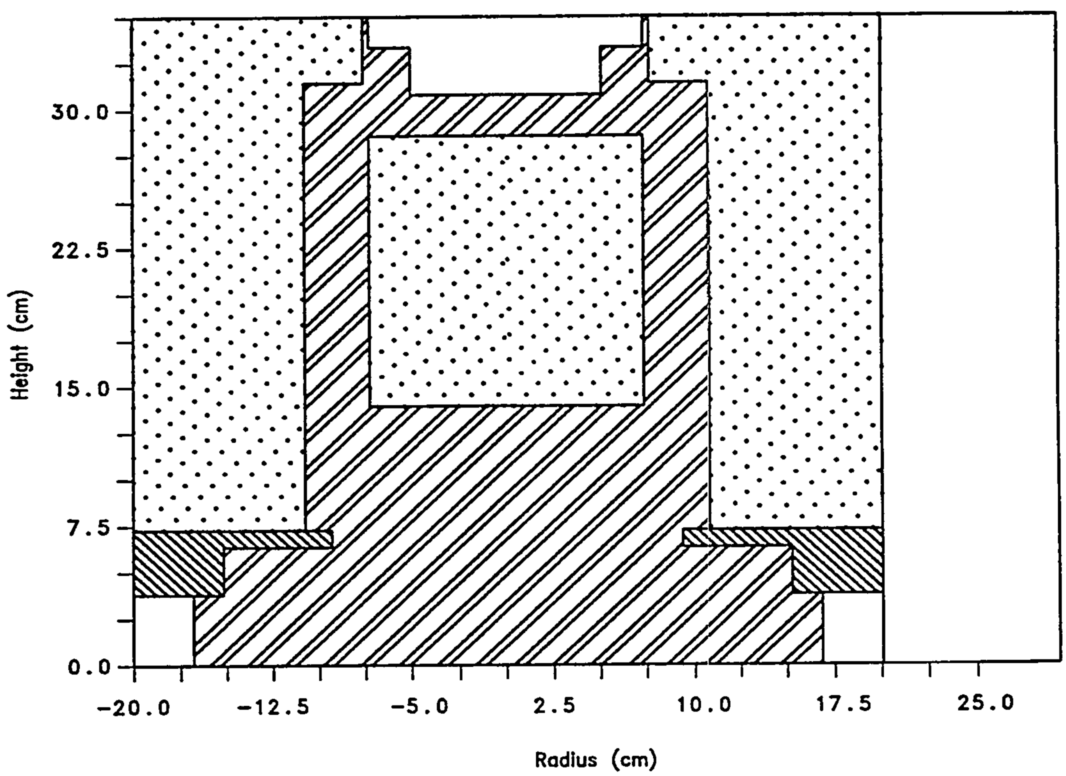

Figure C.2 Expanded View of the DORT Calculational Model of the Loop Transport Carrier Door Plug.

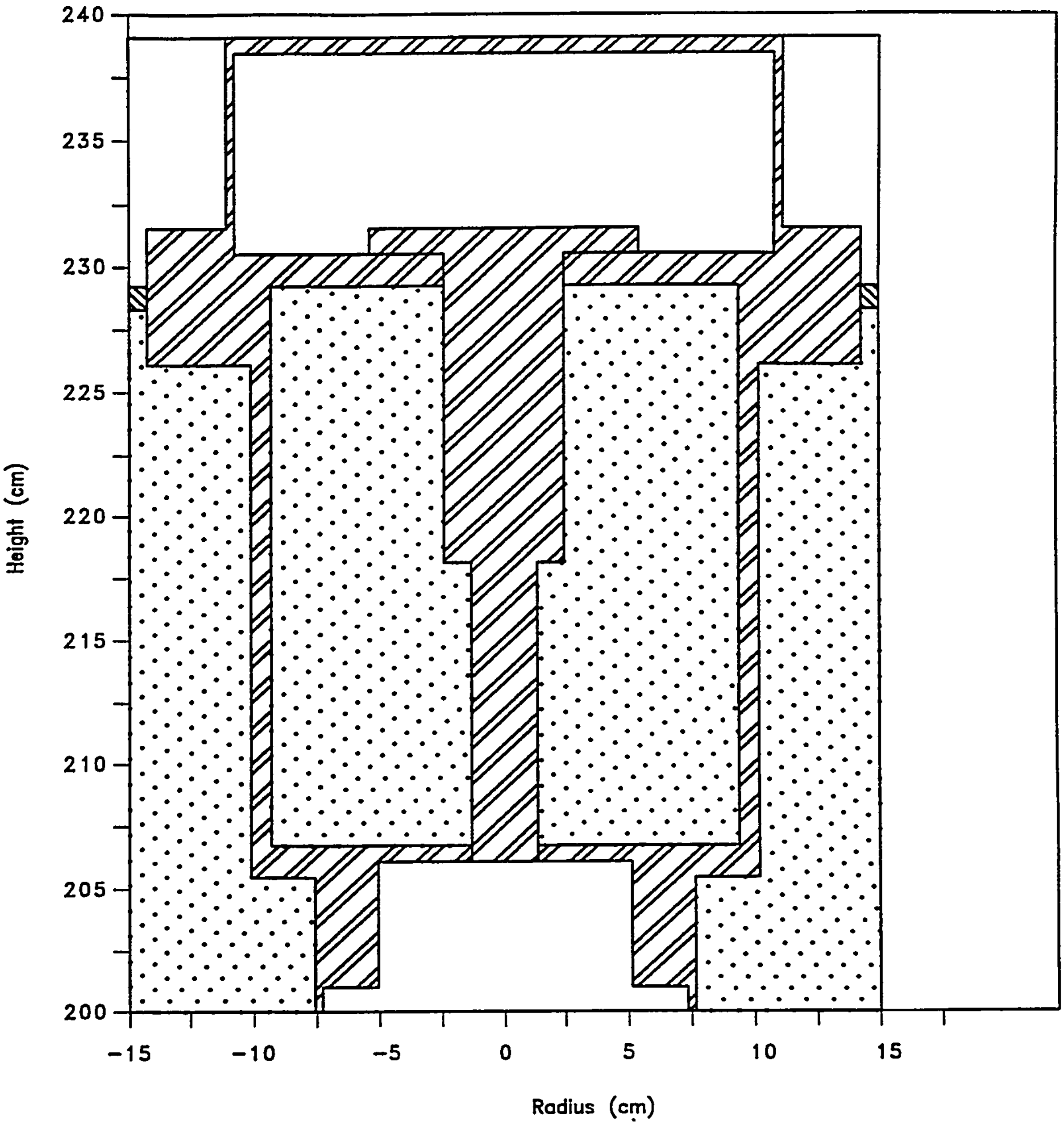

Figure C.3 Expanded View of the DORT Calculational Model of the Loop Transport Carrier End Plug.

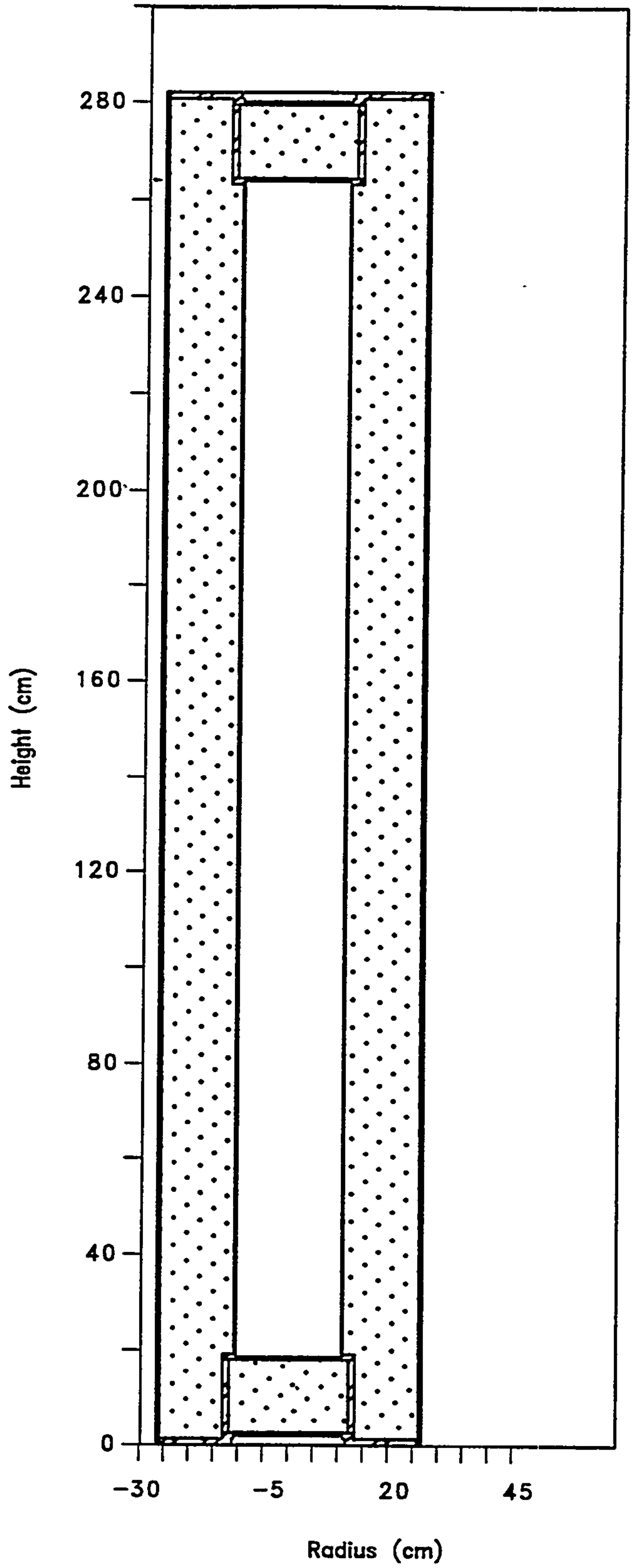

Figure C.4 DORT Calculational Model of the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask.

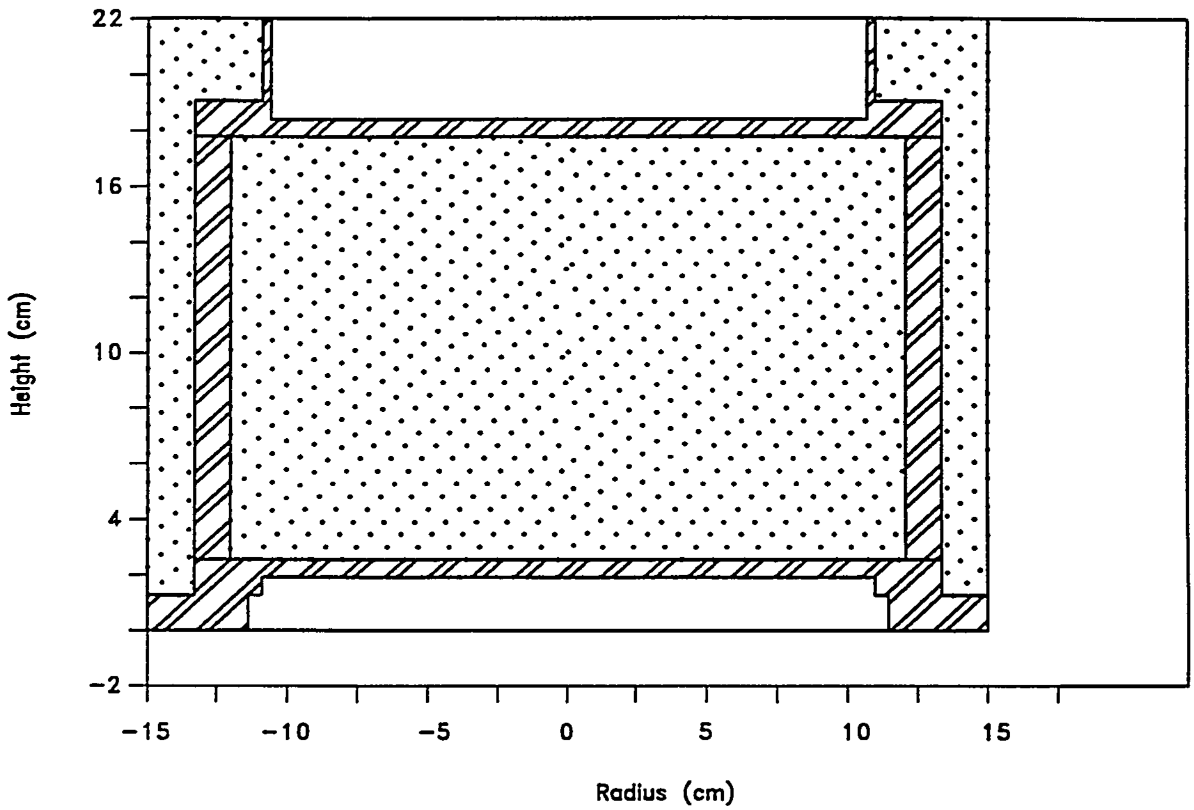

Figure C.5 Expanded View of the DORT Calculational Model of the In-Pile Loop LITR HB-2 Carrier Double Doors.

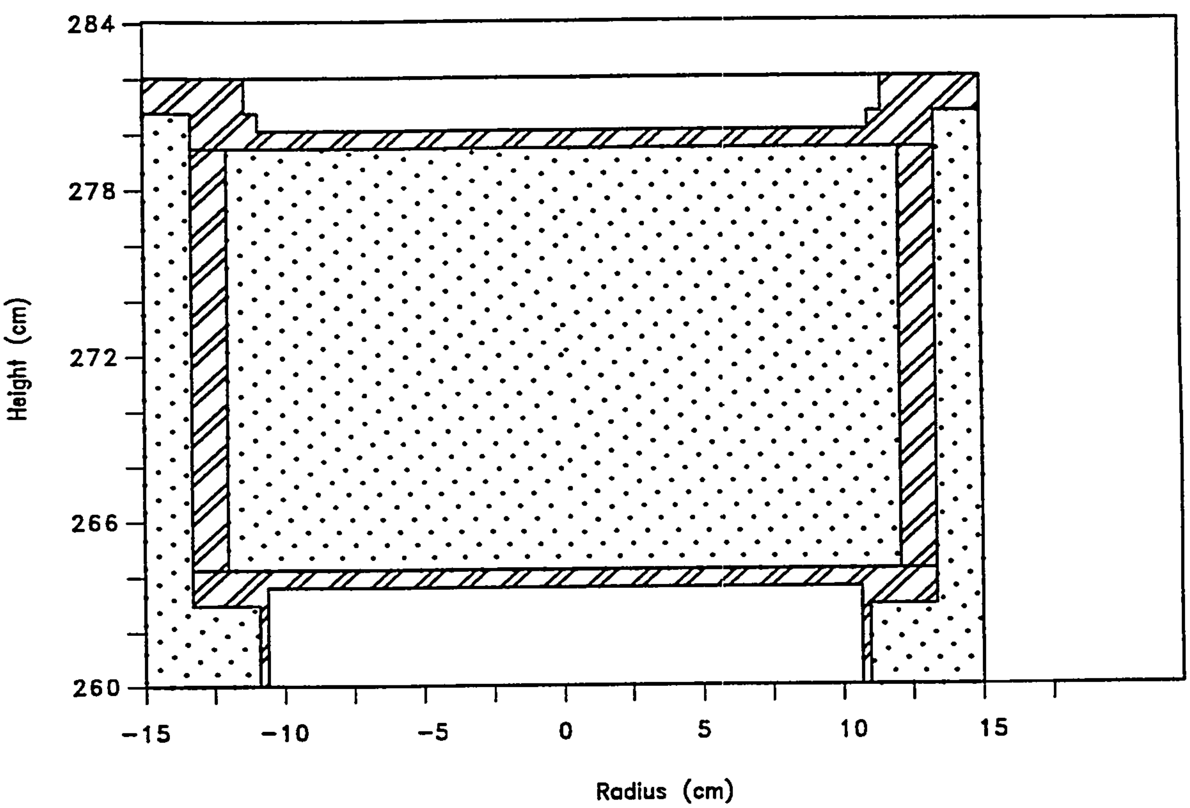

Figure C.6 Expanded View of the DORT Calculational Model of the In-Pile Loop LITR HB-2 Carrier Large Door.

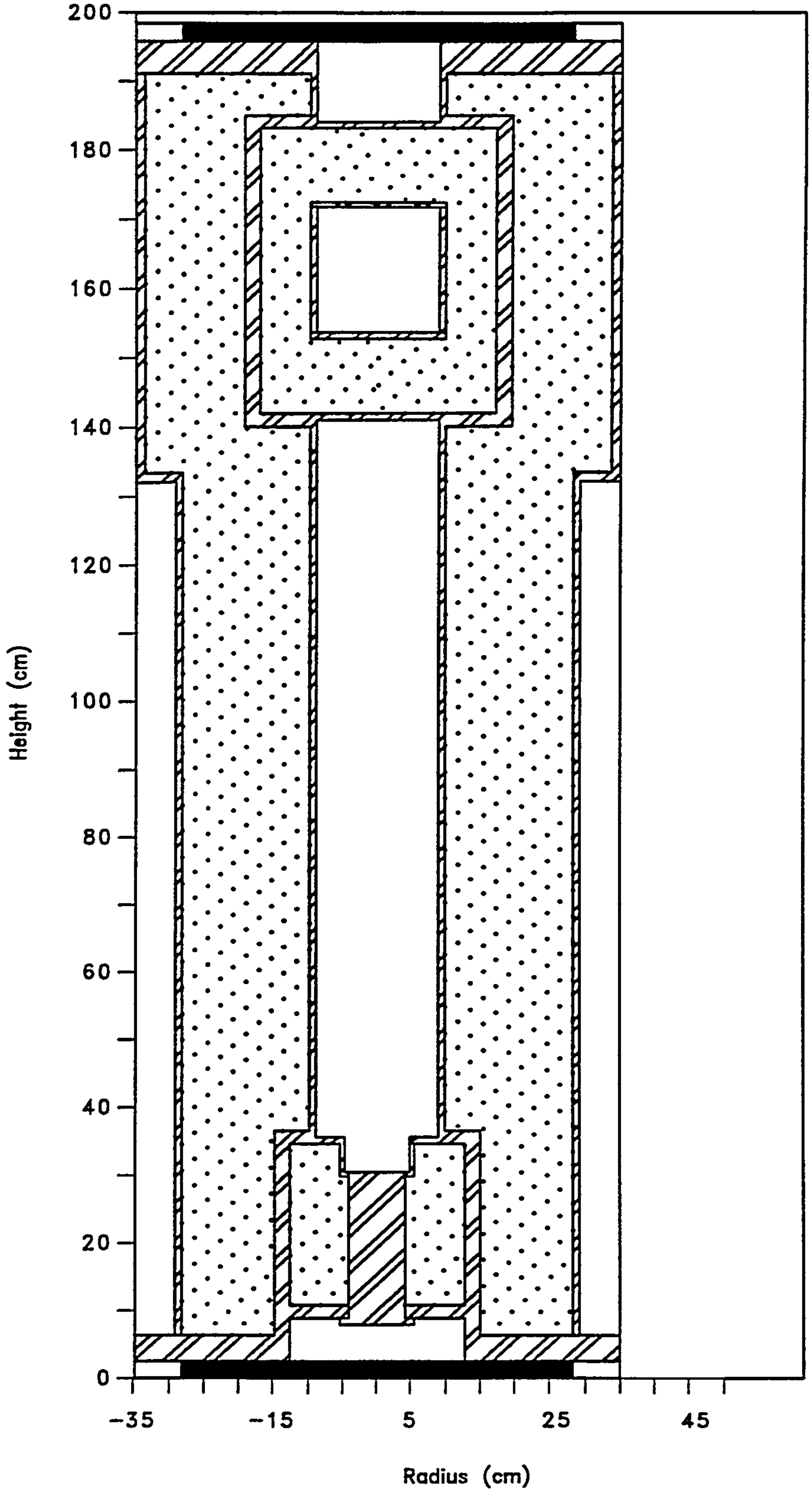

Figure C.7 DORT Calculational Model of the 6.5 Inch HRLEL Carrier SNF Shipping Cask.

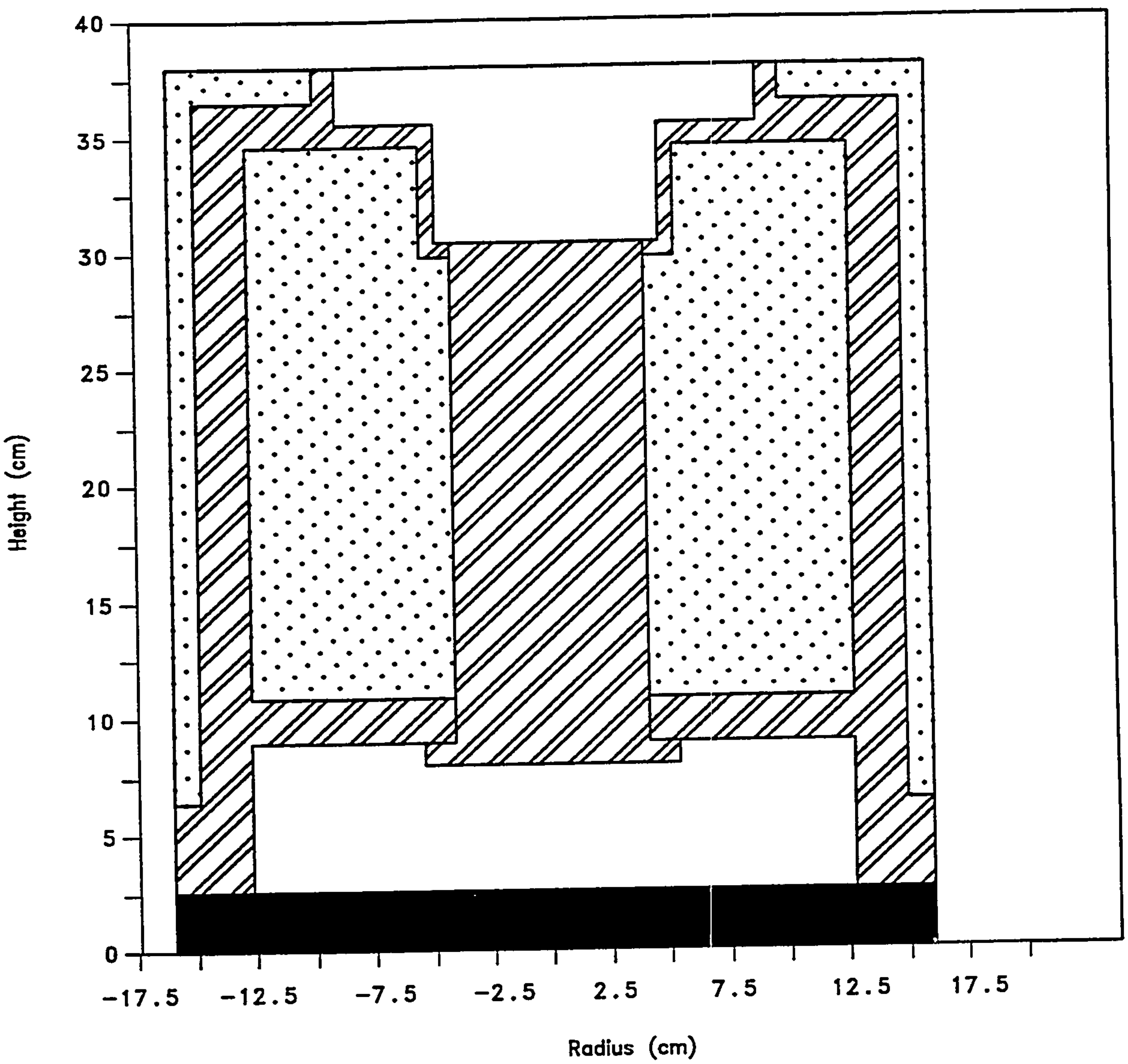

Figure C.8 Expanded View of the DORT Calculational Model of the 6.5 Inch HRLEL Carrier End Plug.

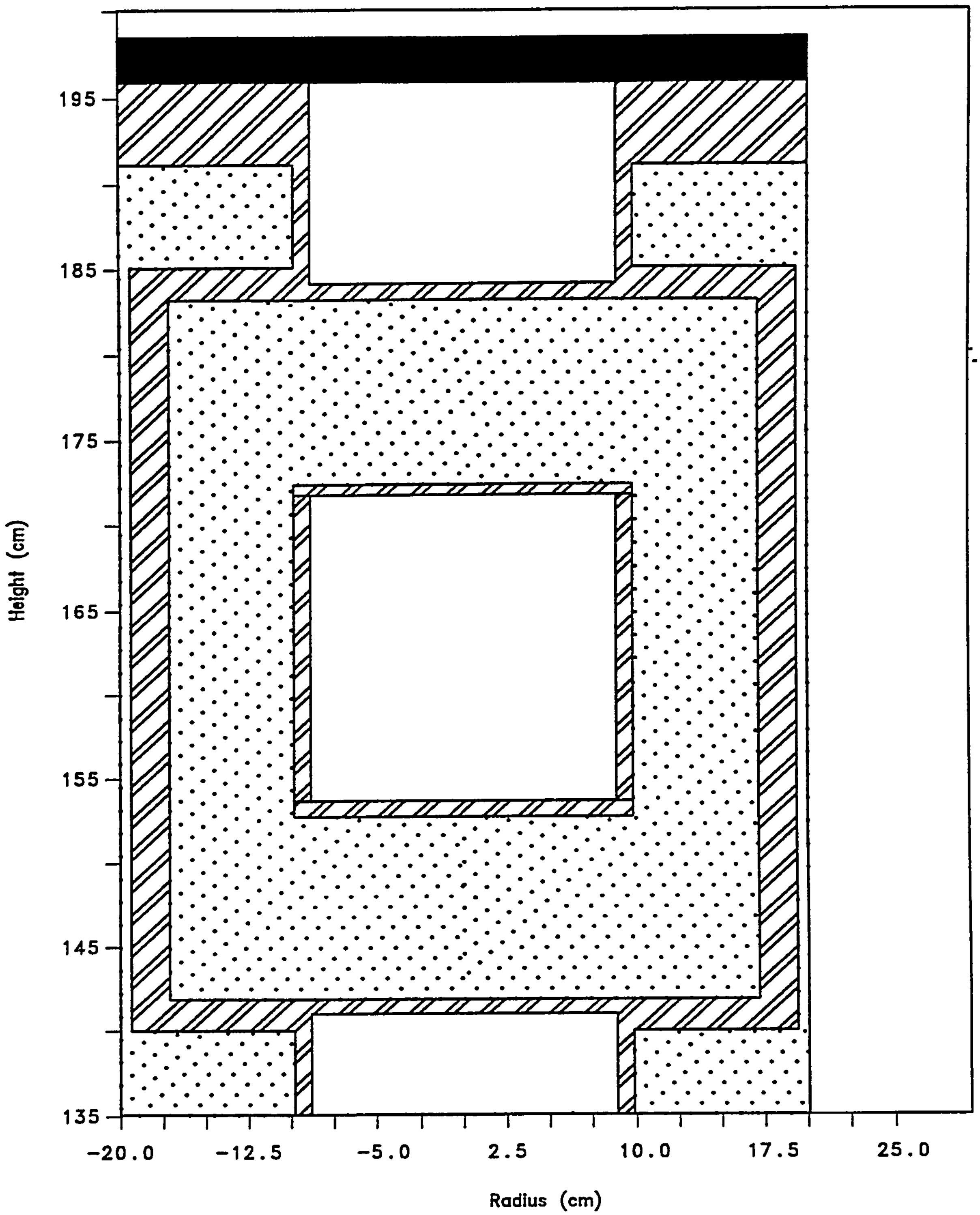

Figure C.9 Expanded View of the DORT Calculational Model of the 6.5 Inch HRLEL Carrier Door.

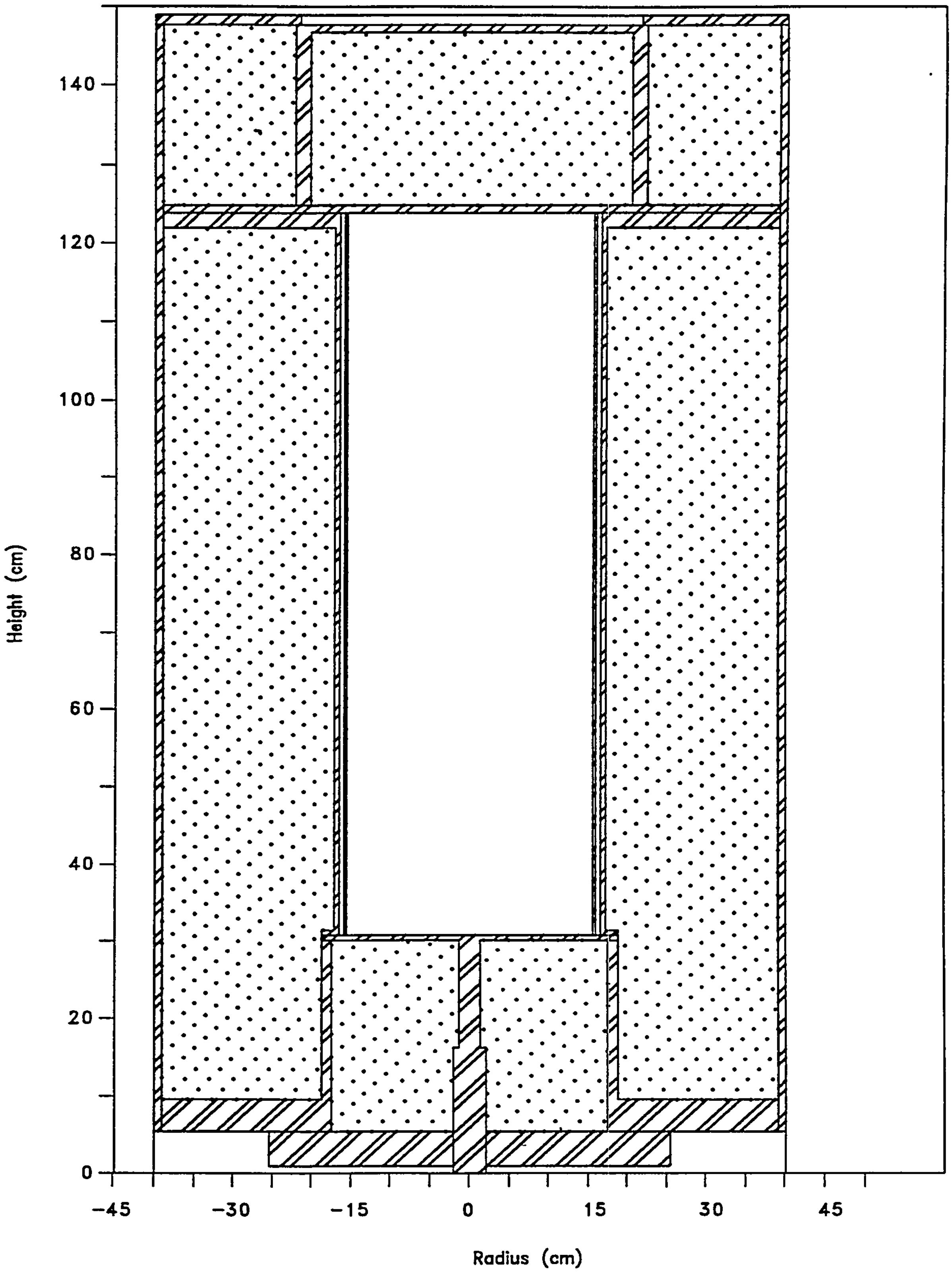

Figure C.10 DORT Calculational Model of the HFIR Hot Scrap Carrier SNF Shipping Cask.

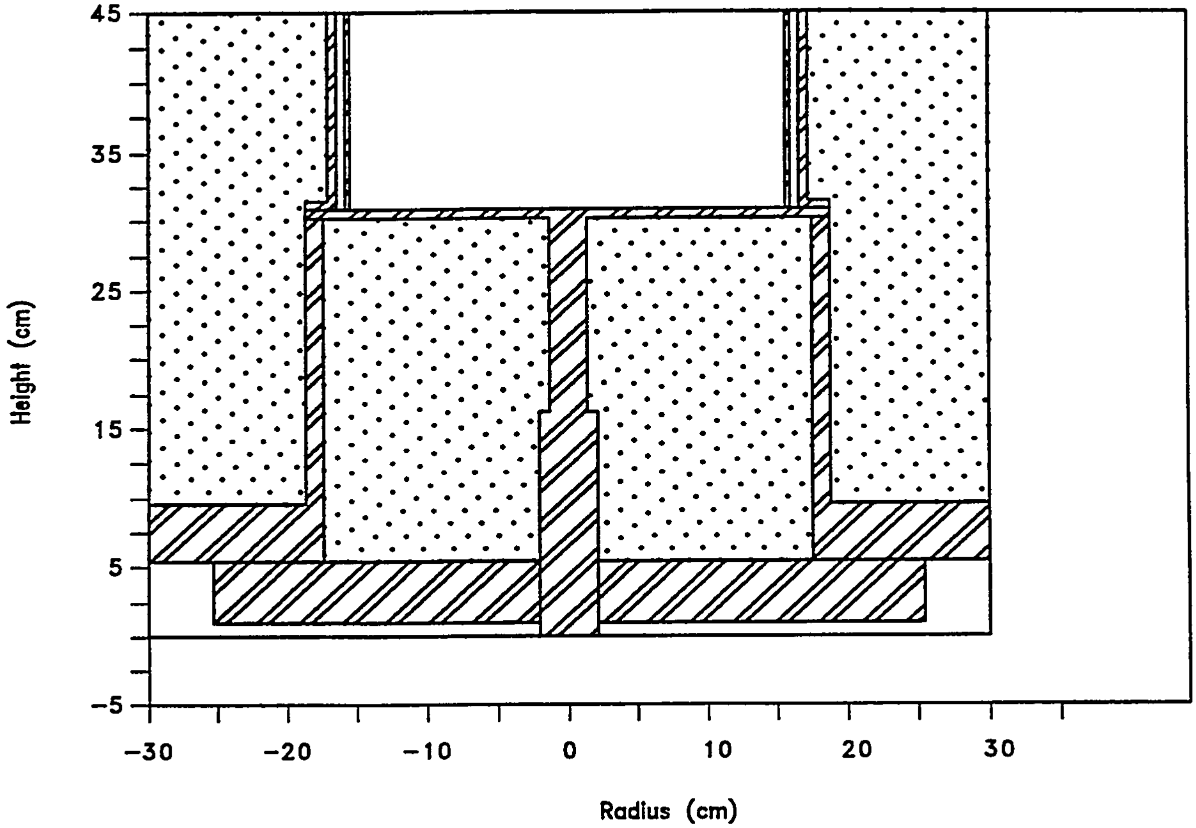

Figure C.11 Expanded View of the DORT Calculational Model of the HFIR Hot Scrap Carrier Top Plug.

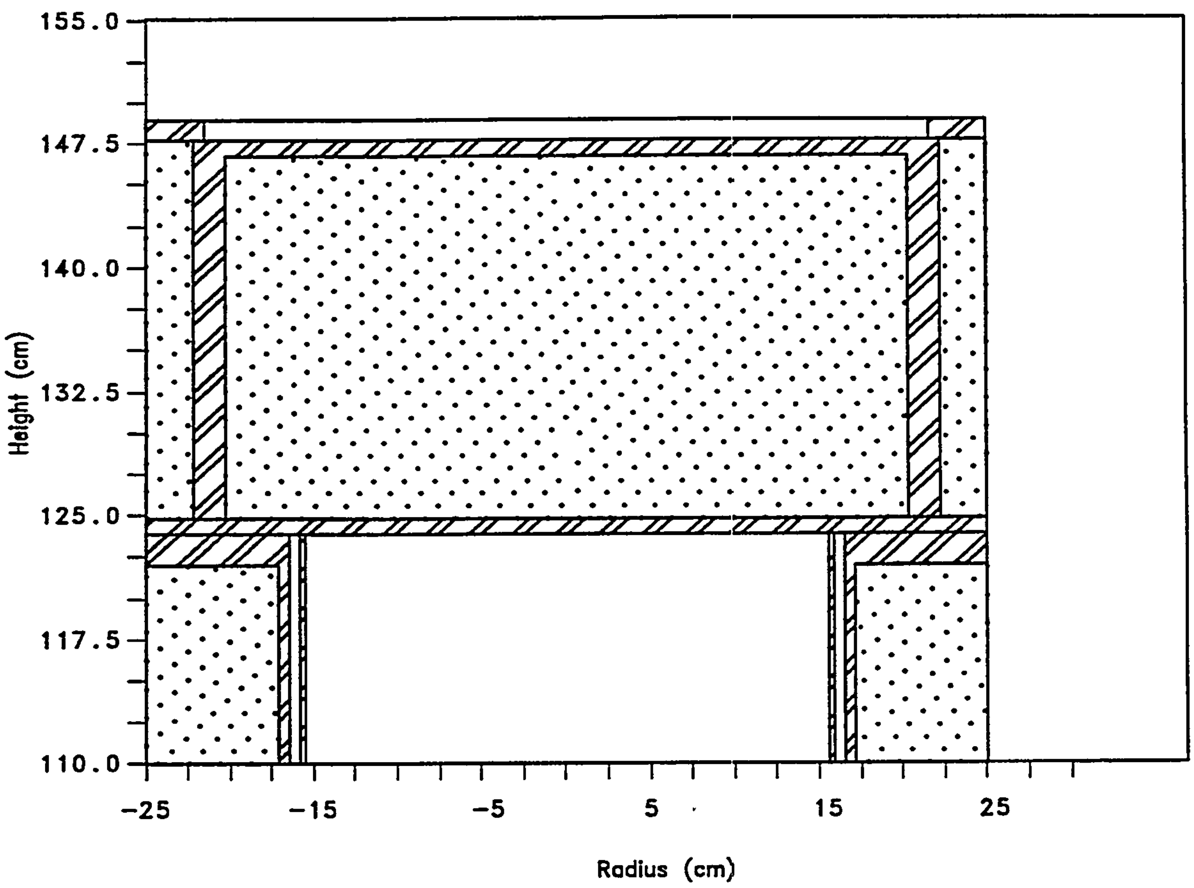

Figure C.12 Expanded View of the DORT Calculational Model of the HFIR Hot Scrap Carrier Bottom Door.

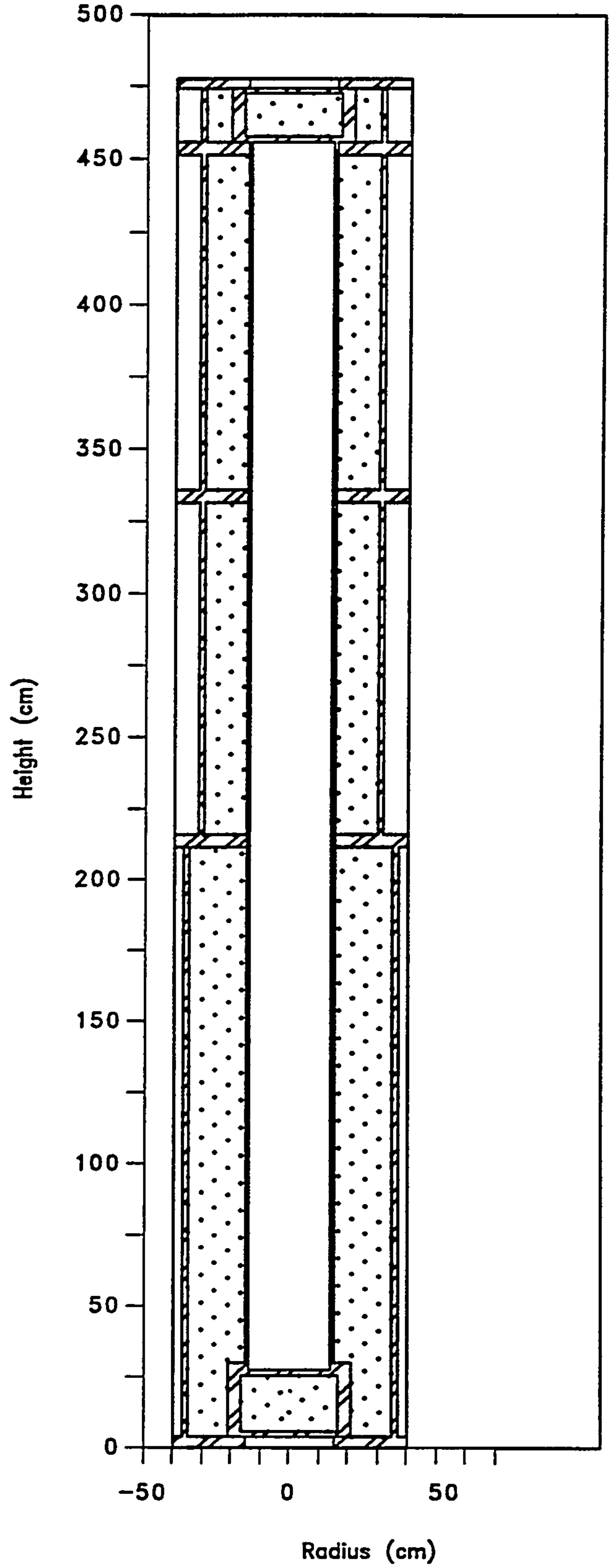

Figure C.13 DORT Calculational Model of the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask.

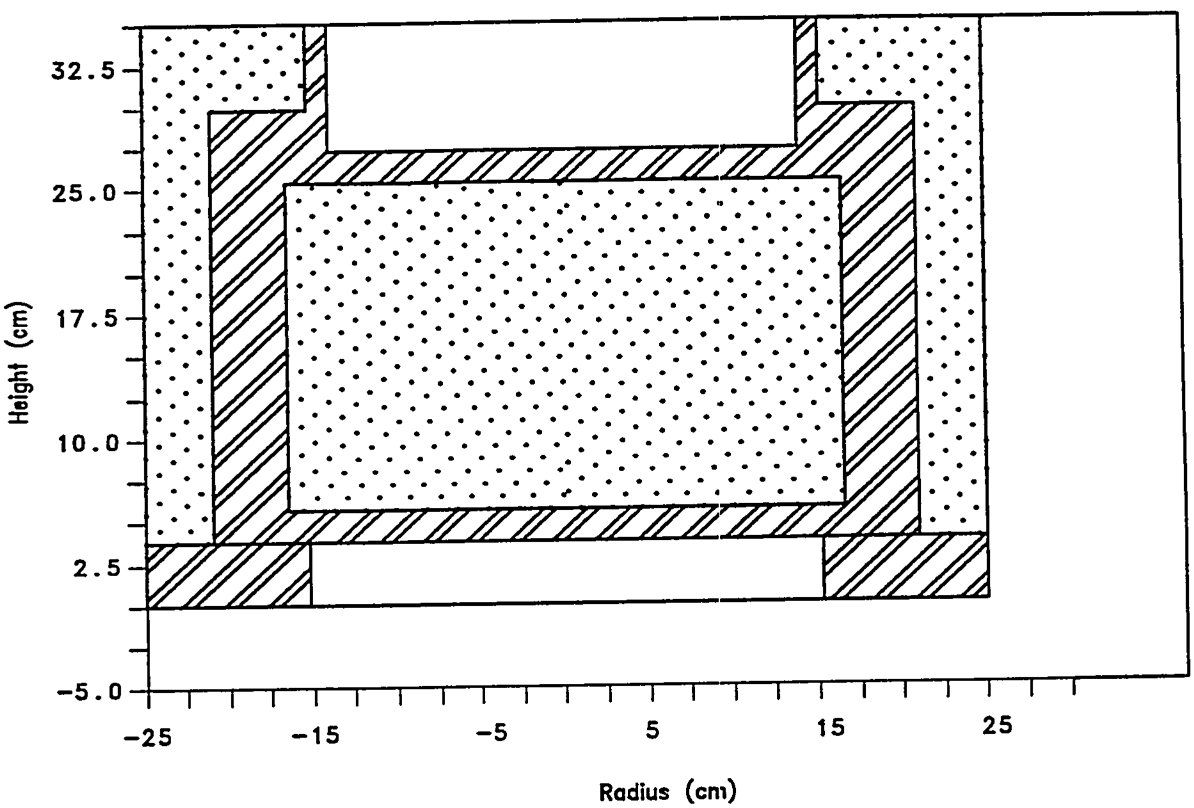

Figure C.14 Expanded View of the DORT Calculational Model of the 10-Inch ORR Experiment Removal Shield Heavy Door.

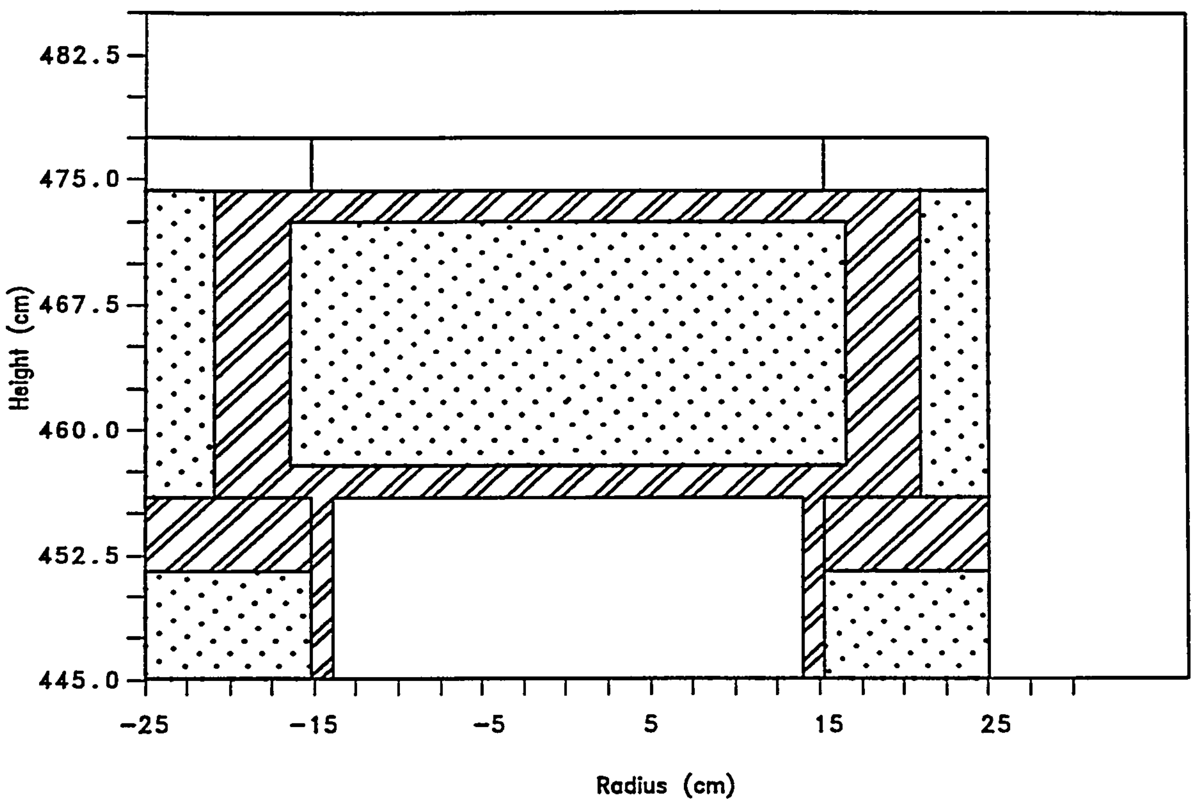

Figure C.15 Expanded View of the DORT Calculational Model of the 10-Inch ORR Experiment Removal Shield Light Door.

APPENDIX D

Isodose Contours for the Representative Sources Used in the Shielding Analysis of the SNF Shipping Casks

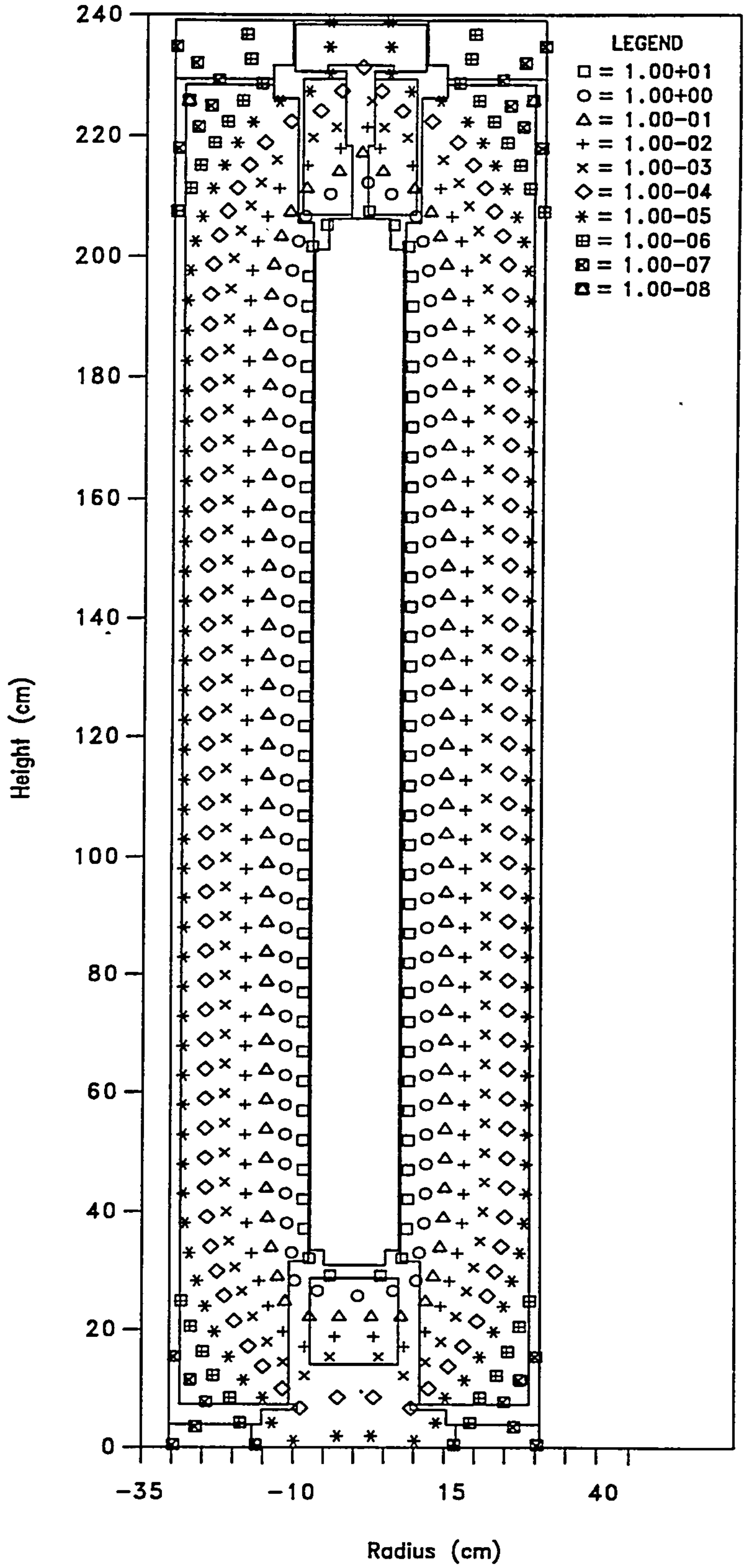

Figure D.1 Isodose Contours for the ^{60}Co Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

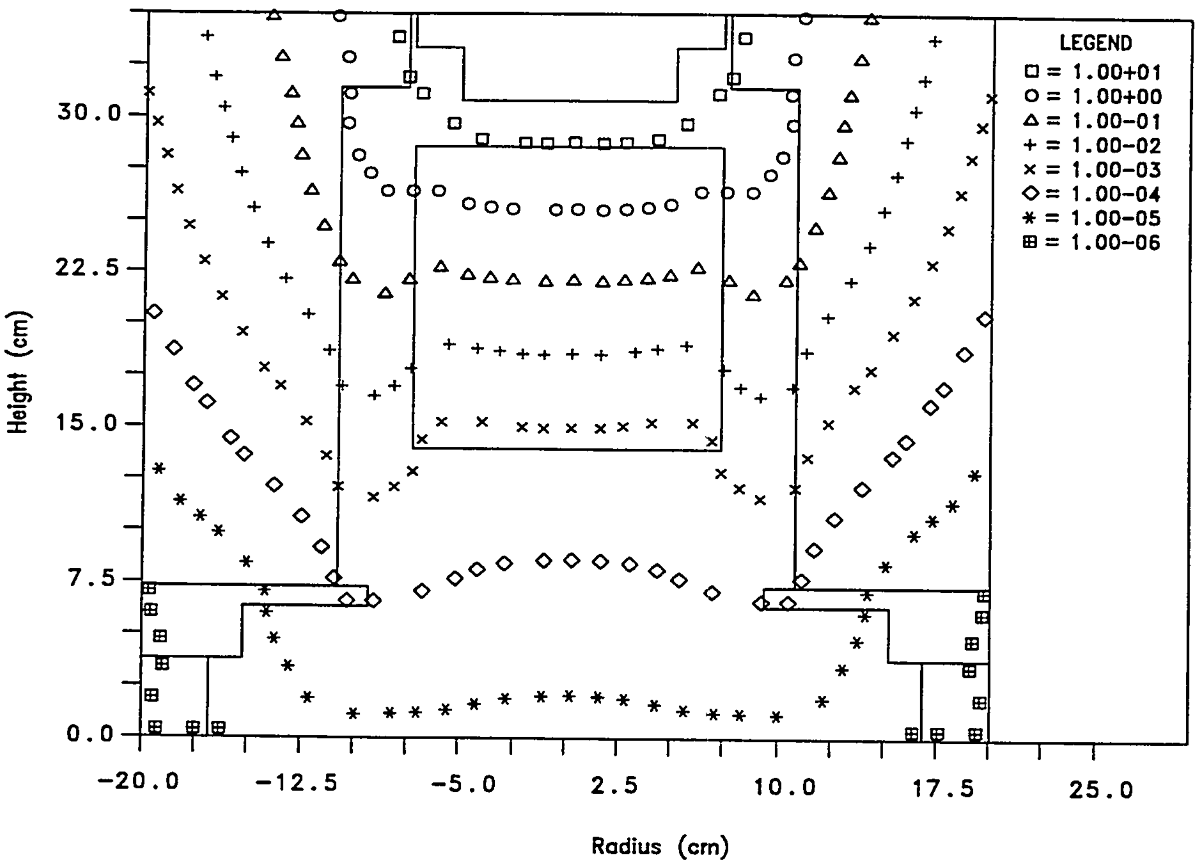

Figure D.2 Expanded View of the Door Plug Isodose Contours for the ^{60}Co Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

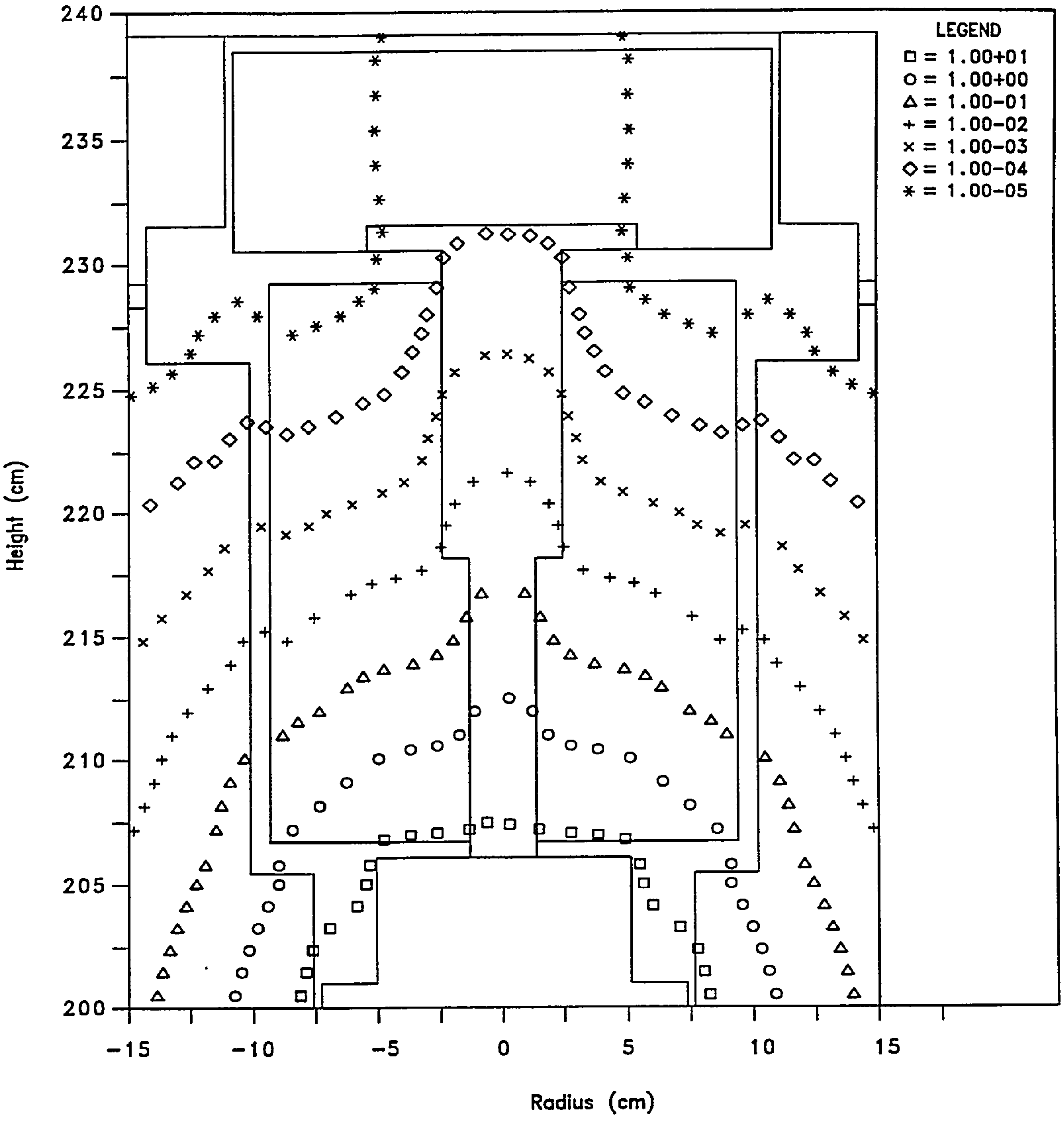

Figure D.3 Expanded View of the End Plug Isodose Contours for the ^{60}Co Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/h·Ci).]

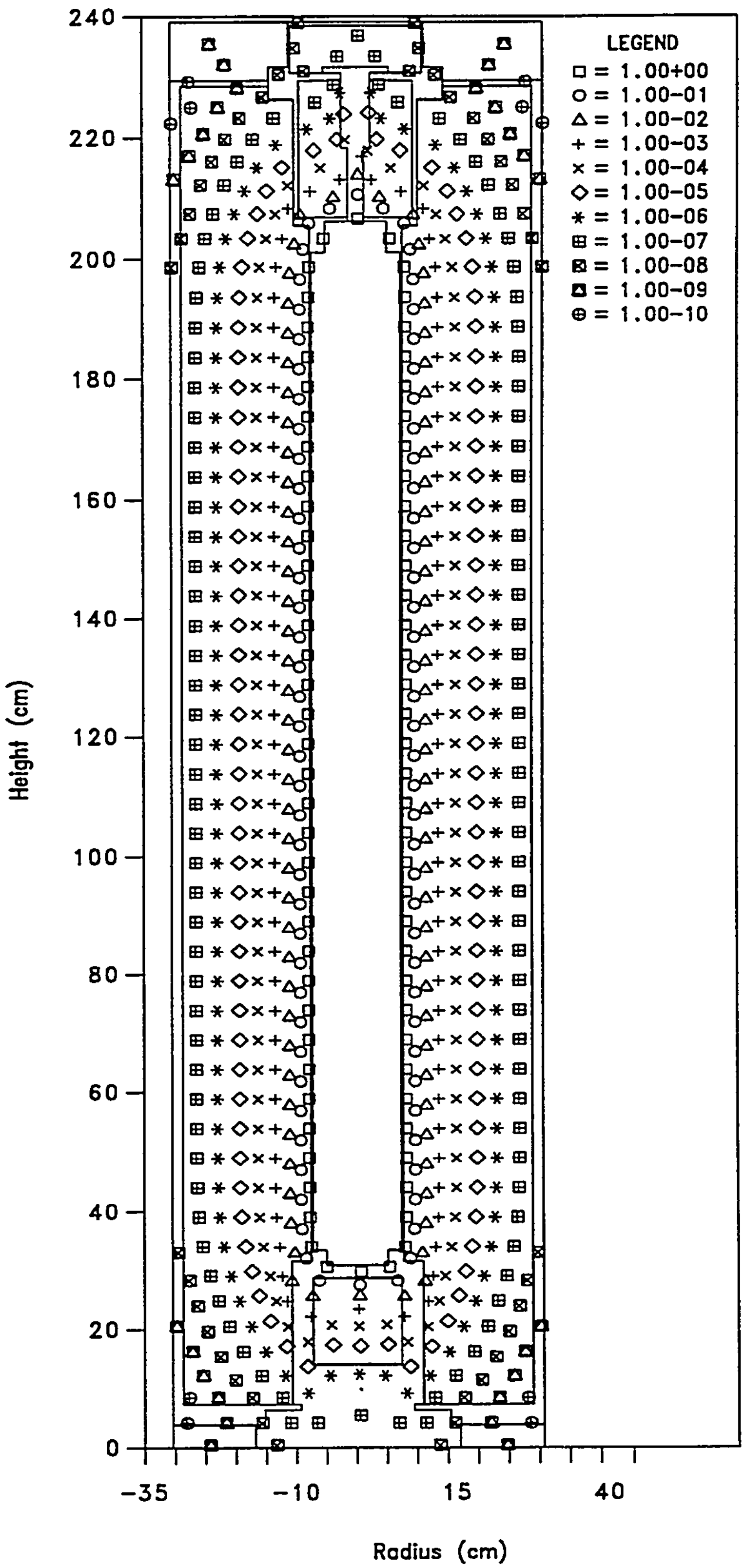

Figure D.4 Isodose Contours for the LWR MFP (25 MWd/kgU) Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

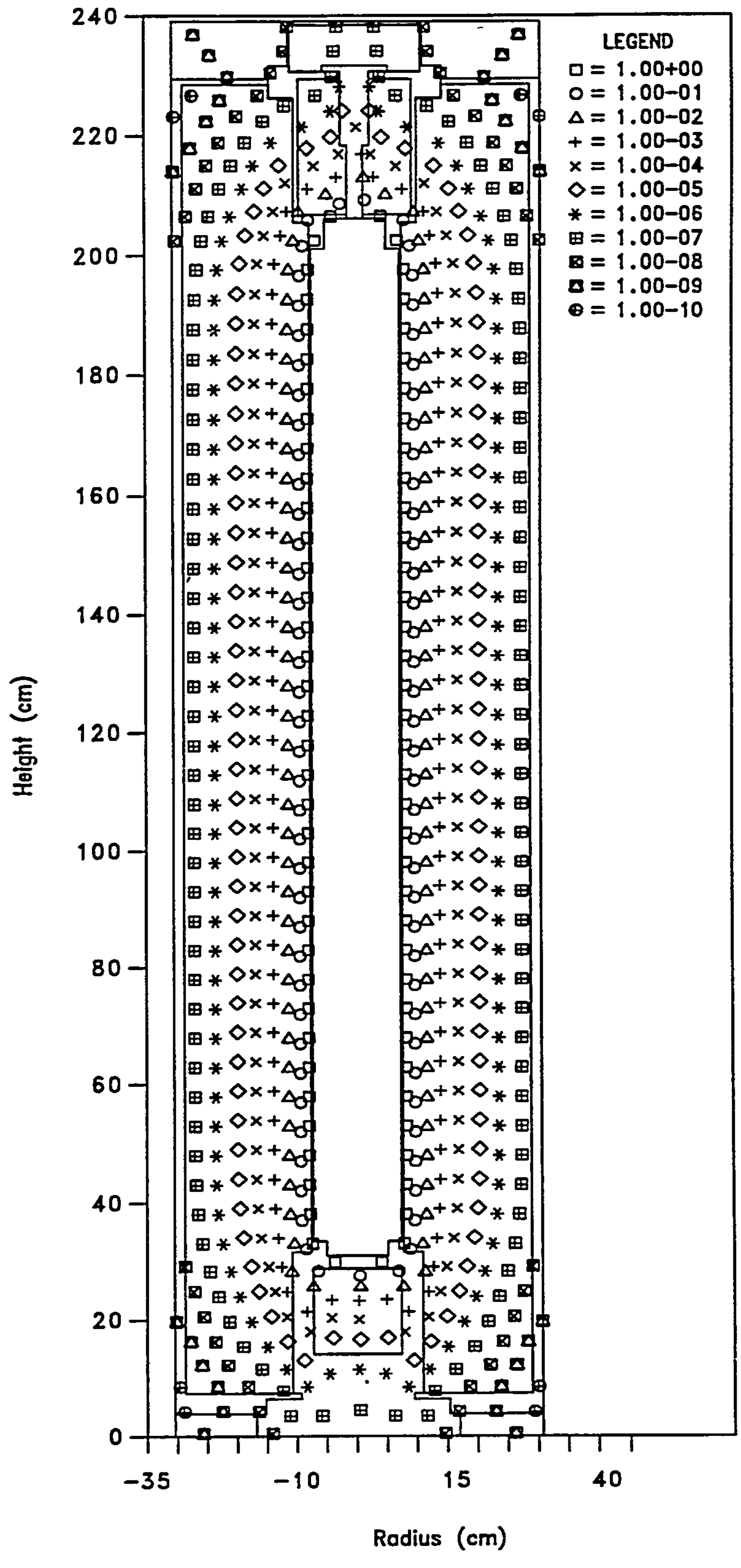

Figure D.5 Isodose Contours for the LWR MFP (50 MWd/kgU) Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

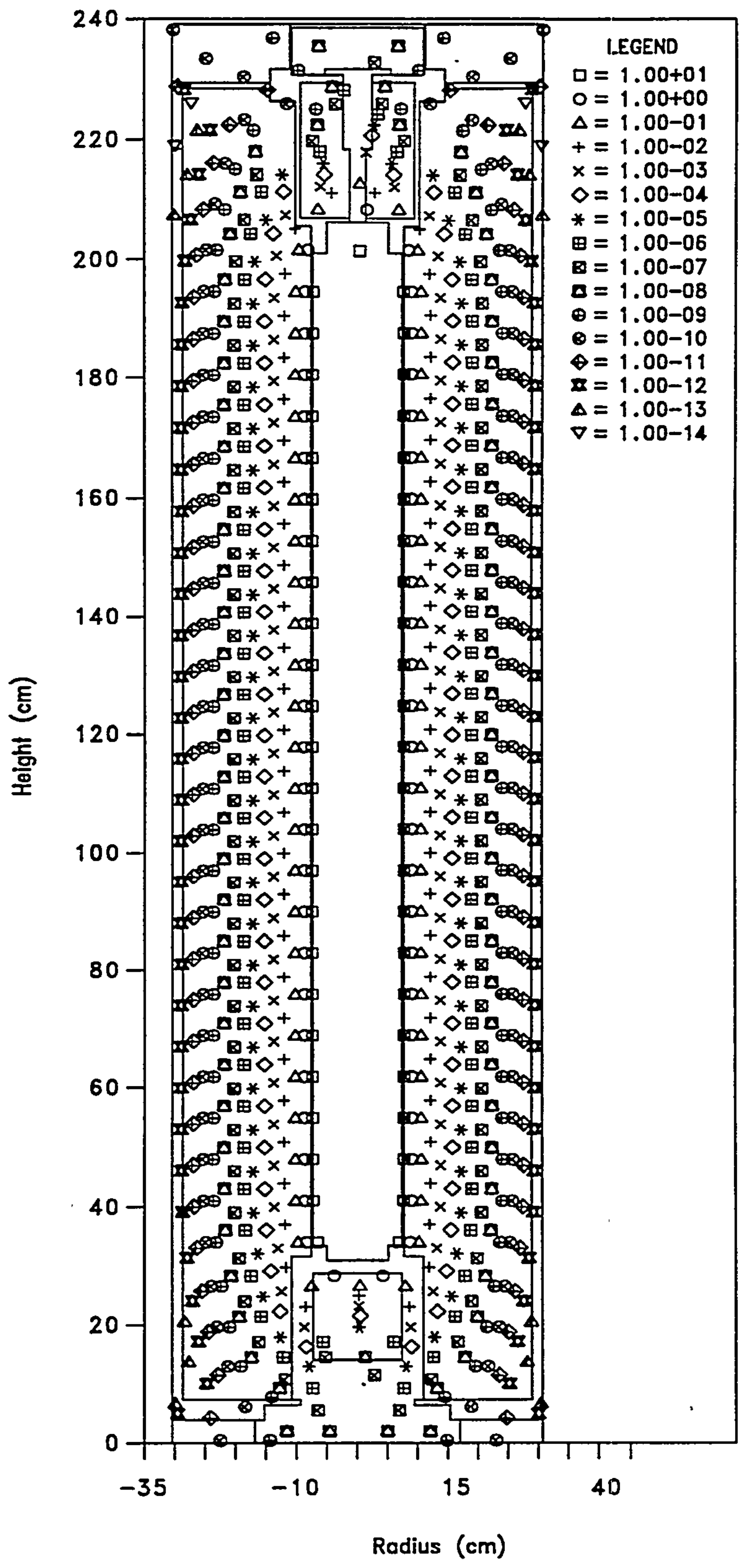

Figure D.6 Isodose Contours for the ^{137}Cs Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

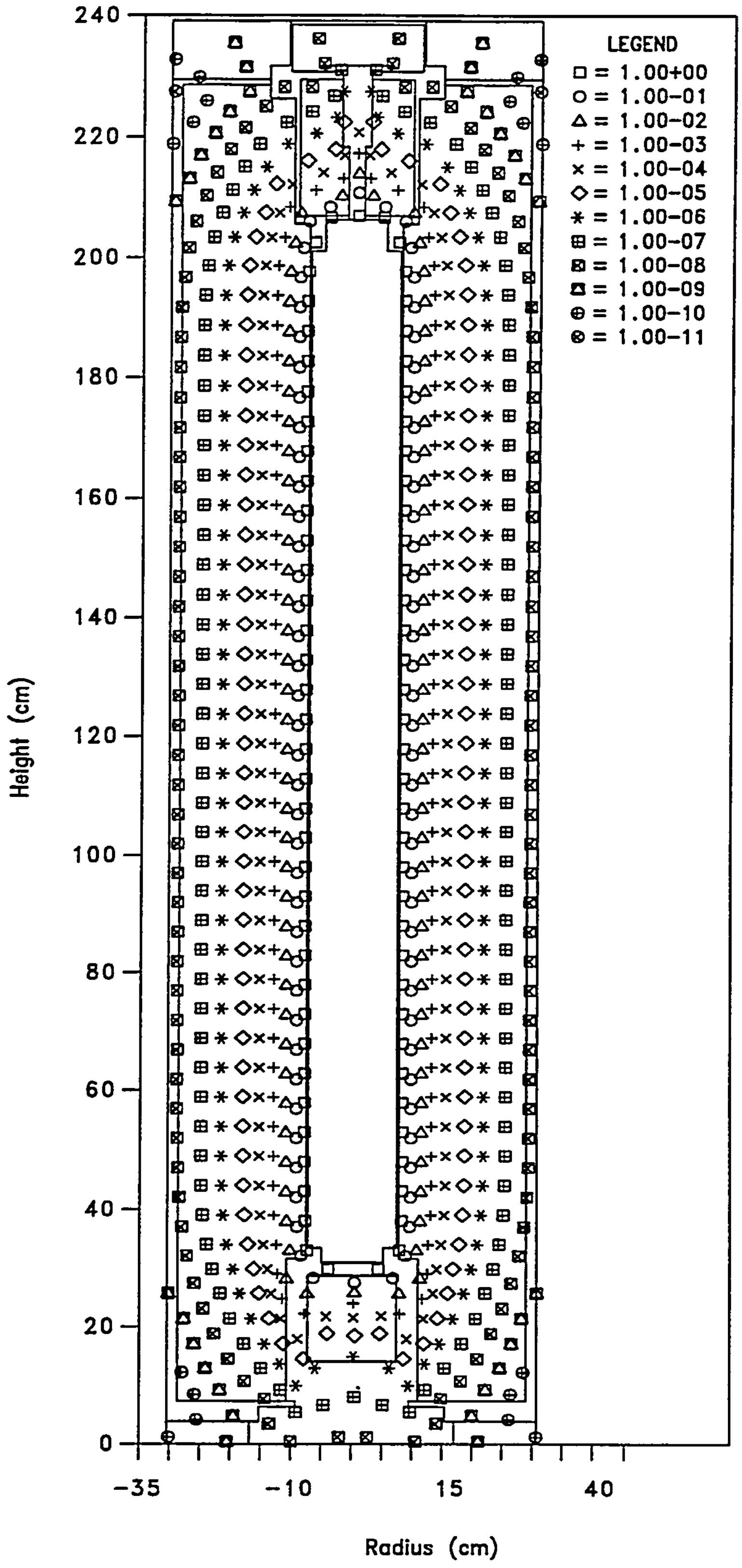

Figure D.7 Isodose Contours for the ORR MFP (20% Enriched ^{235}U) Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

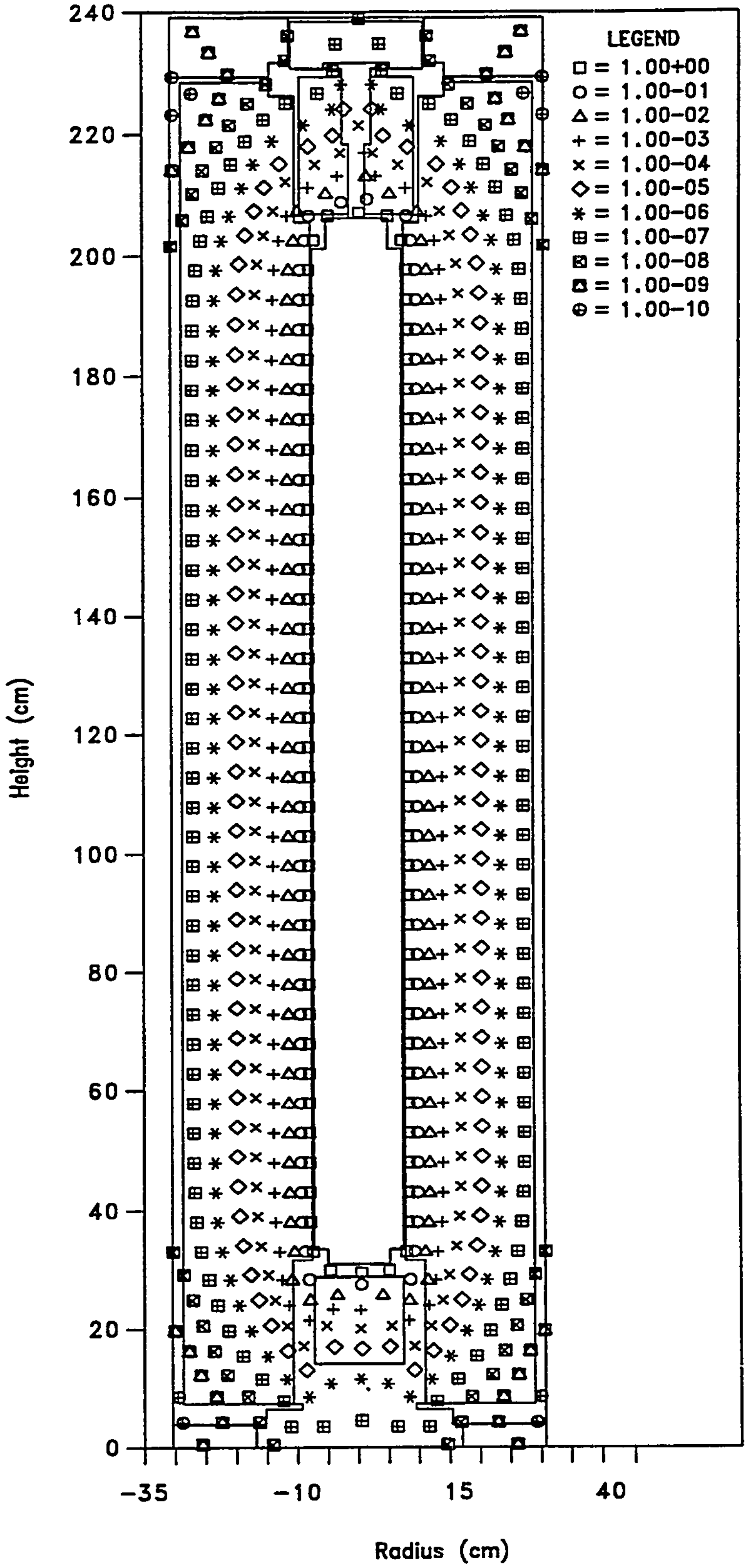

Figure D.8 Isodose Contours for the ORR MFP (40% Enriched ^{235}U) Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

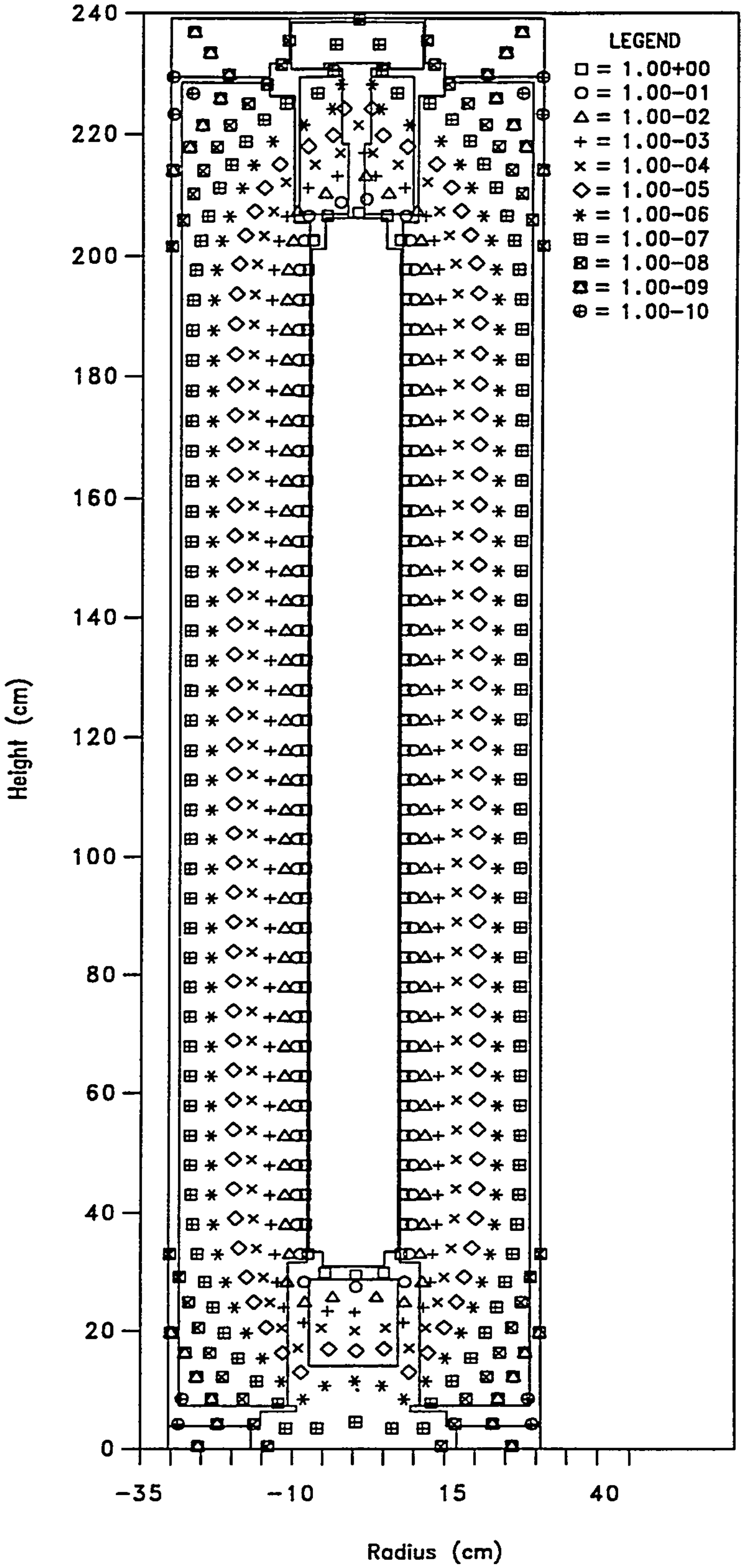

Figure D.9 Isodose Contours for the ORR MFP (93% Enriched ^{235}U) Source Packaged in the Loop Transport Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

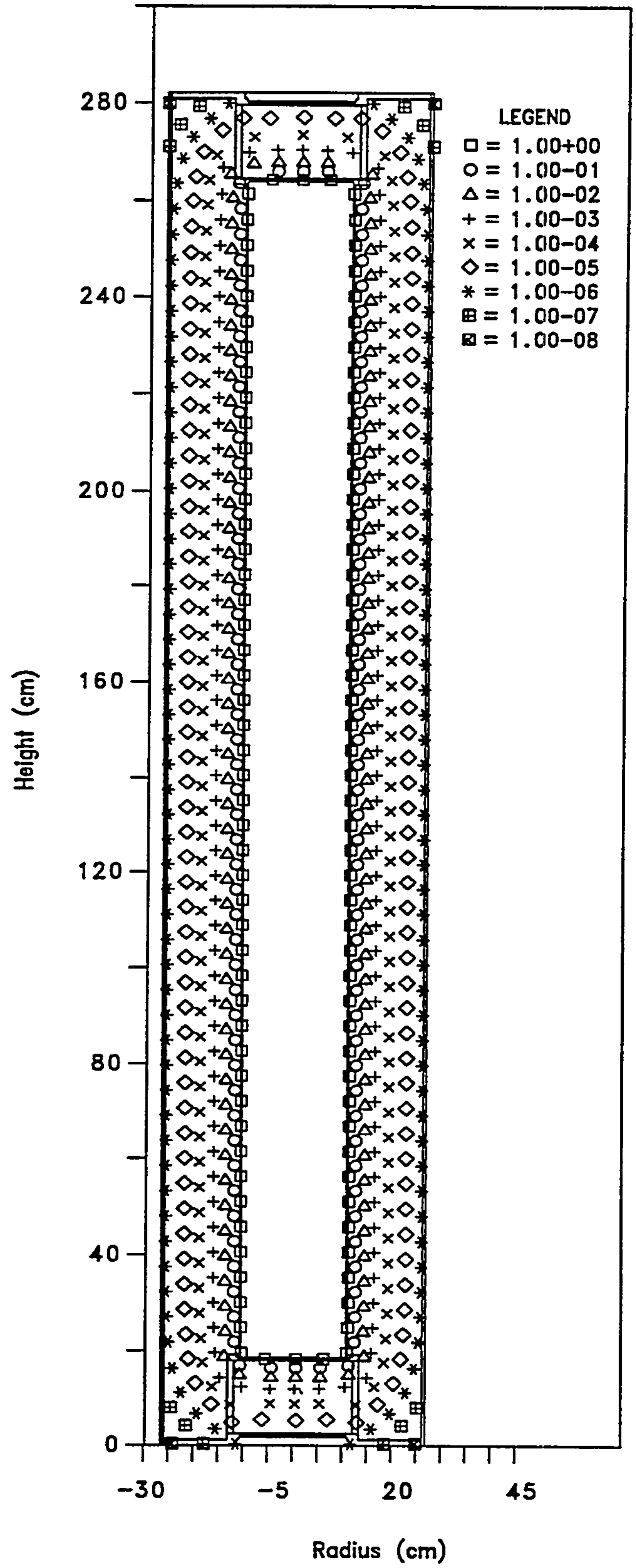

Figure D.10 Isodose Contours for the 60Co Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

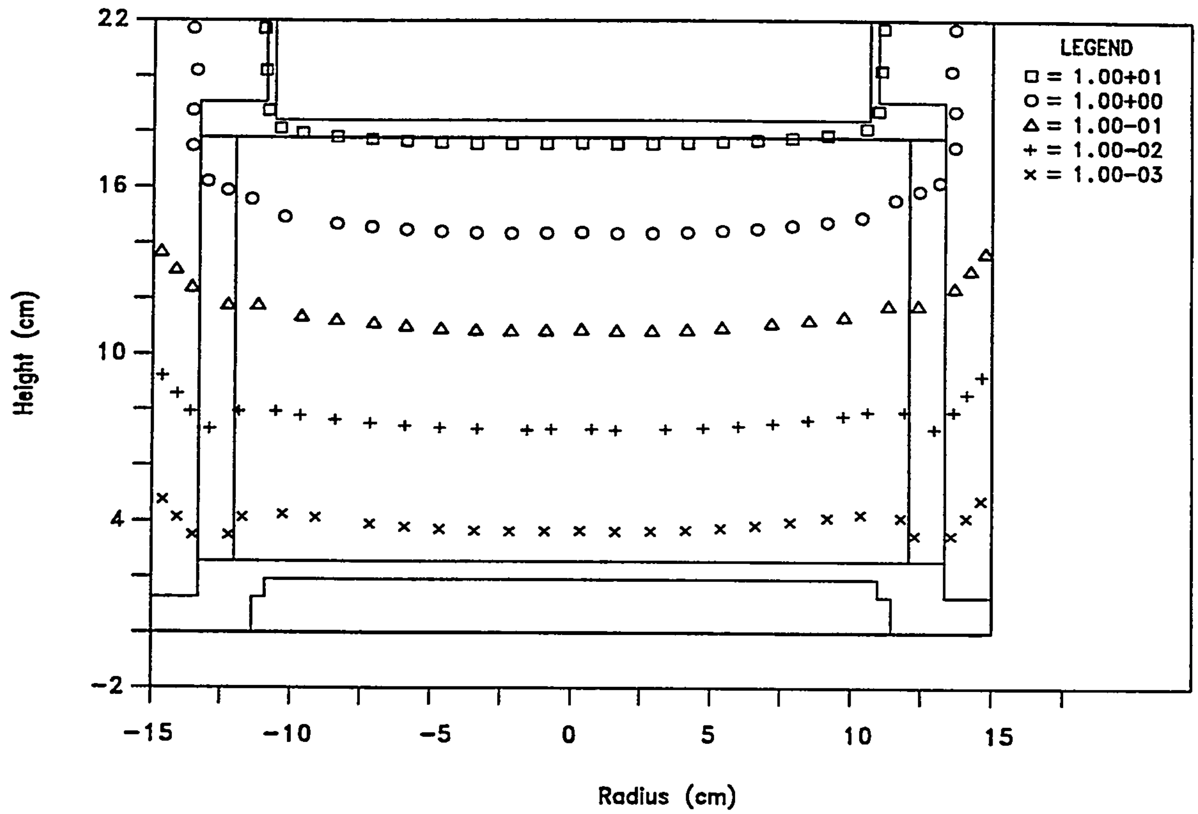

Figure D.11 Expanded View of the Double Doors Isodose Contours for the ^{60}Co Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

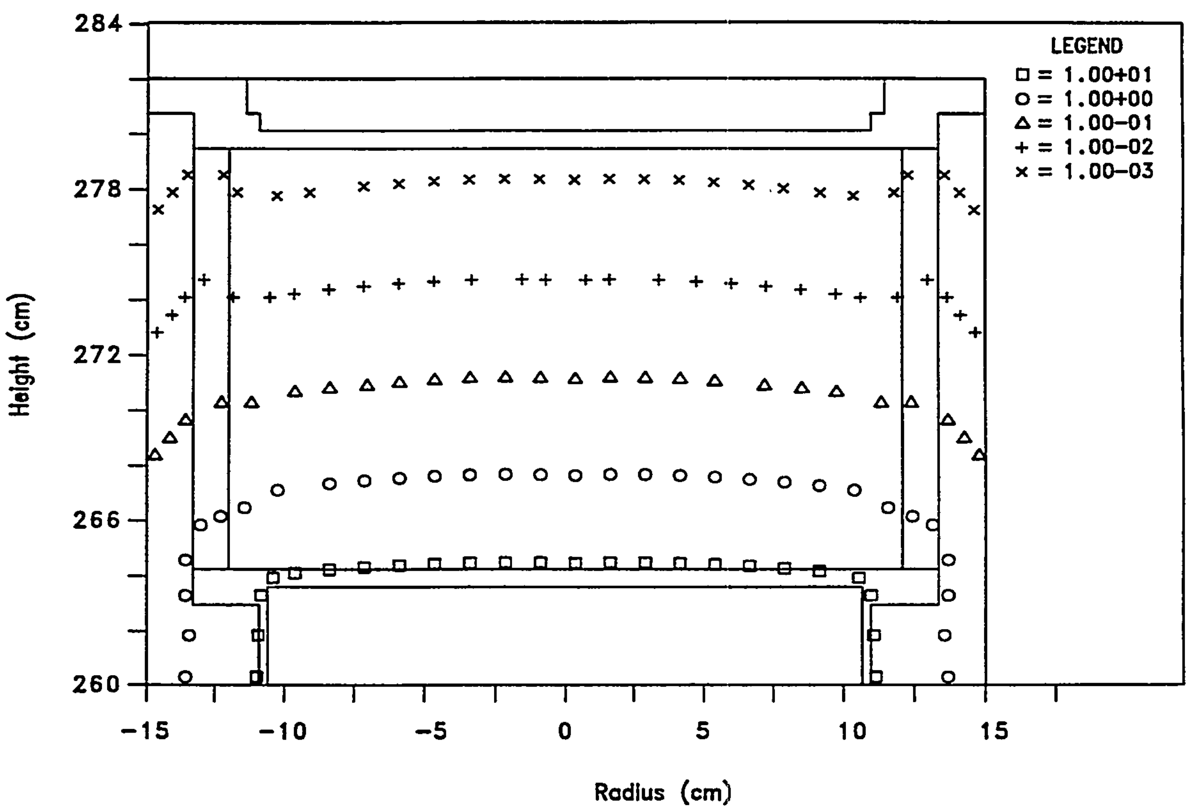

Figure D.12 Expanded View of the Large Door Isodose Contours for the ^{60}Co Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

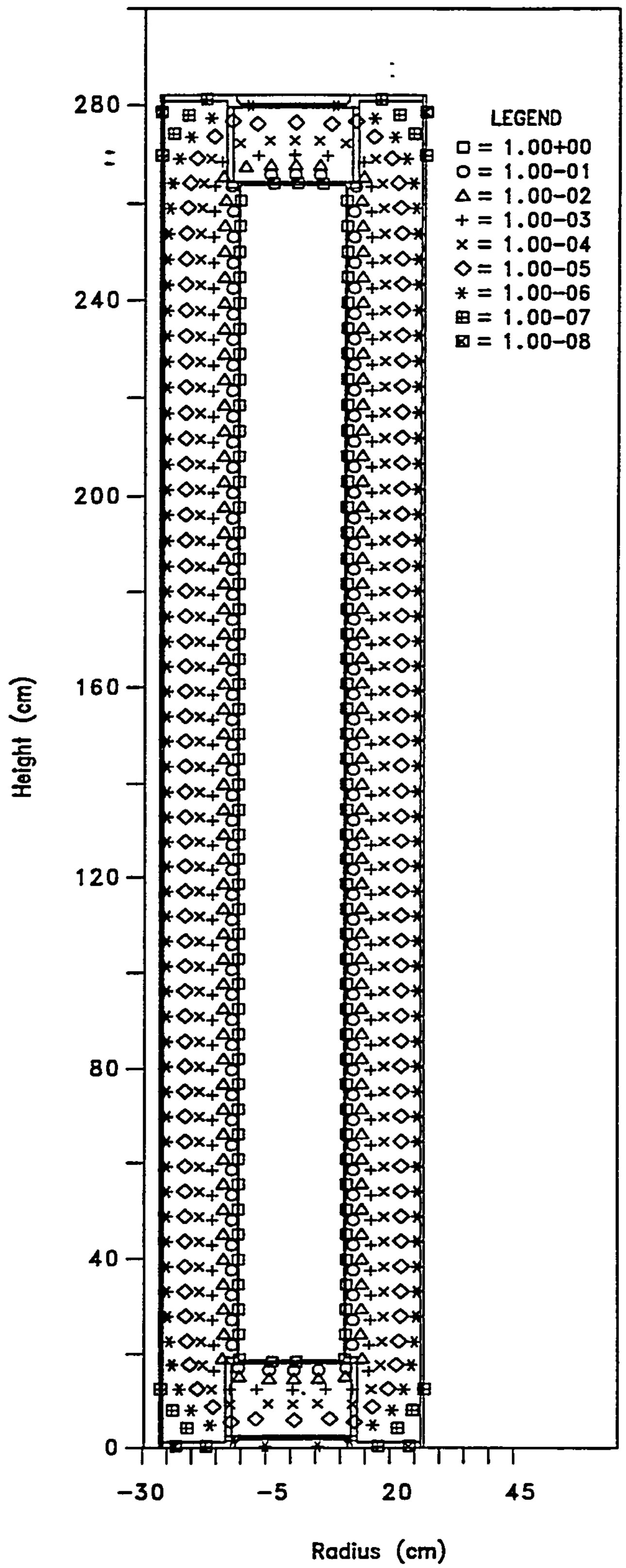

Figure D.13 Isodose Contours for the LWR MFP (25 MWd/kgU) Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/h·Ci).]

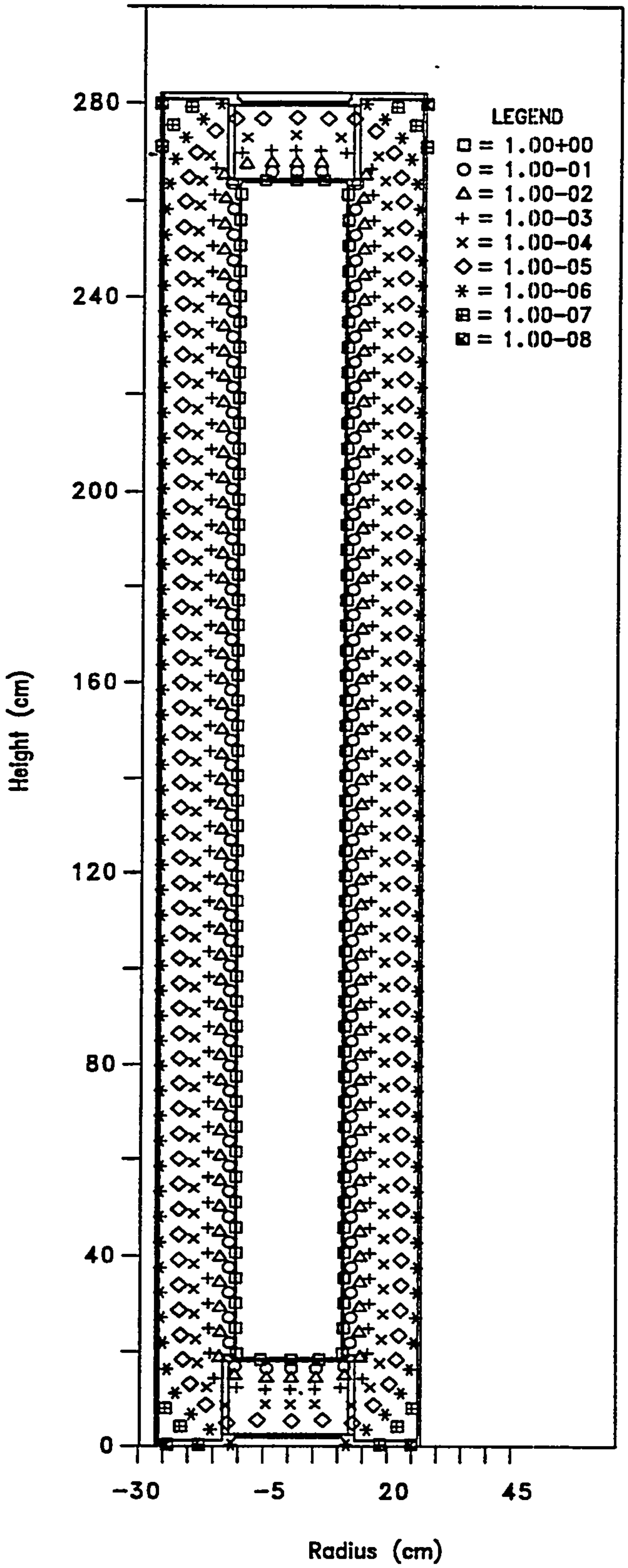

Figure D.14 Isodose Contours for the LWR MFP (50 MWd/kgU) Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

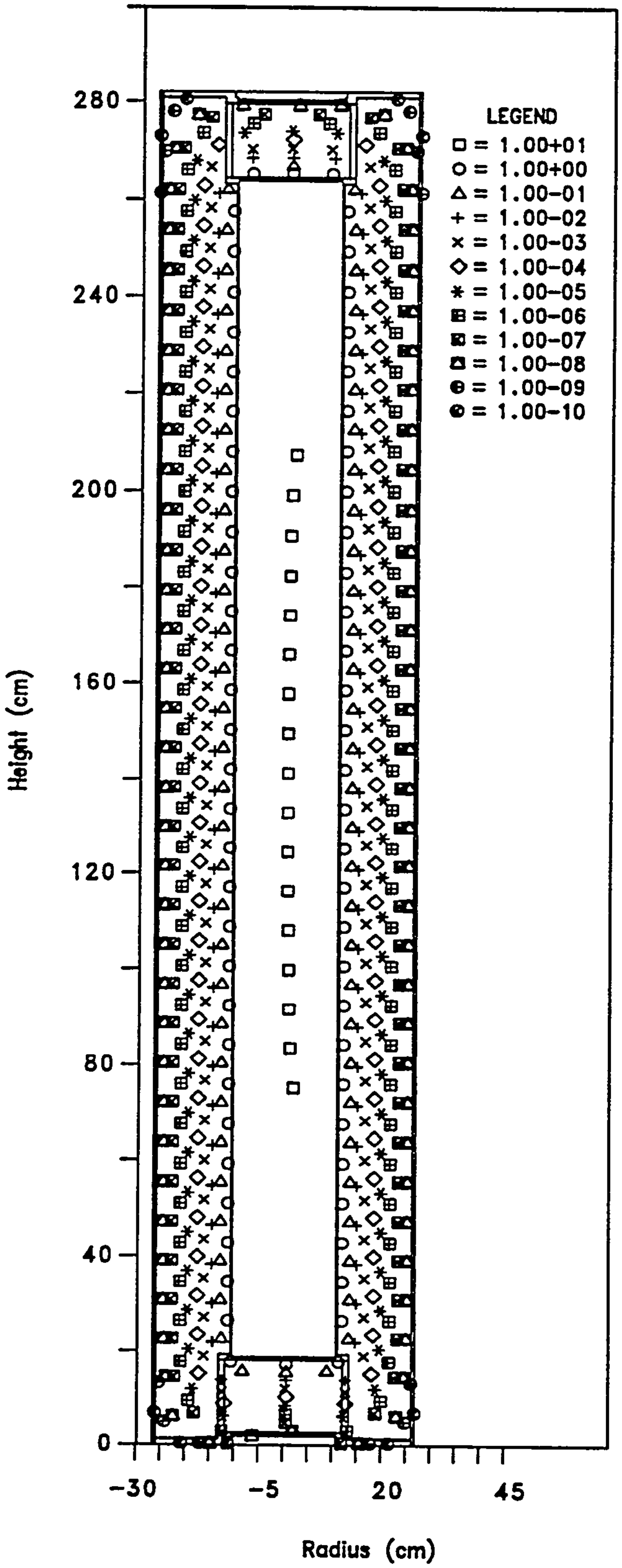

Figure D.15 Isodose Contours for the ^{137}Cs Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

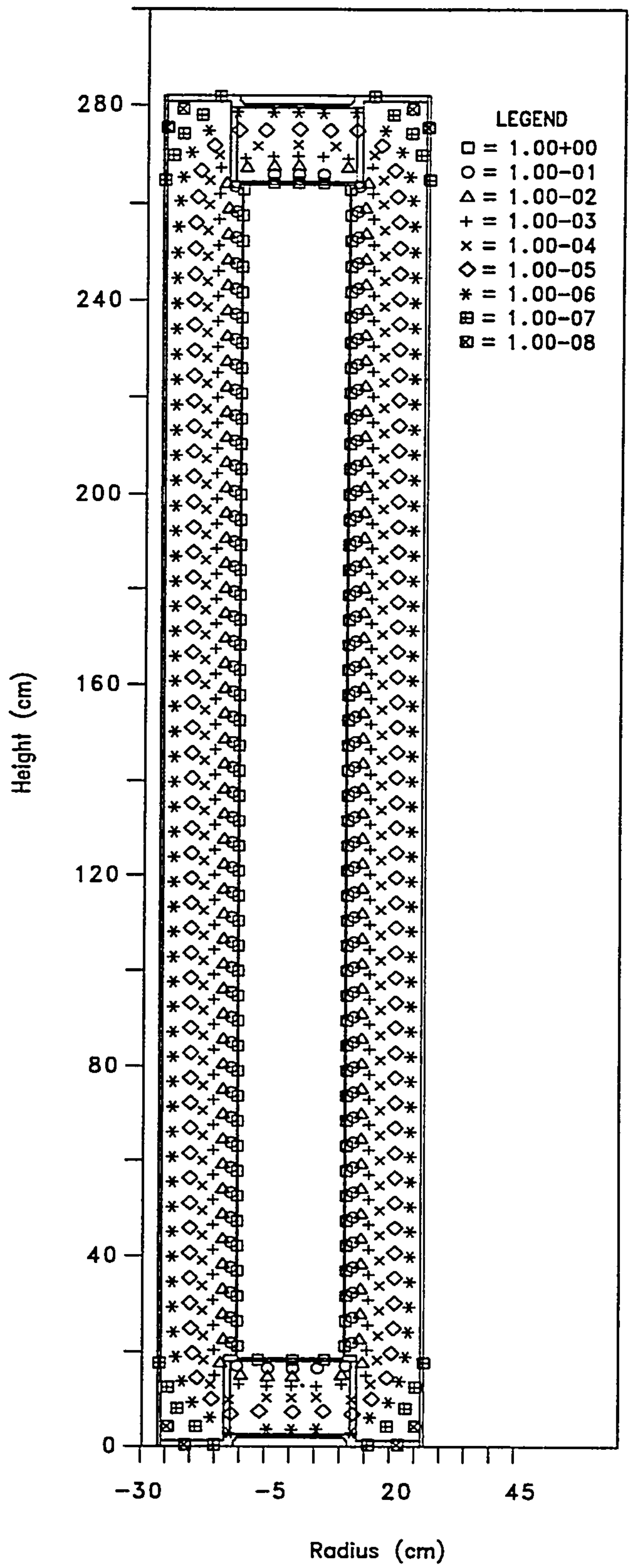

Figure D.16 Isodose Contours for the ORR MFP (20% Enriched ^{235}U) Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

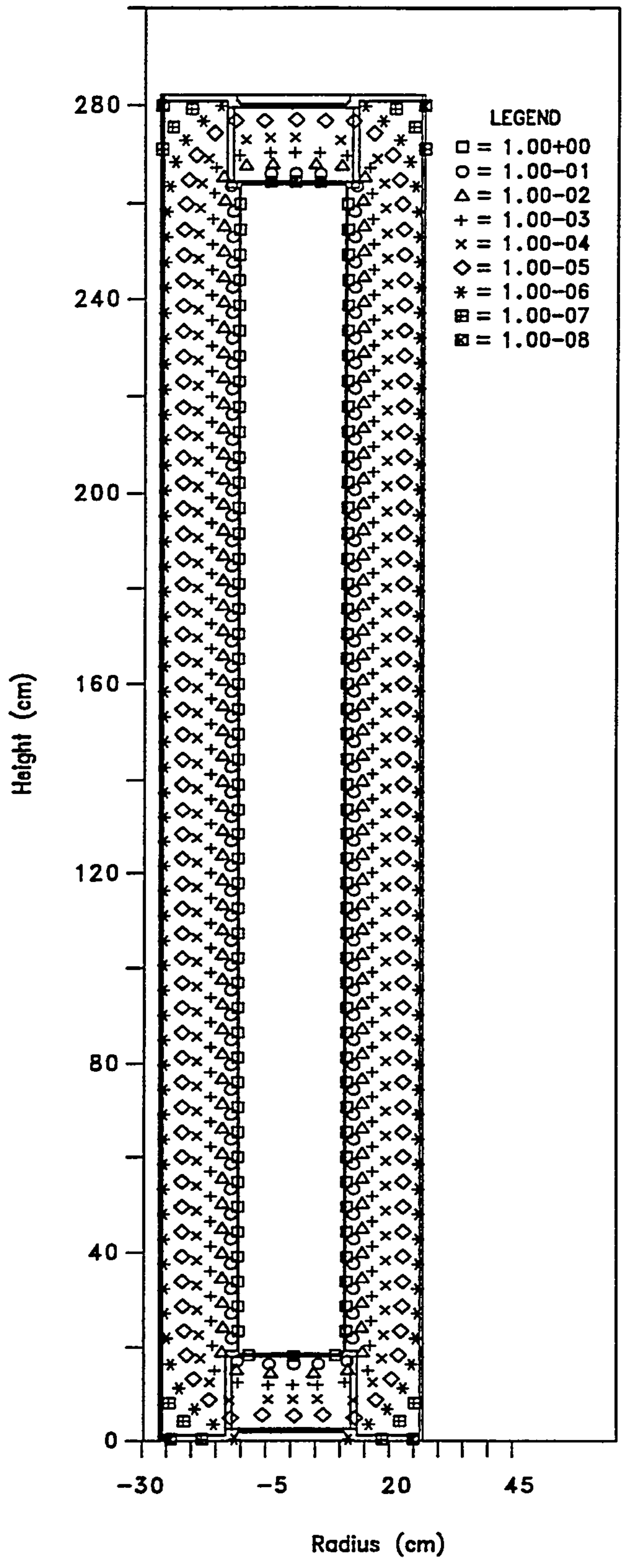

Figure D.17 Isodose Contours for the ORR MFP (40% Enriched ^{235}U) Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

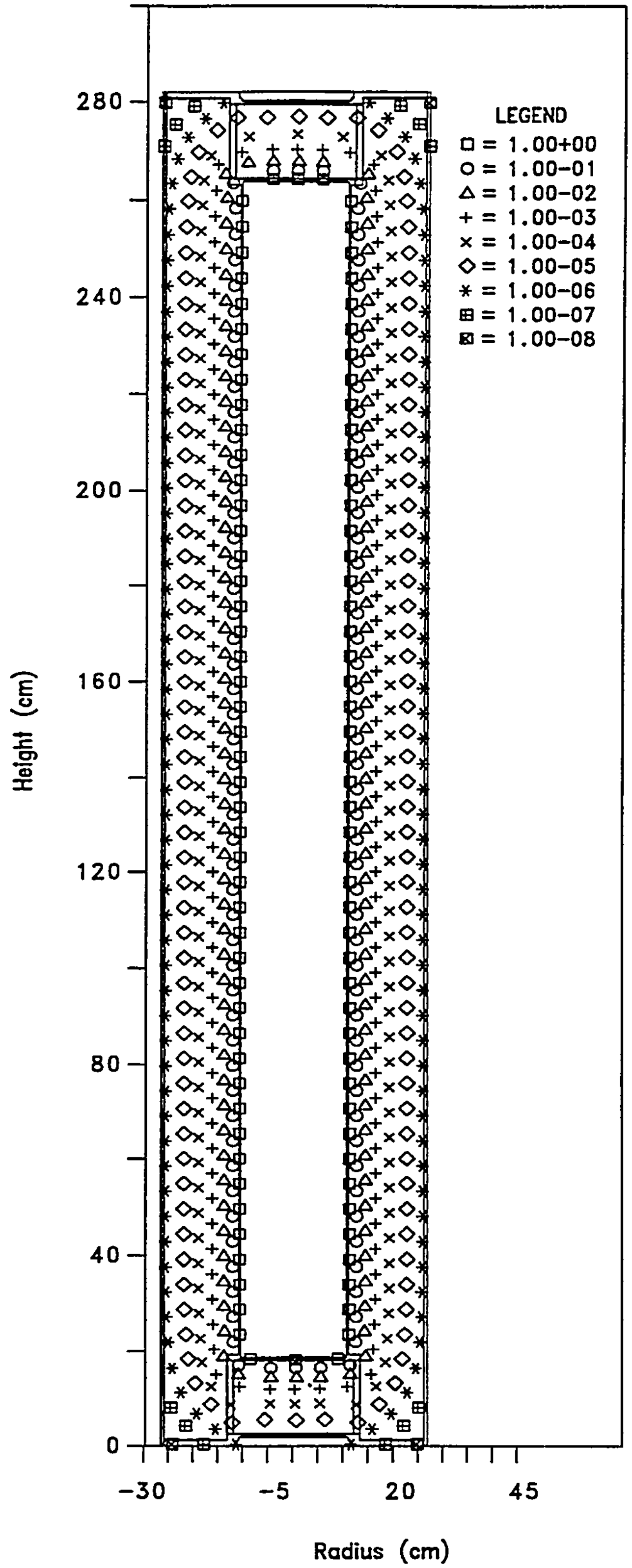

Figure D.18 Isodose Contours for the ORR MFP (93% Enriched ^{235}U) Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

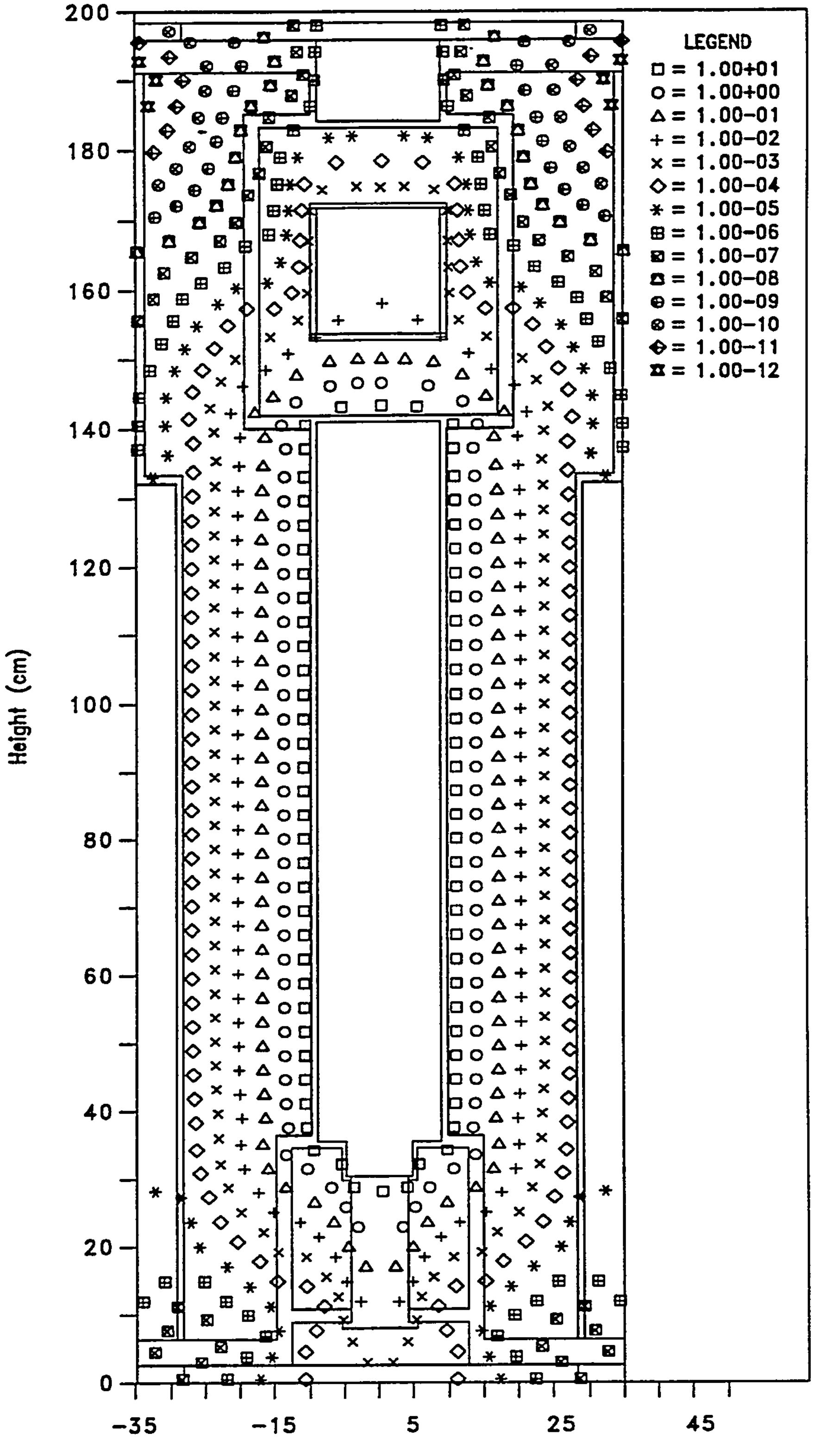

Figure D.19 Isodose Contours for the ^{60}Co Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

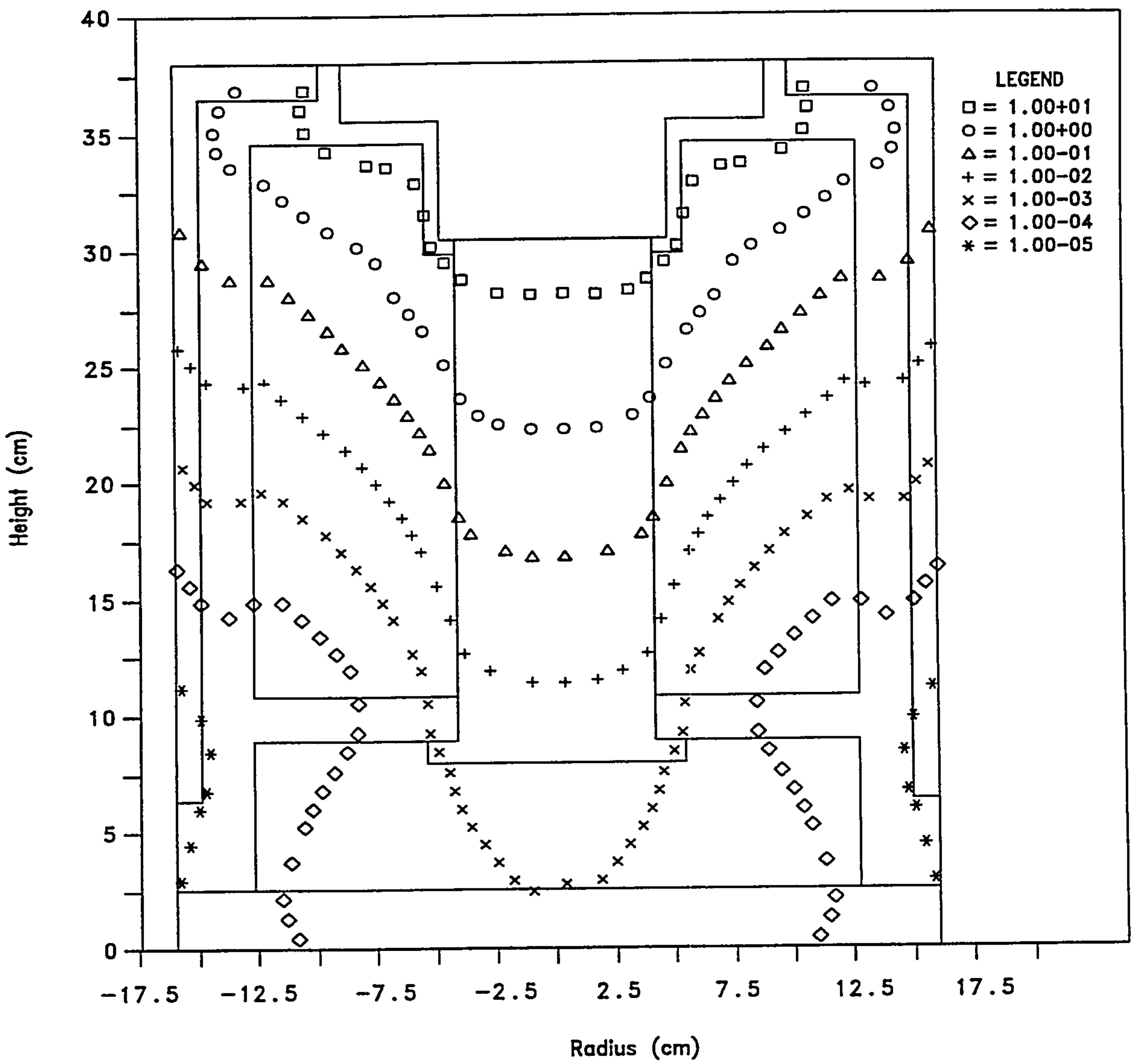

Figure D.20 Expanded View of the End Plug Isodose Contours for the ^{60}Co Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

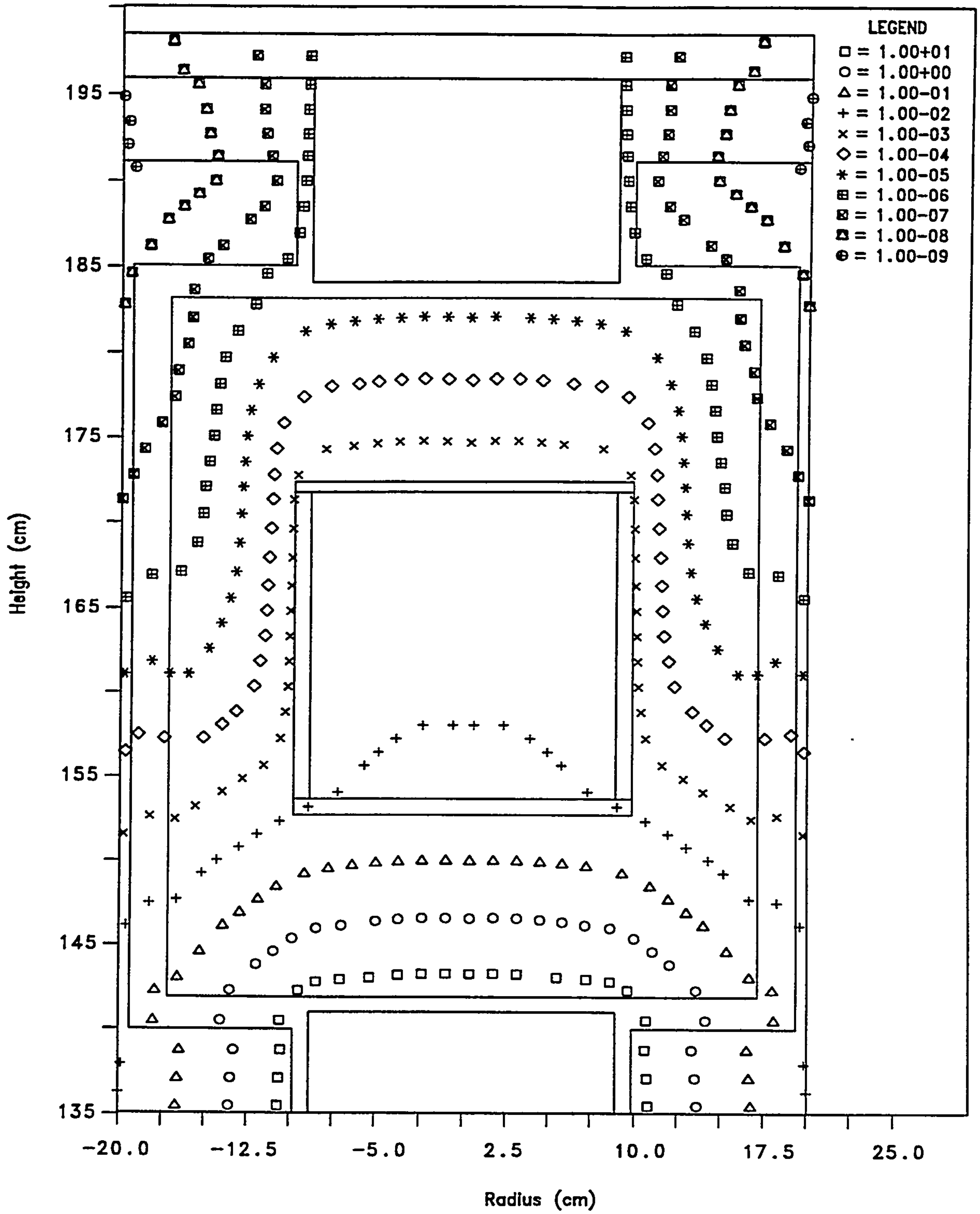

Figure D.21 Expanded View of the Door Isodose Contours for the ^{60}Co Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

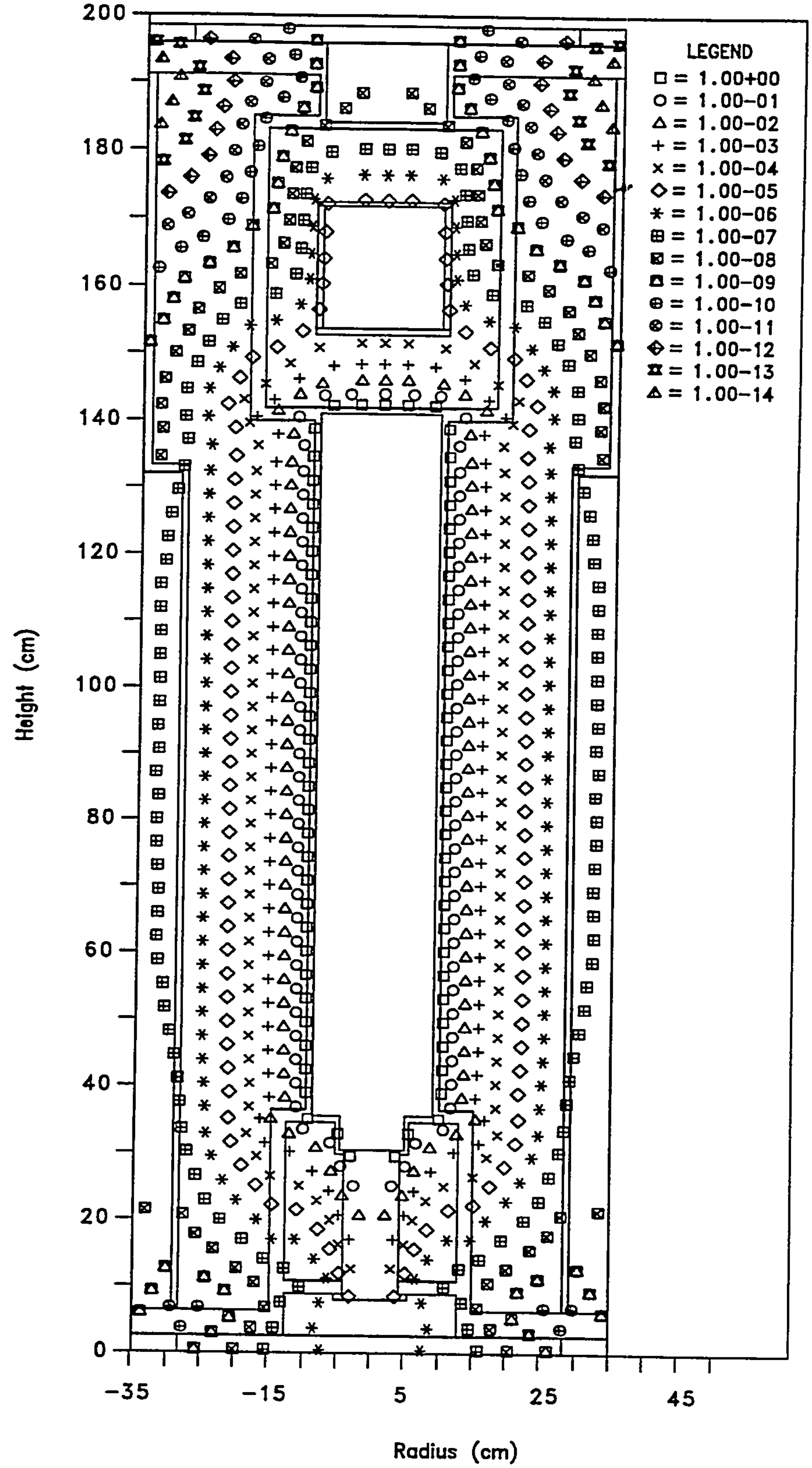

Figure D.22 Isodose Contours for the LWR MFP (25 MWd/kgU) Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

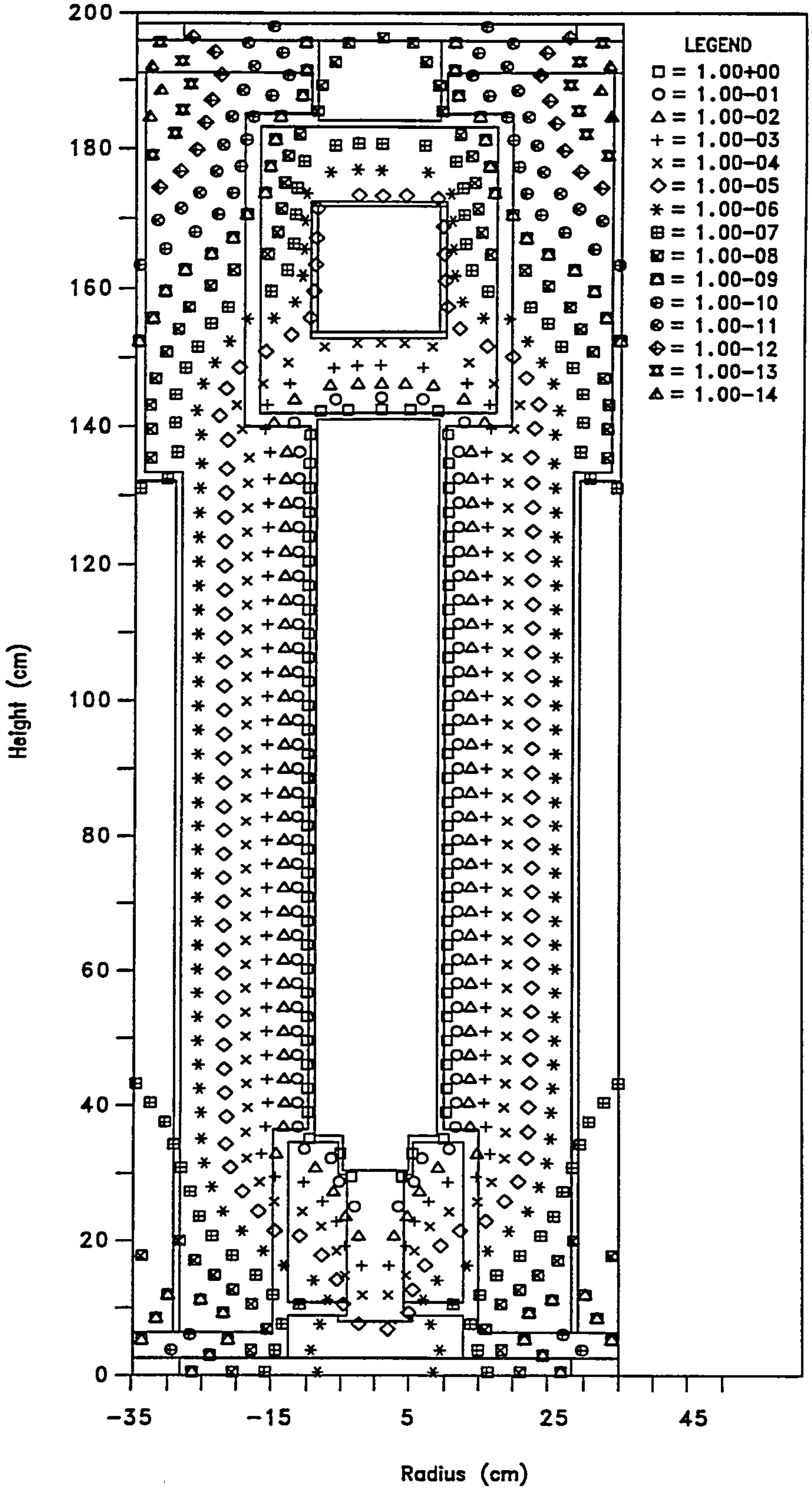

Figure D.23 Isodose Contours for the LWR MFP (50 MWd/kgU) Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

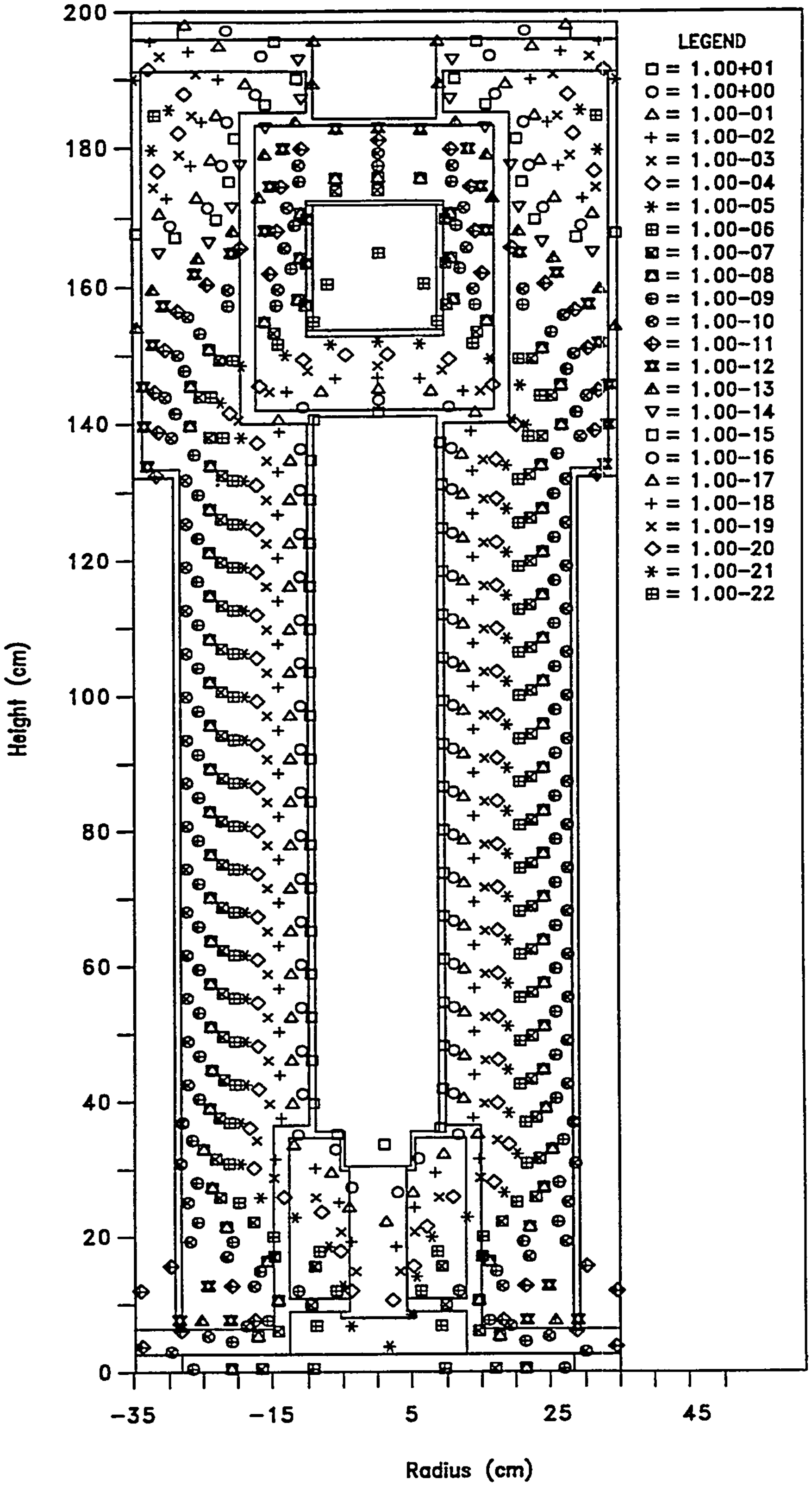

Figure D.24 Isodose Contours for the ^{137}Cs Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

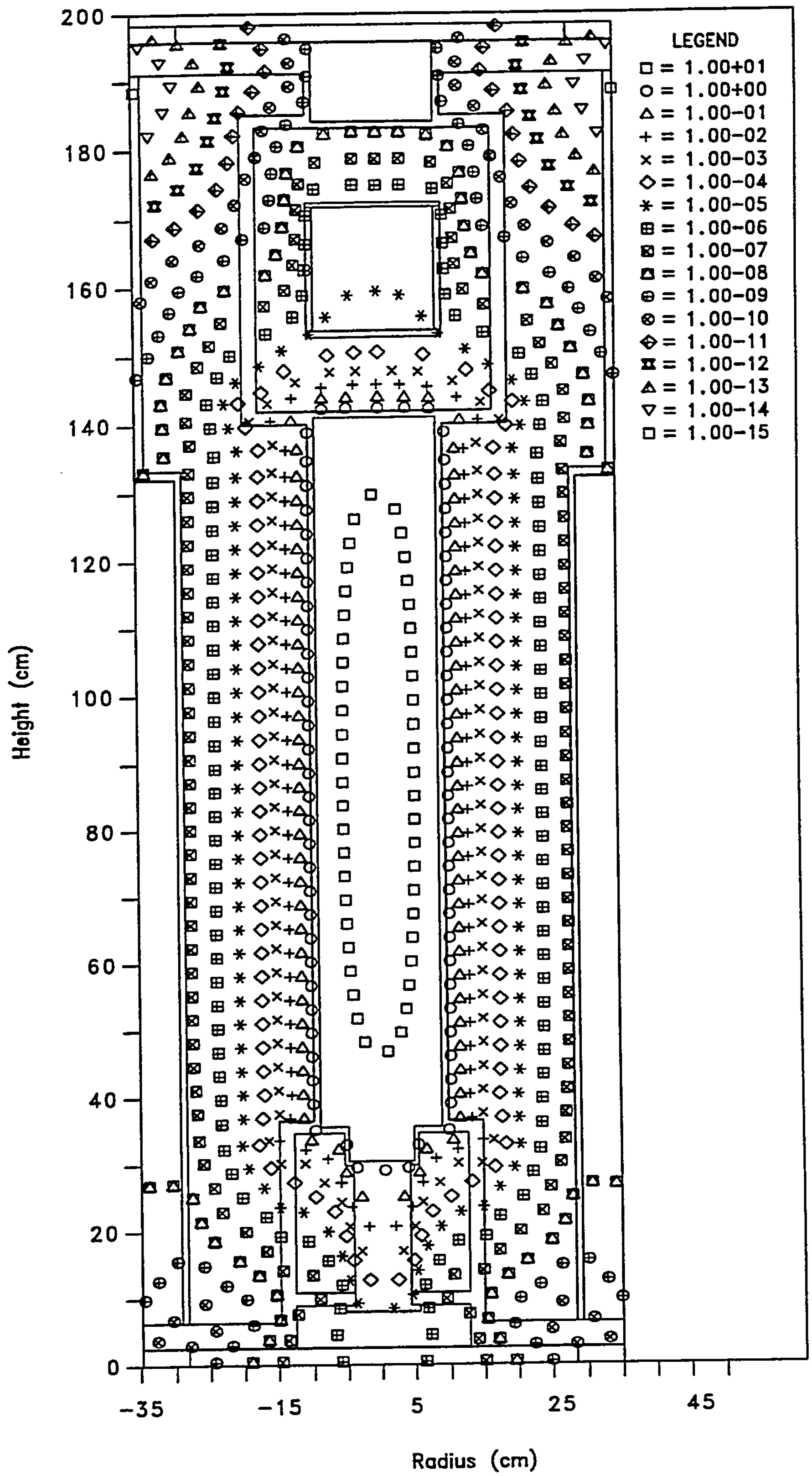

Figure D.25 Isodose Contours for the ORR MFP (20% Enriched ^{235}U) Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

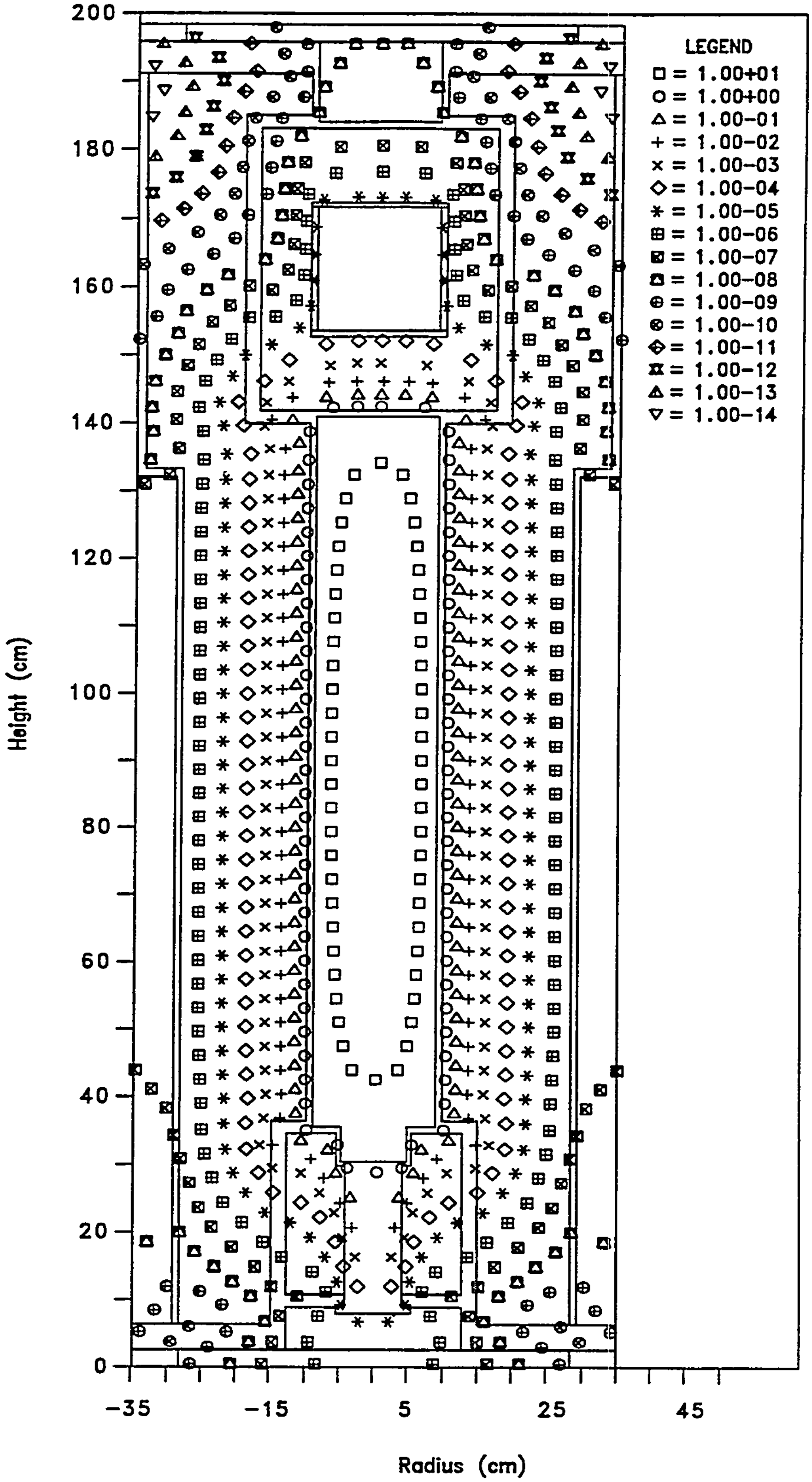

Figure D.26 Isodose Contours for the ORR MFP (40% Enriched ^{235}U) Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

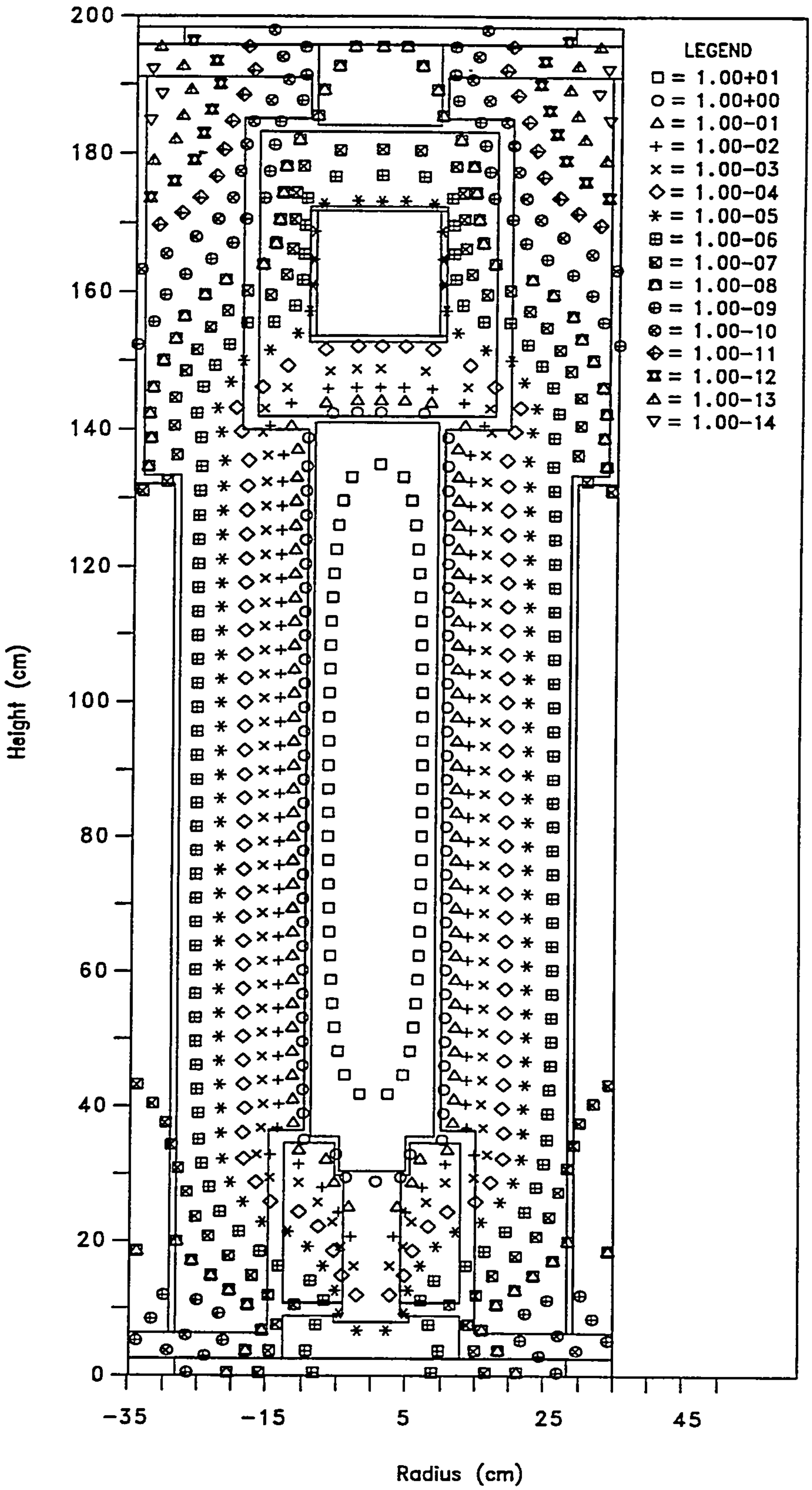

Figure D.27 Isodose Contours for the ORR MFP (93% Enriched ^{235}U) Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

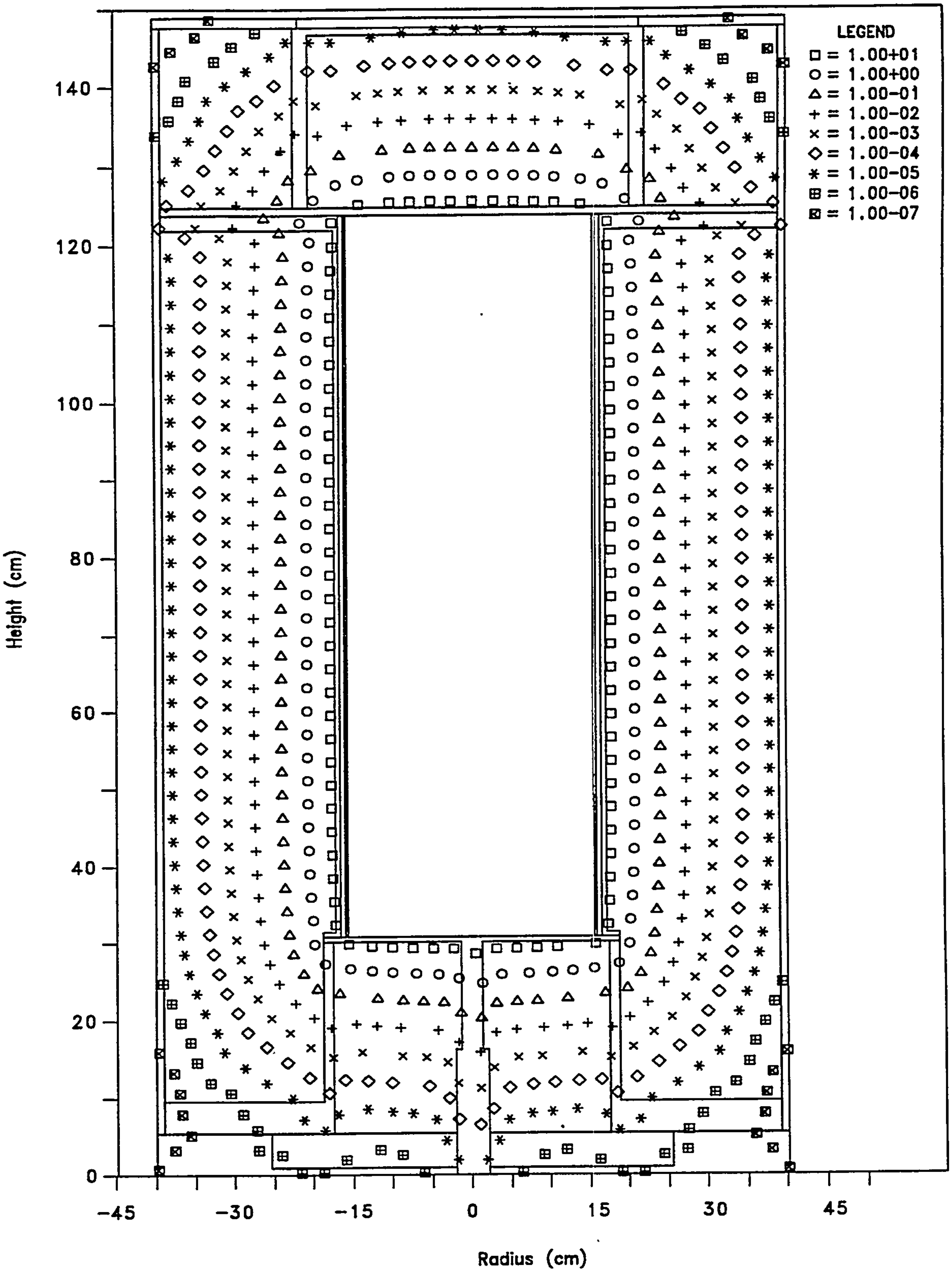

Figure D.28 Isodose Contours for the ^{60}Co Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

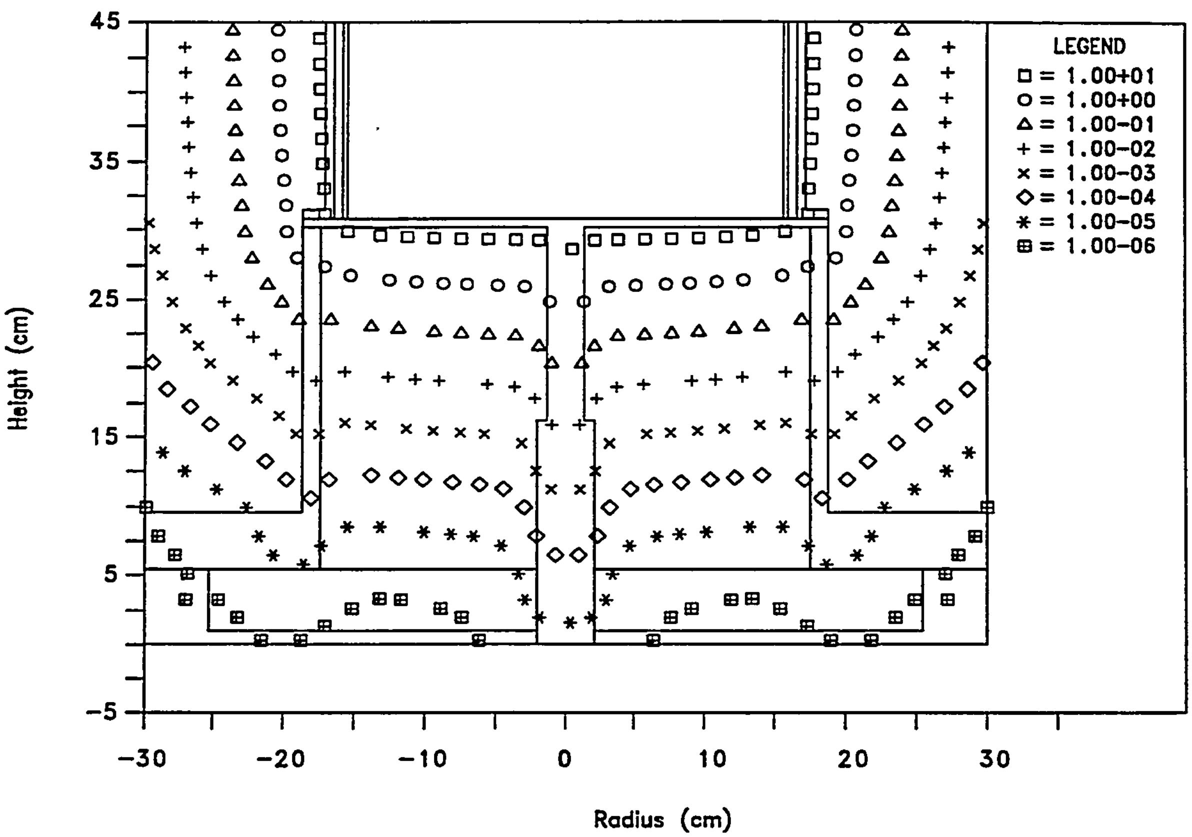

Figure D.29 Expanded View of the Top Plug Isodose Contours for the ^{60}Co Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

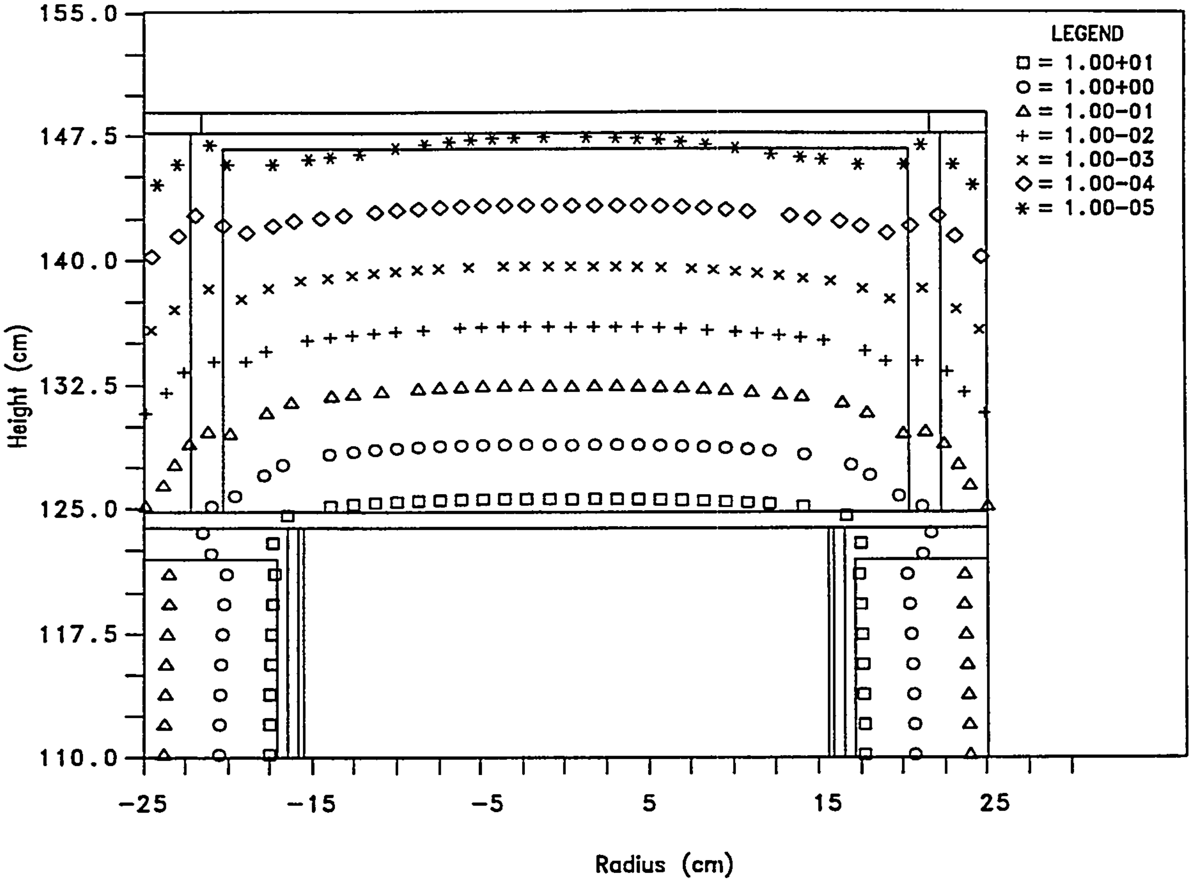

Figure D.30 Expanded View of the Bottom Door Isodose Contours for the ^{60}Co Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

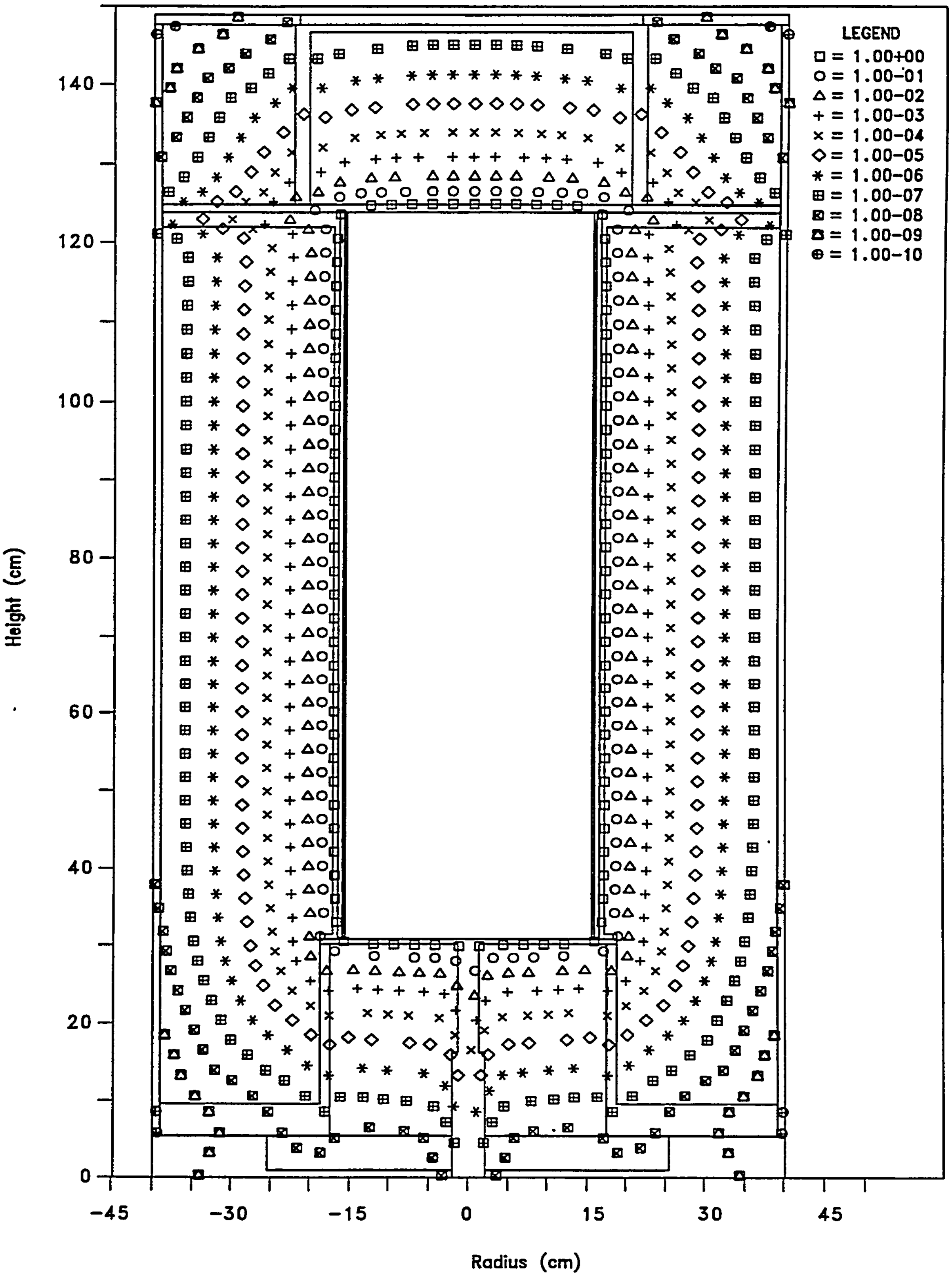

Figure D.31 Isodose Contours for the LWR MFP (25 MWd/kgU) Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

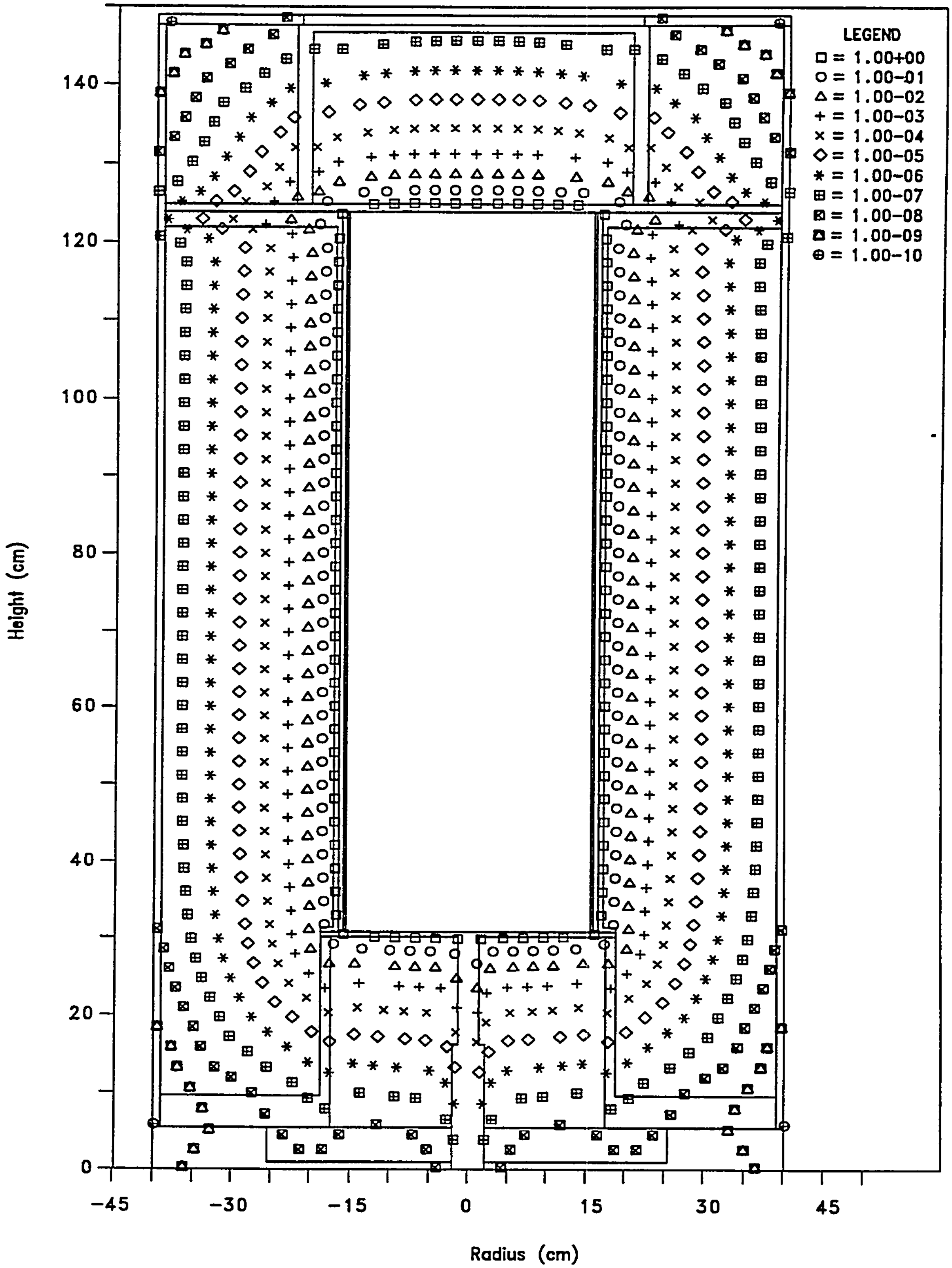

Figure D.32 Isodose Contours for the LWR MFP (50 MWd/kgU) Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

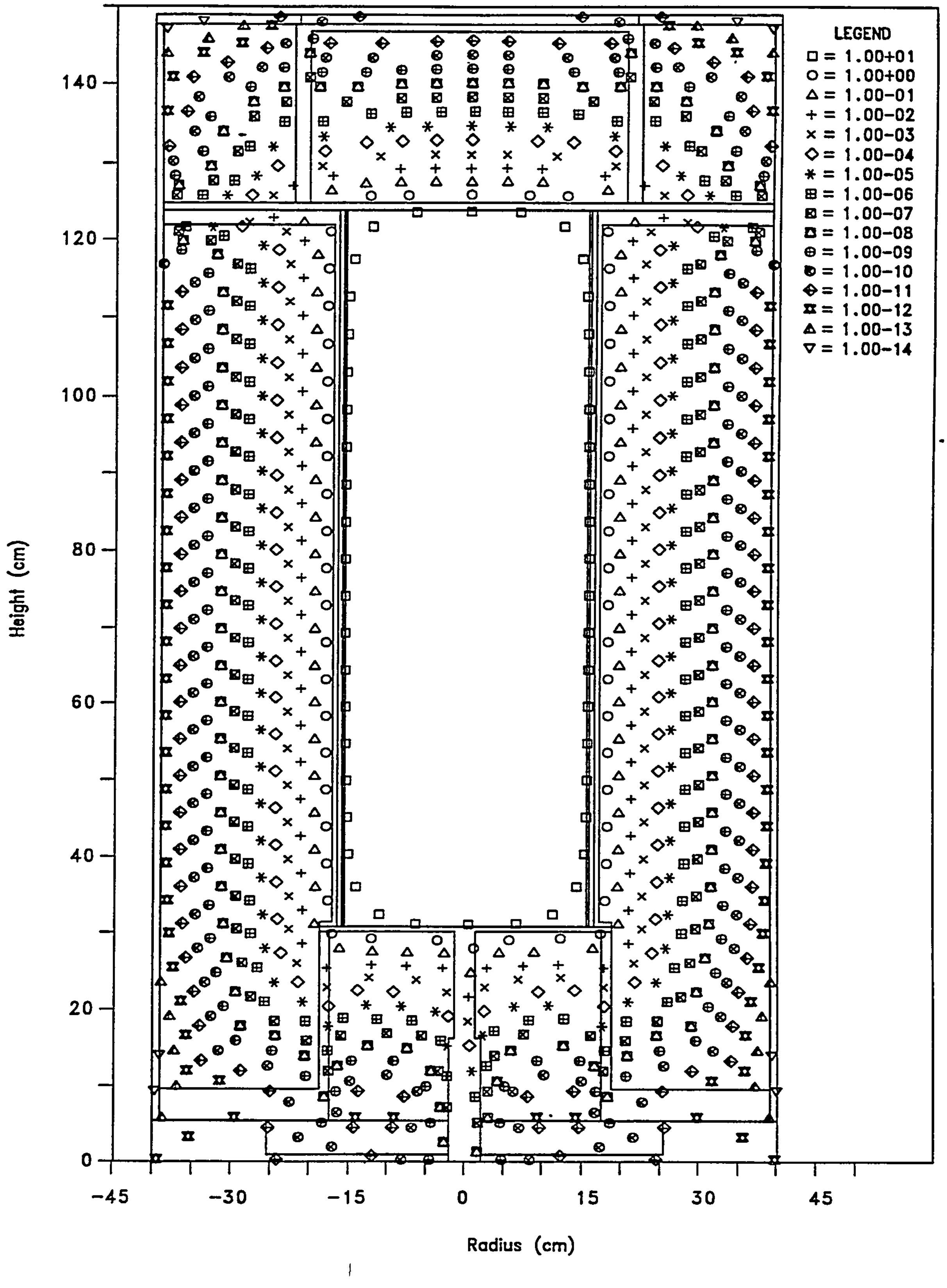

Figure D.33 Isodose Contours for the ^{137}Cs Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

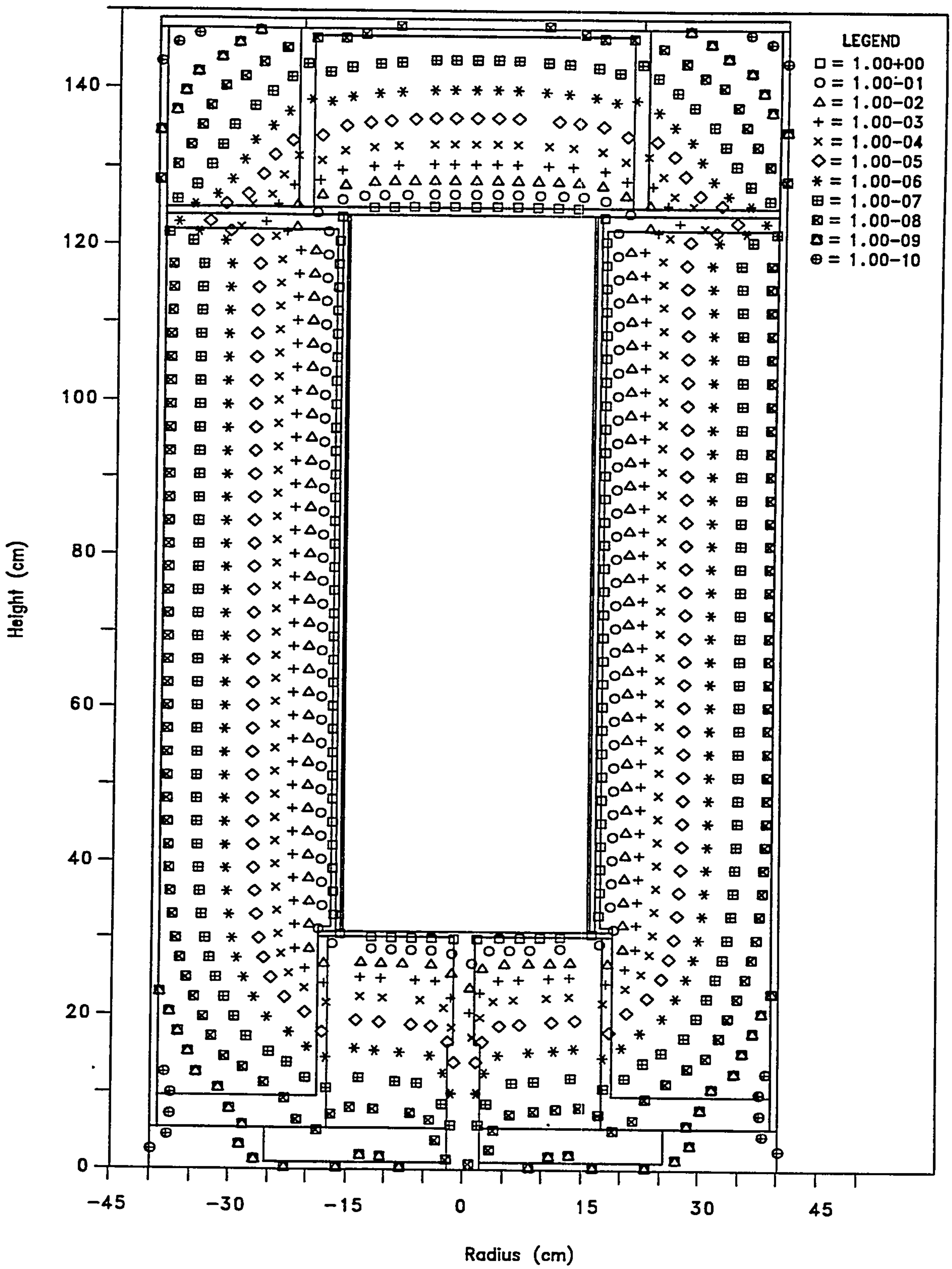

Figure D.34 Isodose Contours for the ORR MFP (20% Enriched ^{235}U) Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

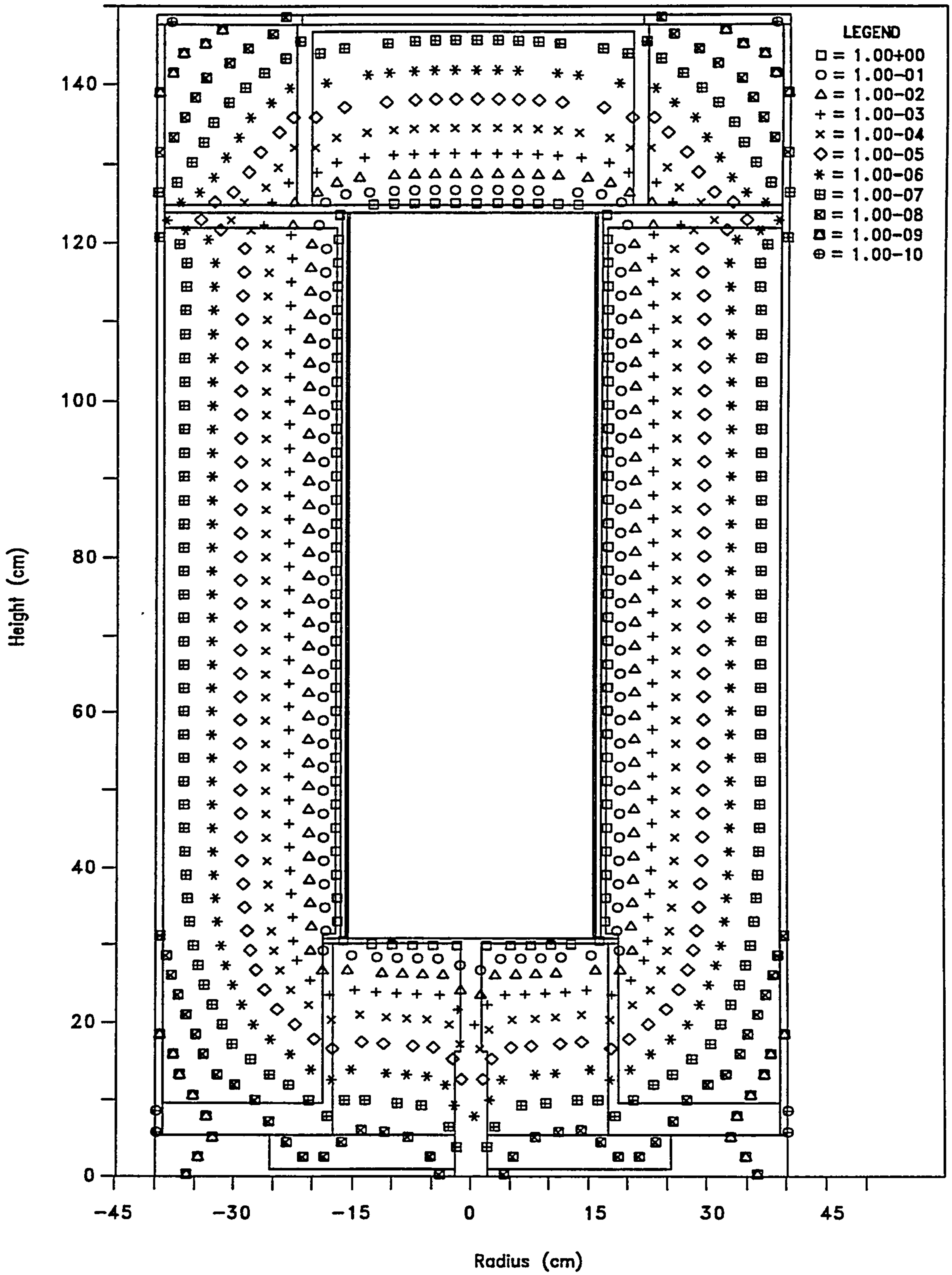

Figure D.35 Isodose Contours for the ORR MFP (40% Enriched ^{235}U) Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

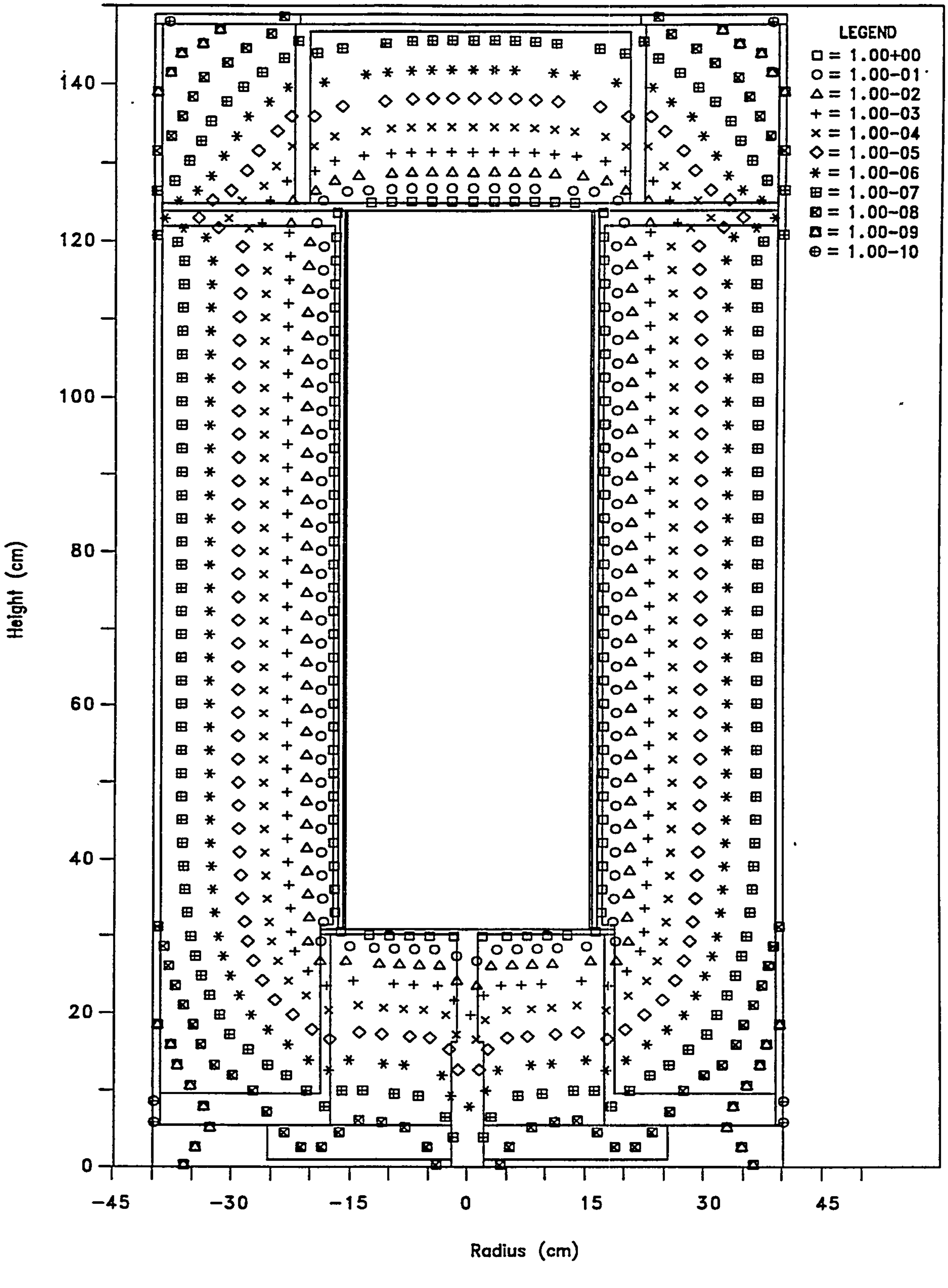

Figure D.36 Isodose Contours for the ORR MFP (93% Enriched ^{235}U) Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask. [Dose units are rem/(h·Ci).]

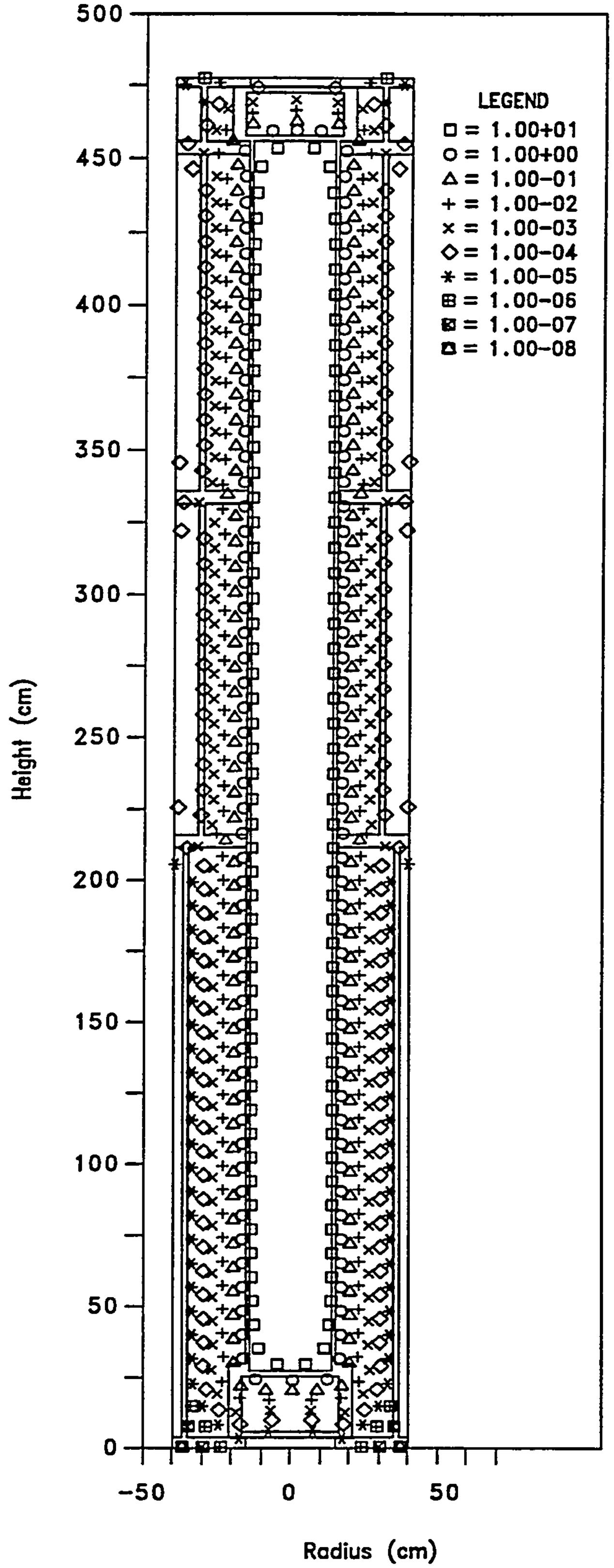

Figure D.37 Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

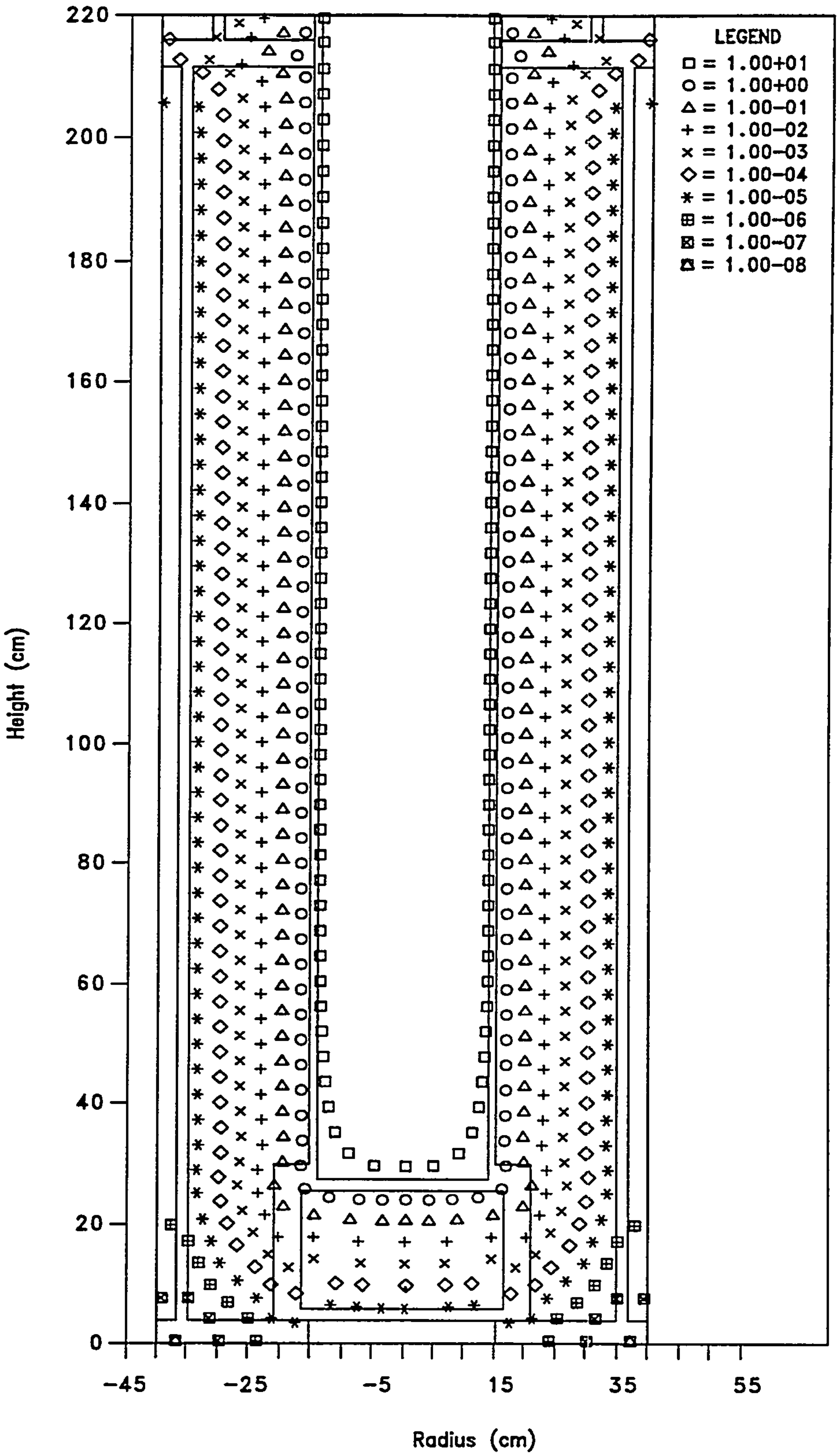

Figure D-38. Expanded View of the Heavy Shield Section Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

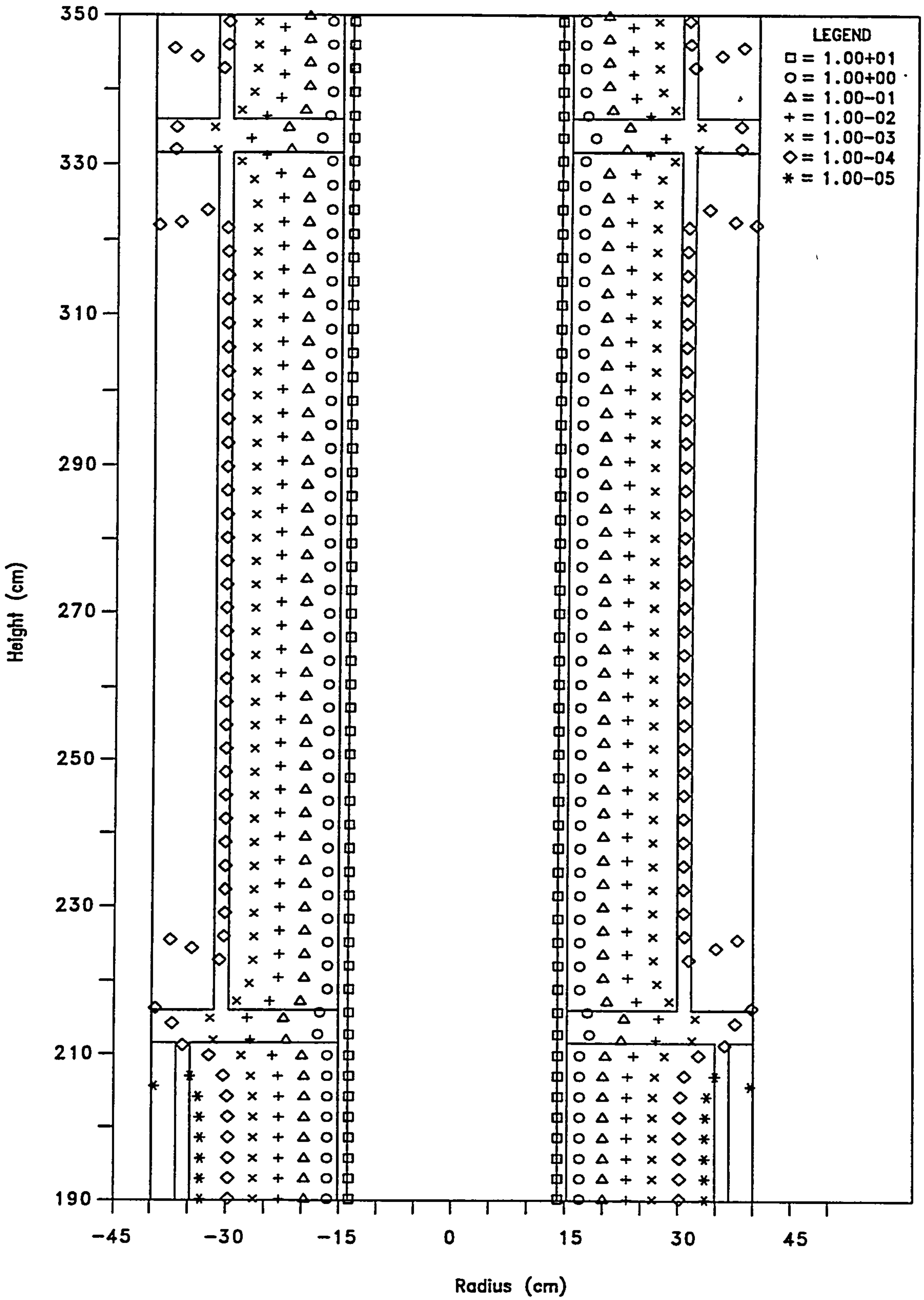

Figure D.39 Expanded View of the Central Light Shield Section Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

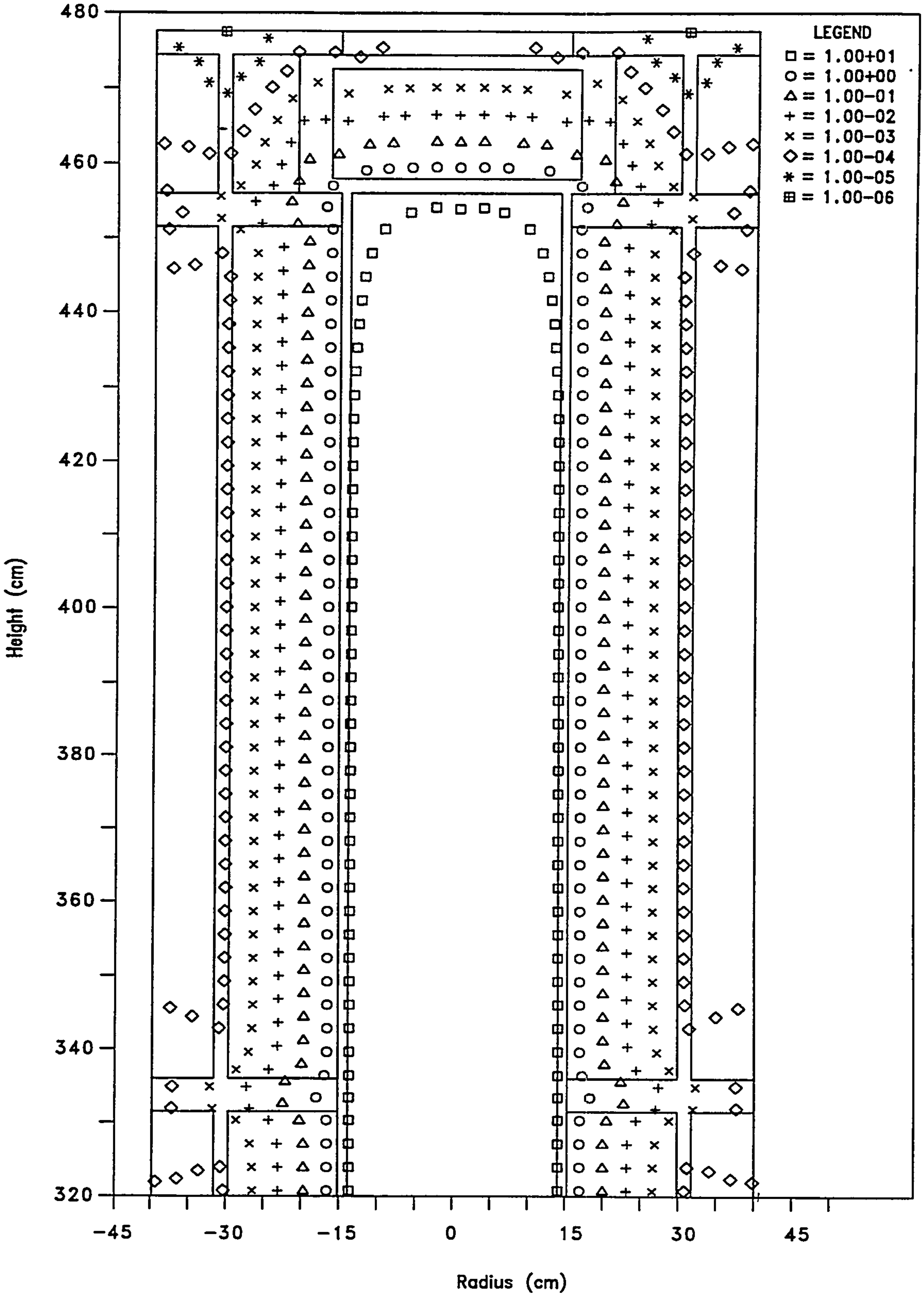

Figure D.40 Expanded View of the Light Shield Section Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/h·Ci).]

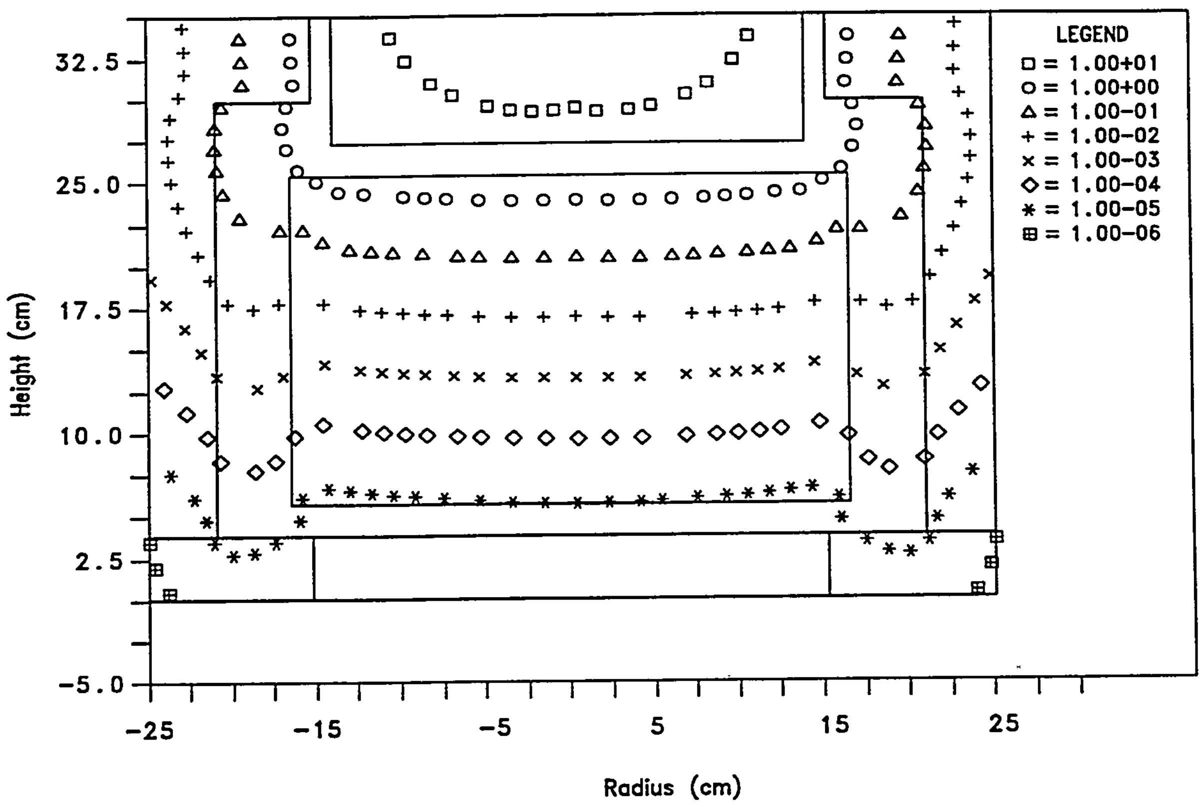

Figure D.41 Expanded View of the Heavy Door Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

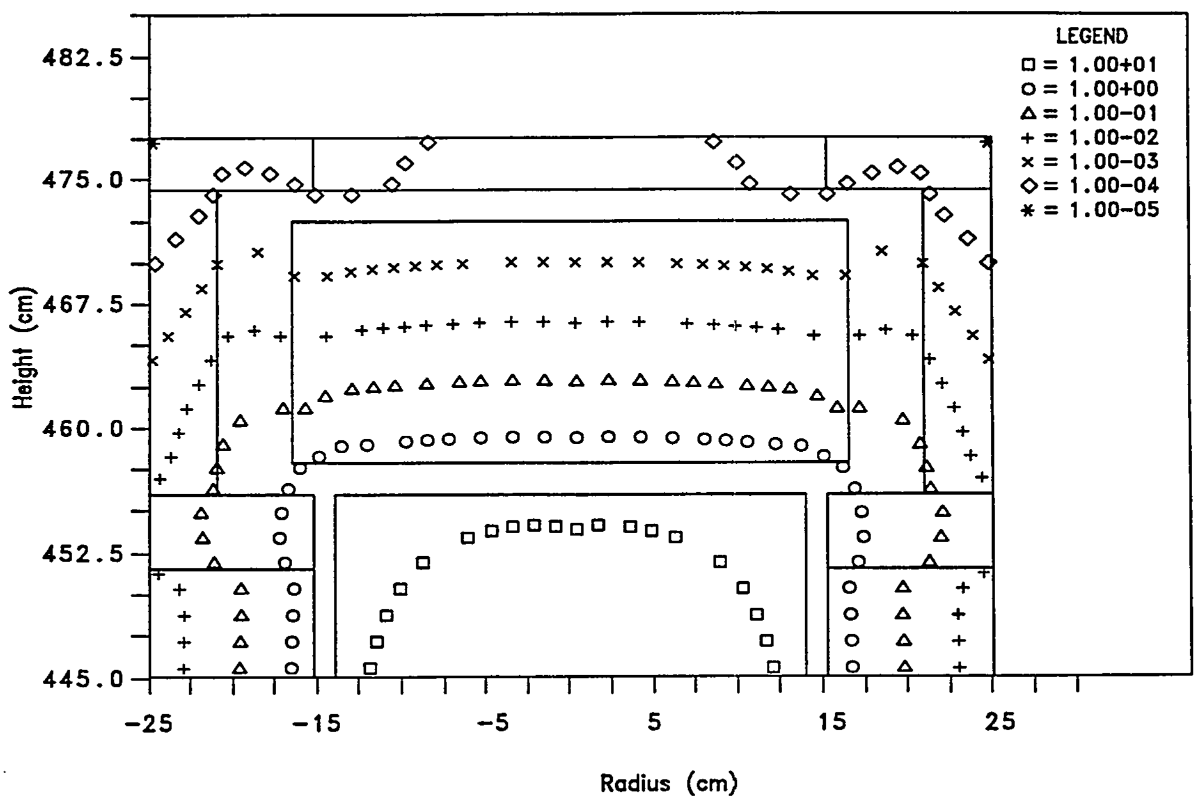

Figure D.42 Expanded View of the Light Door Isodose Contours for the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

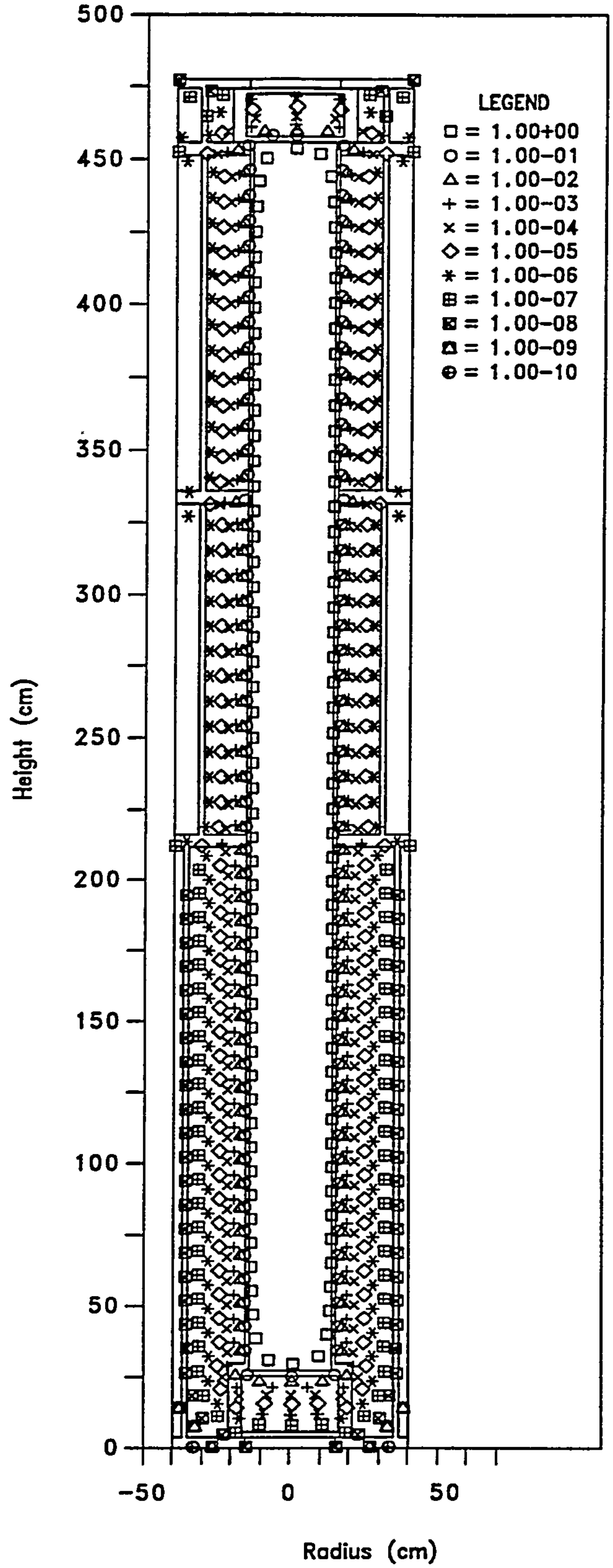

Figure D.43 Isodose Contours for the LWR MFP (25 MWd/kgU) Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

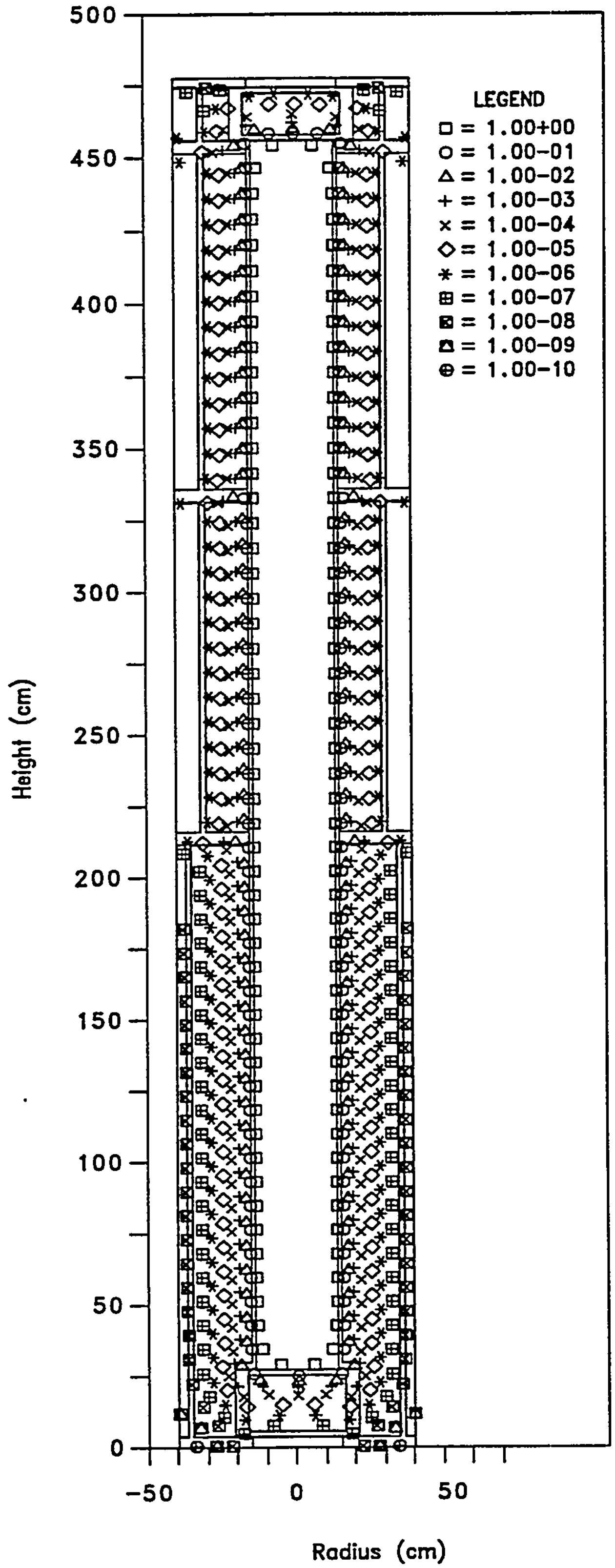

Figure D.44 Isodose Contours for the LWR MFP (50 MWd/kgU) Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

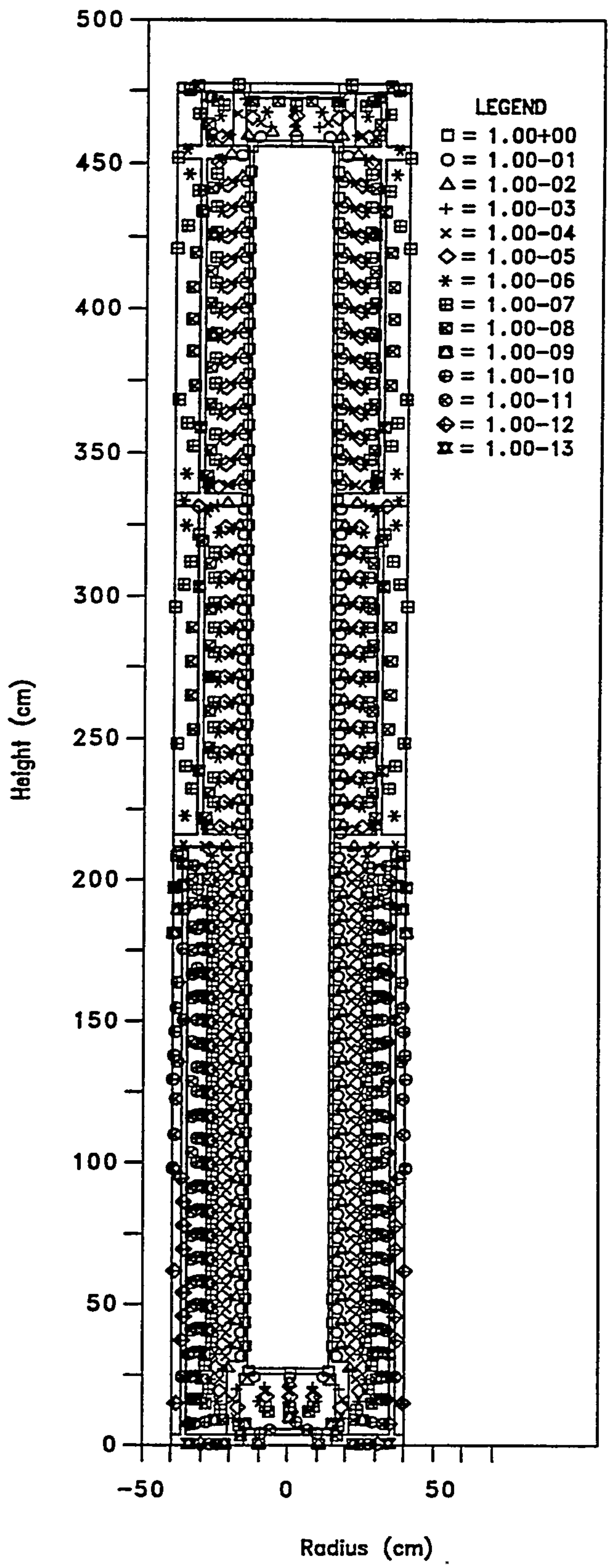

Figure D.45 Isodose Contours for the ^{137}Cs Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

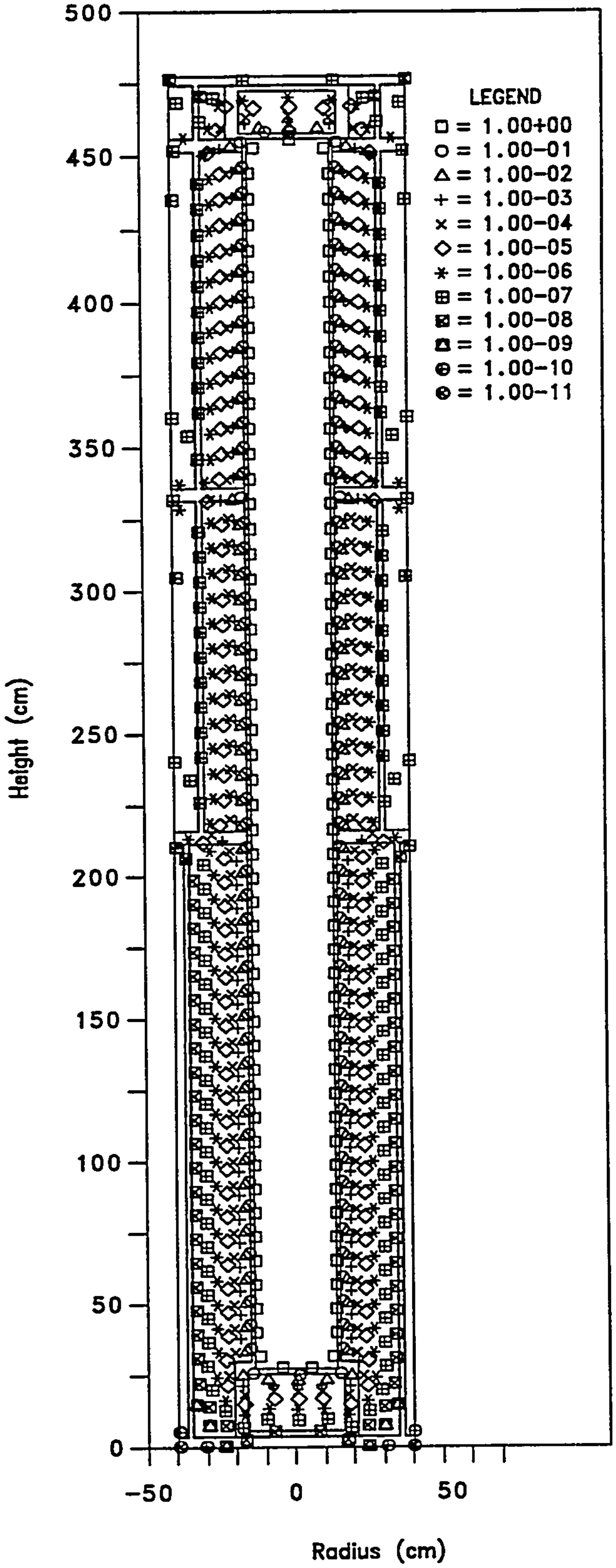

Figure D.46 Isodose Contours for the ORR MFP (20% Enriched ^{235}U) Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

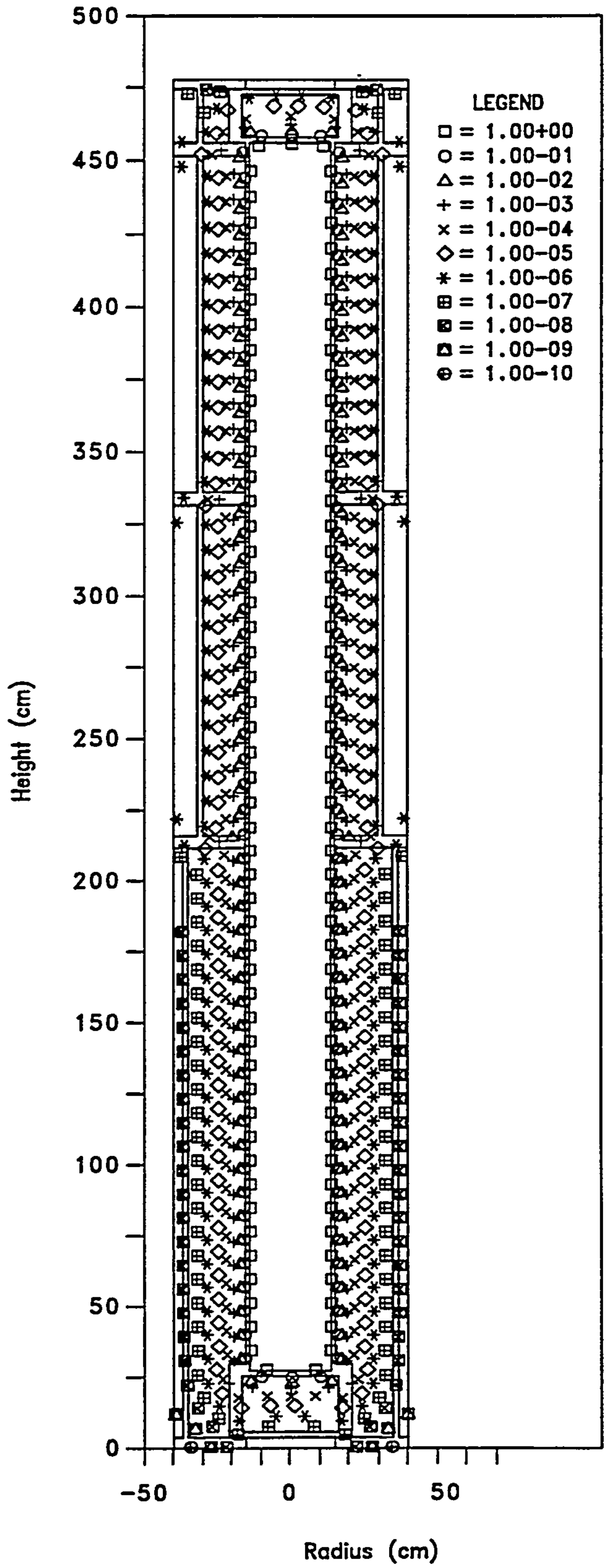

Figure D.47 Isodose Contours for the ORR MFP (40% Enriched ^{235}U) Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/(h·Ci).]

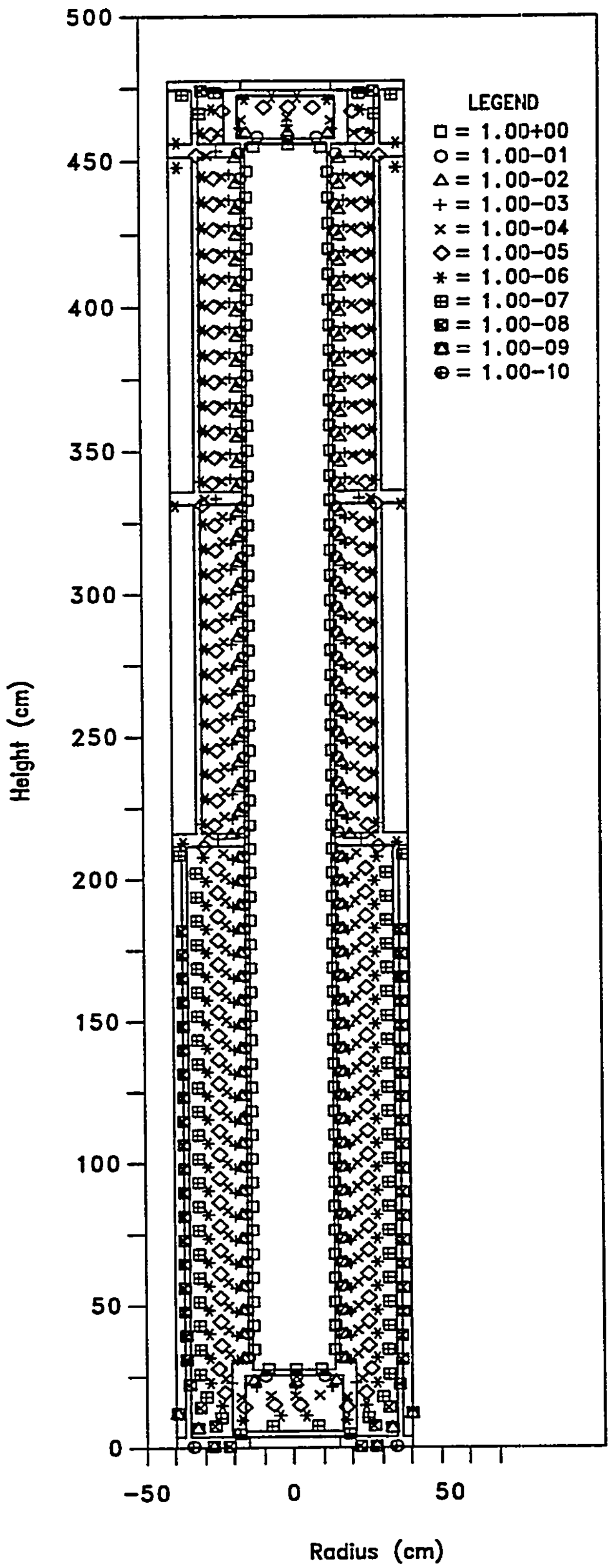

Figure D.48 Isodose Contours for the ORR MFP (93% Enriched ^{235}U) Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask. [Dose units are rem/h·Ci).]

APPENDIX E

Sample Card Input Data Sets for the Computer Codes Used in the Shielding Analysis of the SNF Shipping Casks

```
#!/bin/ksh
set -xv
date

#***** PALSFN1.KSH, 04/07/95, 1543 hrs ****

jvp=/u12/jvp/snf
tmp=/u7/jvp
mkdir $tmp/tdir$$
cd $tmp/tdir$$
# Korn shell script to execute a SCALE job
# ==================================================================
# if you want to create a modified version of a module, DO IT HERE, not later!
# ==================================================================
scale.mod   # /usr/epmnas/jvp/bin/scale.mod) links SCALE modules
# ==================================================================
# if you want to create a modified xsect dataset, DO IT HERE, not later!
# ==================================================================
ln -s /u31/jvp/xs/velm61.ampx.bin ft41f001
#  ft47f001 is necessary for many of the ampx modules
ln -s /usr/epmnas/jvp/scale/ampx.grp.bnds.bin.ft47f001  ft47f001
# ==================================================================
# following touch commands maybe necessary:
# ==================================================================
cat > sysin << 'EOF'
=pal
'PAL - Read & punch 1-d Kerma factors for C,Al,Si,Cr,Mn,Fe,Ni,Pb
'     Input master = 41
' 0$$ --> mmt = input master, mwt = input working, n7 = punch device
0$$ 41 0 7
' 1$$ --> npunch=# punched nuclides, iform=0/1=fixed/free-form,icore=words
1$$ 8 1 5+4
' 2$$ --> mt numbers to be punched
2$$ 1527 f0
   t
' 3$$ --> nuclide id's
3$$ 130601 131301 131401 132401 132502 132603 132802 138202 t
end
EOF
rm  print _prt* \$prt* _out* \$out*
touch \$out
touch \$prt
time scale
cat  print _prt* \$prt*  _out* \$out*  > $jvp/palsnf1.out
mv  \$pun  $jvp/palsnf1.pun
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.1 Job Input Stream for the PAL Cross-Section and Activity Manipulation Program.

```
#!/bin/ksh
set -xv
date
#
#**** AMPSNF1.KSH, 04/07/95, 1628 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u7/jvp
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
=====================================================================
ln -s /usr/local/bin/amp amp
#
=====================================================================
cat > ampinp << 'EOF'
AMP - Put kerma factors for C,Al,Si,Cr,Mn,Fe,Ni,Pb in xs format.
'     Kerma factors changed from (Mev.b/gamma.atom) to (W.s/gamma.cm)
'     Nuclide xs output on fort.7.
1$$   61 23 61 23 0   / igmni,igmgi,igmno,igmgo,itli
          87 0 0 0 8      / itlo,nasc,nast,nam,nat
          8 -7 0 0 0     / naso,k1,k2,k3,k4
        0 0    / kadd,nds13
   t
8$$ f2    / 1=srce/2=resp
9** f1.60219-13   / W.s/MeV
10$$ 1 2 3 4 5 6 7 8 / output ANISN set nos
11$$ f1   / output table positions
14$$ f1  / ANISN print
   t
25**   / input tabular resps
'pal card output
'  nuclide      130601 process1527
   61z
328303-5 262074-5 234424-5 223211-5 206566-5 184073-5 160792-5 136173-5
116198-5 101582-5 85323-5 664423-6 484928-6 381503-6 328135-6 268987-6
203739-6 122423-6 576854-7 350435-7 249999-7 403678-7 188185-6
'  nuclide      131301 process1527
   61z
949707-5 709214-5 613065-5 575061-5 520282-5 448975-5 379069-5 310285-5
258391-5 223007-5 185664-5 144069-5 105203-5 828494-6 713364-6 586172-6
446919-6 280251-6 174221-6 1905-4 331866-6 117375-5 559452-5
'  nuclide      131401 process1527
   61z
105913-4 785369-5 67628-4 633279-5 571451-5 491242-5 412966-5 336514-5
279309-5 240629-5 200087-5 155189-5 113347-5 892939-6 769139-6 632521-6
483338-6 307303-6 205295-6 24553-5 45299-5 162049-5 761686-5
```

Figure E.2 Job Input Stream for the AMP Cross-Section and Activity Manipulation Program.

```
' nuclide     132401 process1527
  61z
243039-4 171337-4 143357-4 13246-3 117037-4 974615-5 790011-5 618606-5
497809-5 421564-5 346332-5 267694-5 19667-4 156368-5 135993-5 114174-5
920502-6 766434-6 10916-4 205257-5 447502-5 154268-4 631279-4
' nuclide     132502 process1527
  61z
259527-4 182273-4 152145-4 140443-4 123894-4 102911-4 831582-5 648857-5
520653-5 440177-5 36123-4 279168-5 205329-5 163529-5 142469-5 12005-4
976606-6 843676-6 127342-5 243213-5 530874-5 181611-4 733396-4
' nuclide     132603 process1527
  61z
27644-3 193491-4 161191-4 148642-4 130912-4 108467-4 873881-5 679528-5
543705-5 458907-5 376197-5 290704-5 214076-5 170813-5 149099-5 126136-5
103602-5 929146-6 1479-3 286135-5 624789-5 212007-4 845638-4
' nuclide     132802 process1527
  61z
311782-4 216776-4 179888-4 165581-4 145398-4 119915-4 960677-5 742041-5
590438-5 496757-5 406364-5 313986-5 23188-4 18581-4 162895-5 139041-5
116634-5 11284-4 197169-5 388885-5 848058-5 283217-4 110153-3
' nuclide     138202 process1527
  61z
188925-3 123943-3 994102-4 900713-4 769587-4 606564-4 45817-3 32839-3
244787-4 199444-4 163691-4 142376-4 141454-4 153794-4 169002-4 200559-4
270027-4 540909-4 130142-3 114175-3 102499-3 291968-3 573929-3
  t
stop
EOF
time ./amp < ampinp > ampout
ls -Ll
mv ampout  $jvp/ampsnf1.out
mv fort.7  $jvp/ampsnf1.pun
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.2 Continued.

```
#!/bin/ksh
set -xv
date
#
#**** ORGN100.KSH, 03/22/95, 0802 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u8/jvp
export DATA_DIR=/scale/datalib
export DATA_BIN=/scale/datalib
export ORDATA_DIR=$DATA_DIR/origen
export PGM_DIR=/scale/exe
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
========================================================================
ln -s $PGM_DIR/scale  scale
ln -s $PGM_DIR/csas   csas
ln -s $PGM_DIR/origns  origns
ln -s $ORDATA_DIR/binrylib/prlimlwr       ft21f001
ln -s $ORDATA_DIR/binrylib/pwr33gwd        ft22f001
ln -s $ORDATA_DIR/binrylib/maphnobr        ft23f001
ln -s $ORDATA_DIR/binrylib/maphh2ob        ft24f001
ln -s $ORDATA_DIR/binrylib/baslmfbr       ft25f001
ln -s $ORDATA_DIR/binrylib/maphuo2b        ft26f001
ln -s $ORDATA_DIR/cardlib/end6dec         ft27f001
ln -s $ORDATA_DIR/cardlib/xsectpho        ft28f001
ln -s $ORDATA_DIR/binrylib/P2518.lib      ft31f001
#ln -s $DATA_DIR/scale.rev02.xn238  ft70f001
ln -s $DATA_KENO/albedos          ft79f001
ln -s $DATA_KENO/weights          ft80f001
ln -s $DATA_BIN/scale.rev02.xn16  ft81f001
ln -s $DATA_BIN/scale.rev03.xn27  ft82f001
ln -s $DATA_BIN/scale.rev02.xn123  ft83f001
ln -s $DATA_BIN/scale.rev03.xn218  ft84f001
ln -s $DATA_BIN/scale.rev02.xn22g18 ft85f001
ln -s $DATA_BIN/scale.rev02.xg18   ft86f001
ln -s $DATA_BIN/scale.rev03.xn27burn ft87f001
ln -s $DATA_BIN/scale.rev03.xn27g18 ft88f001
ln -s $DATA_BIN/scale.rev05.sclib  ft89f001
ln -s $DATA_DIR/h7matlib          h7matlib
ln -s $DATA_DIR/qatable          qatable
ln -s $DATA_DIR/aliases          aliases
ls -Ll
#
========================================================================
cat > sysin << 'EOF'
```

Figure E.3 Job Input Stream for the ORIGEN-S Depletion/Burnup Calculation to Define the LWR MFP (25 MWd/kgU) Source Used in the SNF Shipping Casks Shielding Analysis.

```
=origns
' 25 GWD/MT, 18MW/MT, U-wt%(u234=.021, u235=2.400, u236=.011,
'     u238=97.568); continuous opn = 1388.89 d; Tbl A.4, ORNL-6698.
'     Clad is Zircaloy: Wt%(97.91 Zr, 1.59 Sn, 0.5 Fe -> SCALE 4.2
'     Composition Library). See Tbl 3.11, ORNL-6698 for composition.
1$$ 1
   1t
25GWD/MT,18MW/MT,U-wt%(234=.0921,235=2.400,236=.011,238=97.568);1338.89 d
3$$ 31  a3 2  a33 23 e
   2t
35$$ 0
   4t
56$$ 10  a13 7 4 3 0 2 1 e
57** a3 1-10 e
   5t
IRRADIATION (25GWD/MT,18MW/MT,2.4% U235,continuous opn=1388.89 d)
MT of HM (g-atoms)
58** 10r18
' 1/4 y for 1y (4 steps), 1/3 y for 1 y(3 steps),
' 1/2 y for 1y (2 steps), .8y for .8y (1 step).
60** 2i91.91 2i365.25 1i730.50 1095.75 1388.89
66$$ 1 a5 1  a9 1  e
73$$ 260000 400000 500000 922340 922350 922360 922380
74** 20.22 2422.71 30.24 0.90 102.13 0.47 4099.50
75$$ 3r4 f2
   6t
56$$ 0 10  a10 10  a14 5 3  a17 2  e
   5t
DECAY (25GWD/MT,18MW/MT,2.4% U235,continuous opn=1388.89 d)
MT of HM (g-atoms)
60** 1 7i5 45
61** 1-10  a3 3r1-10 e
65$$ 1  a7 1  a11 1  a14 1  a22 1  a28 1  a32 1  a35 1  7z  1q21
81$$ 2 0 26 1   e     82$$ f2
83**
  14+6 1+7 8+6 75+5 7+6 6+6 5+6 4+6 3+6 25+5 2+6 15+5 1+6 7+5 6+5 51+4
  4+5 3+5 15+4 1+5 7+4 45+3 2+4 1+4
   6t
 1Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
 5Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
10Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
15Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
20Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
25Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
30Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
35Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
40Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
45Y Decay G-Spec(VELM23 Grp;25GWD/MT,18MW/MT;Cont opn=1388.89d;Tbl A4,ORNL-6698)
56$$ f0  5t
end
```

Figure E.3 Continued.

```
EOF
time ./scale
ls -l
cat $DATA_DIR/scale.messages > orgnout
cat $tmp/tdir$$/print >> orgnout
cat $tmp/tdir$$/_prt* >> orgnout
cat $tmp/tdir$$/_out* >> orgnout
mv orgnout  $jvp/orgn100.out
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.3 Continued.

```
#!/bin/ksh
set -xv
date
#
#**** ORGN101.KSH, 03/22/95, 0909 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u8/jvp
export DATA_DIR=/scale/datalib
export DATA_BIN=/scale/datalib
export ORDATA_DIR=$DATA_DIR/origen
export PGM_DIR=/scale/exe
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
==========================================================================
ln -s $PGM_DIR/scale  scale
ln -s $PGM_DIR/csas   csas
ln -s $PGM_DIR/origns  origns
ln -s $ORDATA_DIR/binrylib/prlimlwr      ft21f001
ln -s $ORDATA_DIR/binrylib/pwr33gwd       ft22f001
ln -s $ORDATA_DIR/binrylib/maphnobr       ft23f001
ln -s $ORDATA_DIR/binrylib/maphh2ob       ft24f001
ln -s $ORDATA_DIR/binrylib/baslmfbr       ft25f001
ln -s $ORDATA_DIR/binrylib/maphuo2b       ft26f001
ln -s $ORDATA_DIR/cardlib/end6dec         ft27f001
ln -s $ORDATA_DIR/cardlib/xsectpho        ft28f001
ln -s $ORDATA_DIR/binrylib/P5040.lib      ft31f001
#ln -s $DATA_DIR/scale.rev02.xn238  ft70f001
ln -s $DATA_KENO/albedos        ft79f001
ln -s $DATA_KENO/weights        ft80f001
ln -s $DATA_BIN/scale.rev02.xn16   ft81f001
ln -s $DATA_BIN/scale.rev03.xn27   ft82f001
ln -s $DATA_BIN/scale.rev02.xn123  ft83f001
ln -s $DATA_BIN/scale.rev03.xn218  ft84f001
ln -s $DATA_BIN/scale.rev02.xn22g18 ft85f001
ln -s $DATA_BIN/scale.rev02.xg18   ft86f001
ln -s $DATA_BIN/scale.rev03.xn27burn ft87f001
ln -s $DATA_BIN/scale.rev03.xn27g18 ft88f001
ln -s $DATA_BIN/scale.rev05.sclib   ft89f001
ln -s $DATA_DIR/h7matlib          h7matlib
ln -s $DATA_DIR/qatable         qatable
ln -s $DATA_DIR/aliases         aliases
ls -Ll
#
==========================================================================
cat > sysin << 'EOF'
```

Figure E.4 Job Input Stream for the ORIGEN-S Depletion/Burnup Calculation to Define the LWR MFP (50 MWd/kgU) Source Used in the SNF Shipping Casks Shielding Analysis.

```
=origns
' 50 GWD/MTU, 40MW/MTU, U-wt%(u234=.037, u235=4.200, u236=.019,
'     u238=95.744); continuous opn = 1250.00 d; Tbl A.4, ORNL-6698.
'     Cycle 3 of 5.
'     Clad is Zircaloy: Wt%(97.91 Zr, 1.59 Sn, 0.5 Fe -> SCALE 4.2
'     Composition Library). See Tbl 3.11, ORNL-6698 for composition.
1$$ 1
   1t
25GWD/MTU,18MW/MTU,U-wt%(234=.0371,235=4.200,236=.019,238=95.744);1250.00 d
3$$ 31  a3 3  a33 23 e
   2t
35$$ 0
   4t
56$$ 10  a13 7 4 3 0 2 1 e
57** a3 1-10 e
   5t
IRRADIATION (50GWD/MTU,40MW/MTU,4.2% U235,continuous opn=1250.00 d)
MT of HM (g-atoms)
58** 10r40
' 1/4 y for 1y (4 steps), 1/3 y for 1 y(3 steps),
' 1/2 y for 1y (2 steps), .42y for .42y (1 step).
60** 2i91.91 2i365.25 1i730.50 1095.75 1250.00
66$$ 1 a5 1  a9 1  e
73$$ 260000 400000 500000 922340 922350 922360 922380
74** 20.22 2422.71 30.24 1.58 178.72 0.81 4022.86
75$$ 3r4 f2
   6t
56$$ 0 10  a10 10  a14 5 3  a17 2  e
   5t
DECAY (50GWD/MTU,40MW/MTU,4.2% U235,continuous opn=1250.00 d)
MT of HM (g-atoms)
60** 1 7i5 45
61** 1-10  a3 3r1-10 e
65$$ 1  a7 1  a11 1  a14 1  a22 1  a28 1  a32 1  a35 1  7z  1q21
81$$ 2 0 26 1   e    82$$ f2
83**
  14+6 1+7 8+6 75+5 7+6 6+6 5+6 4+6 3+6 25+5 2+6 15+5 1+6 7+5 6+5 51+4
  4+5 3+5 15+4 1+5 7+4 45+3 2+4 1+4
   6t
 1Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
 5Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
10Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
15Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
20Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
25Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
30Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
35Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
40Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
45Y Decay G-Spec(VELM23 Grp;50GWD/MT,40MW/MT;Cont opn=1250.00d;Tbl A4,ORNL-6698)
```

Figure E.4 Continued.

```
56$$ f0  5t
end
EOF
time ./scale
ls -l
cat $DATA_DIR/scale.messages > orgnout
cat $tmp/tdir$$/print >> orgnout
cat $tmp/tdir$$/_prt* >> orgnout
cat $tmp/tdir$$/_out* >> orgnout
mv orgnout  $jvp/orgn101.out
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.4 Continued.

```
#!/bin/ksh
set -xv
date
#
#**** ORGN13A.KSH, 04/26/95, 1205 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u8/jvp
export DATA_DIR=/scale/datalib
export DATA_BIN=/scale/datalib
export ORDATA_DIR=$DATA_DIR/origen
export PGM_DIR=/scale/exe
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
==================================================================
ln -s $PGM_DIR/scale  scale
ln -s $PGM_DIR/csas  csas
ln -s $PGM_DIR/origns  origns
ln -s $ORDATA_DIR/binrylib/prlimlwr       ft21f001
ln -s $ORDATA_DIR/binrylib/pwr33gwd        ft22f001
ln -s $ORDATA_DIR/binrylib/maphnobr       ft23f001
ln -s $ORDATA_DIR/binrylib/maphh2ob        ft24f001
ln -s $ORDATA_DIR/binrylib/baslmfbr       ft25f001
ln -s $ORDATA_DIR/binrylib/maphuo2b        ft26f001
ln -s $ORDATA_DIR/cardlib/end6dec        ft27f001
ln -s $ORDATA_DIR/cardlib/xsectpho        ft28f001
ln -s $ORDATA_DIR/binrylib/P2518.lib      ft31f001
#ln -s $DATA_DIR/scale.rev02.xn238  ft70f001
ln -s $DATA_KENO/albedos          ft79f001
ln -s $DATA_KENO/weights          ft80f001
ln -s $DATA_BIN/scale.rev02.xn16  ft81f001
ln -s $DATA_BIN/scale.rev03.xn27  ft82f001
ln -s $DATA_BIN/scale.rev02.xn123  ft83f001
ln -s $DATA_BIN/scale.rev03.xn218  ft84f001
ln -s $DATA_BIN/scale.rev02.xn22g18 ft85f001
ln -s $DATA_BIN/scale.rev02.xg18   ft86f001
ln -s $DATA_BIN/scale.rev03.xn27burn ft87f001
ln -s $DATA_BIN/scale.rev03.xn27g18 ft88f001
ln -s $DATA_BIN/scale.rev05.sclib   ft89f001
ln -s $DATA_DIR/h7matlib          h7matlib
ln -s $DATA_DIR/qatable         qatable
ln -s $DATA_DIR/aliases         aliases
ls -Ll
#
==================================================================
cat > sysin << 'EOF'
```

Figure E.5 Job Input Stream for the ORIGEN-S Depletion/Burnup Calculation to Define the ORR MFP (20% Enriched ^{235}U) Source Used in the SNF Shipping Casks Shielding Analysis.

```
=origns
' ORR High-U-Loaded Fuel Element Dev0(HFED); ORR operated at 30 MW FP,
'      93% enrichment, 220 gU235/element, 30 elemts, per R. Hobbs, 3/22/95.
'      Cycle 2 of 3, P2518 Lib.
'      Used tables 1.1, 3.2, B.1, B.5, B.16, B.20, and B.24 in "Summary
'      Report of the HFED Mini-plate Irradiations for the RERTR Pgm,"
'      ORNL-6539, Apr 89.
1$$ 1
    1t
U6Fe, Module 23, Slot 6, U235=.1984g, U238=.8016g, Fe=.042g; 91d; P2518 lib
3$$ 31  a3 2  a33 23 e
    2t
35$$ 0
    4t
56$$ 10 a13 3 4 3 0 2 1 e
57** 0 a3 1-10 e
    5t
IRRADIATION: 9.1-91d of 91d total
G of HM (g-atoms)
58** 10r5.59-4
60** 8i9.1 91
66$$ 1 a5 1   e
73$$ 26+4 922350 922380
74** 7.52-4 8.44-4 3.37-3
75$$ 4 f2
    6t
56$$ 0 10  a10 10  a14 5 3  a17 2  e
    5t
DECAY (91 d Irrad)
G of HM (g-atoms)
60** 1 7i5 45
61** 1-10  a3 3r1-10 e
65$$ 1  a7 1  a11 1  a14 1  a22 1  a28 1  a32 1  a35 1  7z  1q21
81$$ 2 0 26 1   e    82$$ f2
83**
  14+6 1+7 8+6 75+5 7+6 6+6 5+6 4+6 3+6 25+5 2+6 15+5 1+6 7+5 6+5 51+4
  4+5 3+5 15+4 1+5 7+4 45+3 2+4 1+4
    6t
 1Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
 5Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
10Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
15Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
20Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
25Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
30Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
35Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
40Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
45Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,5.59-4MW/gU;Cont opn=91d;ORNL-6539)
```

Figure E.5 Continued.

```
56$$ f0  5t
end
EOF
time ./scale
ls -l
cat $DATA_DIR/scale.messages > orgnout
cat $tmp/tdir$$/print >> orgnout
cat $tmp/tdir$$/_prt* >> orgnout
cat $tmp/tdir$$/_out* >> orgnout
mv orgnout  $jvp/orgn13a.out
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.5 Continued.

```
#!/bin/ksh
set -xv
date
#
#**** ORGN11A.KSH, 04/25/95, 1644 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u8/jvp
export DATA_DIR=/scale/datalib
export DATA_BIN=/scale/datalib
export ORDATA_DIR=$DATA_DIR/origen
export PGM_DIR=/scale/exe
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
=================================================================
ln -s $PGM_DIR/scale  scale
ln -s $PGM_DIR/csas   csas
ln -s $PGM_DIR/origns  origns
ln -s $ORDATA_DIR/binrylib/prlimlwr      ft21f001
ln -s $ORDATA_DIR/binrylib/pwr33gwd       ft22f001
ln -s $ORDATA_DIR/binrylib/maphnobr       ft23f001
ln -s $ORDATA_DIR/binrylib/maphh2ob       ft24f001
ln -s $ORDATA_DIR/binrylib/baslmfbr      ft25f001
ln -s $ORDATA_DIR/binrylib/maphuo2b       ft26f001
ln -s $ORDATA_DIR/cardlib/end6dec        ft27f001
ln -s $ORDATA_DIR/cardlib/xsectpho       ft28f001
ln -s $ORDATA_DIR/binrylib/P2518.lib      ft31f001
#ln -s $DATA_DIR/scale.rev02.xn238  ft70f001
ln -s $DATA_KENO/albedos          ft79f001
ln -s $DATA_KENO/weights          ft80f001
ln -s $DATA_BIN/scale.rev02.xn16  ft81f001
ln -s $DATA_BIN/scale.rev03.xn27  ft82f001
ln -s $DATA_BIN/scale.rev02.xn123  ft83f001
ln -s $DATA_BIN/scale.rev03.xn218  ft84f001
ln -s $DATA_BIN/scale.rev02.xn22g18 ft85f001
ln -s $DATA_BIN/scale.rev02.xg18   ft86f001
ln -s $DATA_BIN/scale.rev03.xn27burn ft87f001
ln -s $DATA_BIN/scale.rev03.xn27g18 ft88f001
ln -s $DATA_BIN/scale.rev05.sclib   ft89f001
ln -s $DATA_DIR/h7matlib           h7matlib
ln -s $DATA_DIR/qatable           qatable
ln -s $DATA_DIR/aliases           aliases
ls -Ll
#
=================================================================
cat > sysin << 'EOF'
```

Figure E.6 Job Input Stream for the ORIGEN-S Depletion/Burnup Calculation to Define the ORR MFP (40% Enriched ^{235}U) Source Used in the SNF Shipping Casks Shielding Analysis.

```
=origns
' ORR High-U-Loaded Fuel Element Dev0(HFED); ORR operated at 30 MW FP.
'     93% enrichment, 220 gU235/element, 30 elemts, per R. Hobbs, 3/22/95.
'     Cycle 2 of 3, P2518 Lib.
'     Used tables 1.1, 3.2, B.1, B.5, B.16, B.20, and B.24 in "Summary
'     Report of the HFED Mini=plate Irradiations for the RERTR Pgm,"
'     ORNL-6539, Apr 89.
1$$ 1
   1t
UAl, Module 1, Slot 1, U235=2.201g, U238=3.269g, Al=.37g; 470d; P2518 lib
3$$ 31  a3 2  a33 23 e
   2t
35$$ 0
   4t
56$$ 10 a13 3 4 3 0 2 1 e
57** 0 a3 1-10 e
   5t
IRRADIATION: 10-100d of 470d total
G of HM (g-atoms)
58** 10r7.65-4
60** 8i10 100
66$$ 1 a5 1    e
73$$ 130270 922350 922380
74** 1.37-2 1.71-3 2.51-3
75$$ 4 f2
   6t
56$$ 10 a10 10 a14 4 3 0 2 1 e
57** 100 a3 1-10 e
   5t
IRRADIATION: 110-200d of 470d total
G of HM (g-atoms)
58** 10r7.65-4
60** 8i110 200
66$$ 1 a5 1    e
   6t
56$$ 10 a10 10 a14 4 3 0 2 1 e
57** 200 a3 1-10 e
   5t
IRRADIATION: 210-300d of 470d total
G of HM (g-atoms)
58** 10r7.65-4
60** 8i210 300
66$$ 1 a5 1    e
   6t
56$$ 10 a10 10 a14 4 3 0 2 1 e
57** 300 a3 1-10 e
   5t
IRRADIATION: 310-400d of 470d total
G of HM (g-atoms)
```

Figure E.6 Continued.

```
58** 10r7.65-4
60** 8i310 400
66$$ 1 a5 1    e
   6t
56$$ 2r7 a10 10 a14 4 3 0 2 1 e
57** 400 a3 1-10 e
     5t
IRRADIATION: 410-470d of 470d total
G of HM (g-atoms)
58** 7r7.65-4
60** 5i410 470
66$$ 1 a5 1    e
   6t
56$$ 0 10  a10 7  a14 5 3  a17 2  e
    5t
DECAY (470 d Irrad)
G of HM (g-atoms)
60** 1 7i5 45
61** 1-10  a3 3r1-10 e
65$$ 1  a7 1  a11 1  a14 1  a22 1  a28 1  a32 1  a35 1  7z  1q21
81$$ 2 0 26 1   e    82$$ f2
83**
   14+6 1+7 8+6 75+5 7+6 6+6 5+6 4+6 3+6 25+5 2+6 15+5 1+6 7+5 6+5 51+4
   4+5 3+5 15+4 1+5 7+4 45+3 2+4 1+4
     6t
  1Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
  5Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 10Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 15Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 20Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 25Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 30Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 35Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 40Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
 45Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,7.65-4MW/gU;Cont opn=470d;ORNL-6539)
56$$ f0  5t
end
EOF
time ./scale
ls -l
cat $DATA_DIR/scale.messages > orgnout
cat $tmp/tdir$$/print >> orgnout
cat $tmp/tdir$$/_prt* >> orgnout
cat $tmp/tdir$$/_out* >> orgnout
mv orgnout  $jvp/orgn11a.out
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.6 Continued.

```
#!/bin/ksh
set -xv
date
#
#**** ORGN12A.KSH, 04/25/95, 1643 hrs ****
#
hostname
jvp=/u12/jvp/snf
tmp=/u8/jvp
export DATA_DIR=/scale/datalib
export DATA_BIN=/scale/datalib
export ORDATA_DIR=$DATA_DIR/origen
export PGM_DIR=/scale/exe
mkdir $tmp/tdir$$
cd $tmp/tdir$$
#
===================================================================
ln -s $PGM_DIR/scale  scale
ln -s $PGM_DIR/csas   csas
ln -s $PGM_DIR/origns  origns
ln -s $ORDATA_DIR/binrylib/prlimlwr      ft21f001
ln -s $ORDATA_DIR/binrylib/pwr33gwd      ft22f001
ln -s $ORDATA_DIR/binrylib/maphnobr      ft23f001
ln -s $ORDATA_DIR/binrylib/maphh2ob      ft24f001
ln -s $ORDATA_DIR/binrylib/baslmfbr      ft25f001
ln -s $ORDATA_DIR/binrylib/maphuo2b      ft26f001
ln -s $ORDATA_DIR/cardlib/end6dec        ft27f001
ln -s $ORDATA_DIR/cardlib/xsectpho       ft28f001
ln -s $ORDATA_DIR/binrylib/P2518.lib     ft31f001
#ln -s $DATA_DIR/scale.rev02.xn238 ft70f001
ln -s $DATA_KENO/albedos         ft79f001
ln -s $DATA_KENO/weights         ft80f001
ln -s $DATA_BIN/scale.rev02.xn16  ft81f001
ln -s $DATA_BIN/scale.rev03.xn27  ft82f001
ln -s $DATA_BIN/scale.rev02.xn123  ft83f001
ln -s $DATA_BIN/scale.rev03.xn218  ft84f001
ln -s $DATA_BIN/scale.rev02.xn22g18 ft85f001
ln -s $DATA_BIN/scale.rev02.xg18  ft86f001
ln -s $DATA_BIN/scale.rev03.xn27burn ft87f001
ln -s $DATA_BIN/scale.rev03.xn27g18 ft88f001
ln -s $DATA_BIN/scale.rev05.sclib  ft89f001
ln -s $DATA_DIR/h7matlib         h7matlib
ln -s $DATA_DIR/qatable        qatable
ln -s $DATA_DIR/aliases        aliases
ls -Ll
#
===================================================================
cat > sysin << 'EOF'
```

Figure E.7 Job Input Stream for the ORIGEN-S Depletion/Burnup Calculation to Define the ORR MFP (93% Enriched ^{235}U) Source Used in the SNF Shipping Casks Shielding Analysis.

```
=origns
' ORR High-U-Loaded Fuel Element Dev0(HFED); ORR operated at 30 MW FP,
'     93% enrichment, 220 gU235/element, 30 elemts, per R. Hobbs, 3/22/95.
'     Cycle 2 of 3, P2518 Lib.
'     Used tables 1.1, 3.2, B.1, B.5, B.16, B.20, and B.24 in "Summary
'     Report of the HFED Mini-plate Irradiations for the RERTR Pgm,"
'     ORNL-6539, Apr 89.
1$$ 1
   1t
U3O8, Module 5, Slot 10, U235=1.448g, U238=0.105g, O=.181g; 268d; P2518 lib
3$$ 31  a3 2  a33 23 e
   2t
35$$ 0
   4t
56$$ 10 a13 3 4 3 0 2 1 e
57** 0 a3 1-10 e
   5t
IRRADIATION: 10-100d of 268d total
G of HM (g-atoms)
58** 10r2.65-3
60** 8i10 100
66$$ 1 a5 1   e
73$$ 80160 922350 922380
74** 1.13-2 3.97-3 2.85-4
75$$ 4 f2
   6t
56$$ 10 a10 10 a14 4 3 0 2 1 e
57** 100 a3 1-10 e
   5t
IRRADIATION: 110-200d of 268d total
G of HM (g-atoms)
58** 10r2.65-3
60** 8i110 200
66$$ 1 a5 1   e
  6t
56$$ 2r7 a10 10 a14 4 3 0 2 1 e
57** 200 a3 1-10 e
   5t
IRRADIATION: 210-268d of 268d total
G of HM (g-atoms)
58** 7r2.65-3
60** 4i210 260 268
66$$ 1 a5 1   e
  6t
56$$ 0 10  a10 7  a14 5 3  a17 2  e
   5t
DECAY (268 d Irrad)
G of HM (g-atoms)
```

Figure E.7 Continued.

```
60** 1 7i5 45
61** 1-10  a3 3r1-10 e
65$$ 1  a7 1  a11 1  a14 1  a22 1  a28 1  a32 1  a35 1  7z  1q21
81$$ 2 0 26 1   e    82$$ f2
83**
   14+6 1+7 8+6 75+5 7+6 6+6 5+6 4+6 3+6 25+5 2+6 15+5 1+6 7+5 6+5 51+4
   4+5 3+5 15+4 1+5 7+4 45+3 2+4 1+4
      6t
  1Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
  5Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
10Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
15Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
20Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
25Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
30Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
35Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
40Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
45Y Decay G-Spec(VELM23 Gp;1.99MWD/gU,2.65-3MW/gU;Cont opn=470d;ORNL-6539)
56$$ f0  5t
end
EOF
time ./scale
ls -l
cat $DATA_DIR/scale.messages > orgnout
cat $tmp/tdir$$/print >> orgnout
cat $tmp/tdir$$/_prt* >> orgnout
cat $tmp/tdir$$/_out* >> orgnout
mv orgnout  $jvp/orgn12a.out
cd $jvp
rm -rf $tmp/tdir$$
date
```

Figure E.7 Continued.

```
GIP mixtures for the SNF Shipping Casks calculations -- P5  forward
1$$  84 3 4 87 162  /igm,iht,ihs,ihm,ms
      48 84 186 0 5  /mcr,mtp,mtm,ith,isct
      2 2 2 120  /iprt,iout,idot,nbuf
e t
10$$ 4i133 138 2q6  4i139 144 5q6  4i145 150  4i151 156 3q6  4i157 162
 /    air       ss-347      lead      sae-1020     aluminum
      4i163 168 5q6  4i169 174  4i175 180 3q6  4i181 186
 /  ss-347      lead      sae-1020      aluminum  (g-heating)
11$$  4i61 66 4i67 72 4i91 96  / air
        4i55 60 4i79 84 4i97 102 4i103 108 4i109 114 4i115 120  / ss-347
        4i127 132  / lead
        4i55 60 4i79 84 4i103 108 4i109 114  / sae-1020
        4i73 78  / aluminum
        4i1 6 4i13 18 4i19 24 4i25 30 4i31 36 4i37 42  / ss-347
        4i43 48  / lead
        4i1 6 4i13 18 4i25 30 4i31 36  / sae-1020
        4i7 12  / aluminum
12**  /number densities (atoms/b-cm)
        6r3.980-05 6r1.068-05 6r2.370-07  / dry air
        6r3.189-04 6r1.705-03 6r1.658-02
        6r1.743-03 6r5.909-02 6r8.156-03  / ss-347
        6r3.296-02  / lead
        6r7.883-04 6r4.214-04 6r3.878-04 6r8.401-02  / sae-1020
        6r6.027-02  / aluminum
        6r3.189-04 6r1.705-03 6r1.658-02
        6r1.743-03 6r5.909-02 6r8.156-03  / ss-347
        6r3.296-02  / lead
        6r7.883-04 6r4.214-04 6r3.878-04 6r8.401-02  / sae-1020
        6r6.027-02  / aluminum
13$$  1 2 3 4 5 6 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89
        90 109 110 111 112 113 114 115 116 117 118 119 120 133 134 135
        136 137 138 139 140 141 142 143 144 169 170 171 172 173 174 175
        176 177 178 179 180 181 182 183 184 185 186 193 194 195 196 197
        198 229 230 231 232 233 234 355 356 357 358 359 360
 / h,c,n,o,al,si,cl,ar,cr,mn,fe,ni,nb,pb
  t
 / c,al,si,cr,mn,fe,ni,pb g-heating factors (Watt-sec-barn/gamma-atom)
14**
5307z 526004-18 86z 419892-18 86z 375592-18 86z 357626-18 86z 330958-18
86z 29492-17 86z 257619-18 86z 218175-18 86z 186171-18 86z 162754-18 86z
136704-18 86z 106453-18 86z 776947-19 86z 61124-18 86z 525735-19 86z
430968-19 86z 326429-19 86z 196145-19 86z 92423-19 86z 561464-20 86z
400546-20 86z 646769-20 86z 301508-19 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
```

Figure E.8 Card Input Data for the GIP Cross-Section and Gamma-Ray Heating Activity Mixing Calculation.

14**
5307z 152161-17 86z 11363-16 86z 982247-18 86z 921357-18 86z 833591-18
86z 719343-18 86z 607341-18 86z 497136-18 86z 413992-18 86z 3573-16 86z
297469-18 86z 230826-18 86z 168555-18 86z 13274-17 86z 114294-18 86z
939159-19 86z 716049-19 86z 449015-19 86z 279135-19 86z 305217-19 86z
531712-19 86z 188057-18 86z 896348-18 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 169693-17 86z 125831-17 86z 108353-17 86z 101463-17 86z 915573-18
86z 787063-18 86z 66165-17 86z 539159-18 86z 447506-18 86z 385533-18 86z
320577-18 86z 248642-18 86z 181603-18 86z 143066-18 86z 123231-18 86z
101342-18 86z 774399-19 86z 492358-19 86z 328922-19 86z 393386-19 86z
725776-19 86z 259633-18 86z 122037-17 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 389395-17 86z 274514-17 86z 229685-17 86z 212226-17 86z 187516-17
86z 156152-17 86z 126575-17 86z 991125-18 86z 797585-18 86z 675426-18
86z 55489-17 86z 428897-18 86z 315103-18 86z 250531-18 86z 217887-18 86z
182928-18 86z 147482-18 86z 122797-18 86z 174895-18 86z 328861-18 86z
716983-18 86z 247167-17 86z 101143-16 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 415812-17 86z 292036-17 86z 243765-17 86z 225016-17 86z 198502-17
86z 164883-17 86z 133235-17 86z 103959-17 86z 834185-18 86z 705247-18
86z 578759-18 86z 44728-17 86z 328976-18 86z 262005-18 86z 228262-18 86z
192343-18 86z 156471-18 86z 135173-18 86z 204026-18 86z 389673-18 86z
850561-18 86z 290975-17 86z 117504-16 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 442909-17 86z 310009-17 86z 258259-17 86z 238153-17 86z 209746-17
86z 173785-17 86z 140012-17 86z 108873-17 86z 871119-18 86z 735256-18
86z 602739-18 86z 465763-18 86z 34299-17 86z 273675-18 86z 238885-18 86z
202094-18 86z 16599-17 86z 148867-18 86z 236964-18 86z 458443-18 86z
100103-17 86z 339676-17 86z 135487-16 86z

Figure E.8 Continued.

14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 499534-17 86z 347316-17 86z 288215-17 86z 265292-17 86z 232955-17 86z 192127-17 86z 153919-17 86z 118889-17 86z 945994-18 86z 795899-18 86z 651073-18 86z 503065-18 86z 371516-18 86z 297703-18 86z 260989-18 86z 22277-17 86z 18687-17 86z 180791-18 86z 315902-18 86z 623068-18 86z 135875-17 86z 453767-17 86z 176486-16 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14**
5307z 302694-16 86z 19858-15 86z 159274-16 86z 144311-16 86z 123302-16 86z 971831-17 86z 734075-17 86z 526143-17 86z 392195-17 86z 319547-17 86z 262264-17 86z 228113-17 86z 226636-17 86z 246407-17 86z 270773-17 86z 321334-17 86z 432635-17 86z 866639-17 86z 208512-16 86z 18293-15 86z 164223-16 86z 467788-16 86z 919543-16 86z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
14** 7308z
t

Figure E.8 Continued.

```
 RTFLUM - Strip DORT Scalar Fluxes to p0 Component
1$$  21 22 0 -1 0  / ntrtf,ntfog,iedit,mm,iscat
      120 0 0 0 0  / nbuf,intype,iotype,spare,spare
  e t
    t
```

Figure E.9 Card Input Data for the RTFLUM Flux Conversion Utility Program.

```
 DORT - Loop Transport Carrier Calculation. Co-60 source
' VELM61 61n-23g, P-5. endf/b-v. mm = 240 (sym)
61$$ 0 21 4 0 23 / ntflx,ntfog,ntsig,ntbsi,ntdsi
      0 0 0 0 0 / ntfci,ntibi,ntibo,ntnpr,ntdir
      24 e      / ntdso
62$$ 0 5 7 53 259 / iadj,isctm,izm,im,jm
      84 3 4 87 0 / igm,iht,ihs,ihm,mixl
      0 54 54 0 240 / mmesh,mtp,mtm,idfac,mm
      1 1 0 0 0 / ingeom,ibl,ibr,ibb,ibt
      1 -1 0 4 0 / isrmx,ifxmi,ifxmf,mode,ktype
      2 0 0 0 3 / iacc,kalf,igtype,inpfxm,inpsrm
      0 0 0 0 -4 / njntsr,nintsr,njntfx,nintfx,iact
      4 0 1 1 0 / ired,ipdb2,ifxprt,icsprt,idirf
      0 0 120 11 0 / jdirf,jdirl,nbuf,iepsbz,minblk
      0 1 1 1 1 / maxblk,isbt,msbt,msdm,ibfscl
      4 50 1 0 4 / intscl,itmscl,nofis,ifdb2z,iswp
      218 1 0 0 0 / keyjn,keyin,nsigtp,norpos,normat
      0 1 1500 0 -10 / mstmax,negfix,locobj,lcmobj,nkeyfx
      4 61 0 0 0 / ncndin,neut,itally,isp1,isp2
      e
63** 0.0 7.4+10 1-4 1-3 1-3 / tmax,xnf,eps,epp,epv
      1-3 1.0 0.2 1.5 10.0 /epf,ekobj,evth,evchm,evmax
      1.0 1.0 -1.0 0.3 10.0 /evkmx,evi,devdki,evdelk,sormin
      1.0 1-4 1-2 0.0 -1.5 /conacc,conscl,coneps,wsolmn,wsolii
      1.5 0.6 0.0 1-30 0.0 /wsolcn,orf,fsnacc,flxmin,smooth
      1-2 0.2 0.9 / epo,extrcv,theta
      e t
      t
81**    / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
82**    / mus mm240
   -641230-7 -421582-7 m1 -142963-6 -939923-7 m1 -229252-6
   -150724-6 m1 -315291-6 -207291-6 m1 -399349-6 -262555-6 m1
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
   -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
```

Figure E.10 Card Input Data for the DORT Calculation of the ^{60}Co Source Packaged in the Loop Transport Carrier SNF Shipping Cask.

```
    -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
    -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
    -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
    -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
    -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120
83**    / etas mm240
    3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
    5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
    7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
    9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120
84$$ 1 2 3 4 3 2 3 / reg nos by zone
     t
1** f0  / fission spectrum
2**  /axii (jm+1)
   4i0.0 3i3.81 1i6.35 8i7.30 16i13.98 2i28.59 30.81 1i31.45
   167i33.35 4i200.99 205.43 206.07 11i206.71 8i218.13 2i226.07
   1i228.30 1i229.25 1i230.52 9i231.52 238.45 239.09
4**  /radii (im+1)
   2i0.0 1i1.33 4i2.41 5.08 3i5.40 7.30 3i7.62 1i9.36 1i10.16
   10.80 5i11.12 1i14.29 1i15.24 14i16.83 2i28.73 30.48
5** f1  / energy group boundaries
8$$  / zone numbers by interval
' zone 1-air, 2-ss347, 3-lead, 4-sae1020
   35r2 18r1 4q53  /j-ints 1-5
   33r2 20r4 3q53  /j-ints 6-9
   20r2 33r4 1q53  /j-ints 10-11
   24r2 26r3 3r4 8q53  /j-ints 12-20
   15r5 9r2 26r3 3r4 16q53   /j-ints 21-37
   24r2 26r3 3r4 2q53  /j-ints 38-40
   10r1 14r2 26r3 3r4  /j-int 41
   10r1 6r2 34r3 3r4 1q53  /j-ints 42-43
   15r1 1r2 34r3 3r4 167q53  /j-ints 44-211
   10r1 6r2 34r3 3r4  4q53  /j-ints 212-216
   10r1 12r2 28r3 3r4  /j-int 217
   3r6 19r2 28r3 3r4  /j-int 218
   3r6 17r7 2r2 28r3 3r4 11q53  /j-ints 219-230
   5r6 15r7 2r2 28r3 3r4 8q53  /j-ints 231-239
   5r6 15r7 11r2 19r3 3r4 2q53  /j-ints 240-242
   5r6 15r7 11r2 22r4 1q53  /j-ints 243-244
   5r6 26r2 22r1 1q53  /j-ints 245-246
   11r6 13r1 7r2 22r1 1q53  /j-ints 247-248
   24r1 1r2 28r1 9q53  /j-ints 249-258
   25r2 28r1  /j-int 259
9$$  1 7 13 19 13 7 13 / mat by zone
24** f1  / importance by zone
25$$ -31 -37 -43 -49  / mats for activity calcs
26$$   1   1   1   1  / x-sec positions for activity calcs
27** 1.0 1.0 1.0 1.0  / activity multipliers
28$$ 61r0 23r25  / inners by grp
```

Figure E.10 Continued.

```
29$$ 1  1  6 39 127 218 244 246 248 248 / j-pos key fluxes
30$$ 1 27 41 53  53  53  41   13   1  27 / i-pos key fluxes
      t
96**  15r1.0 38r0.0   /fi(i), i=1,im
      t
97**  43r0.0 168r1.0 48r0.0   /  fj(j), j=1,jm
      t
98**  61r0.0 11r0.0 1.0 11r0.0   / fg(g), g=1,igm
      t
```

Figure E.10 Continued.

***** DORT Input Changes for 25GWD/MTU LWR MFP Source *****

```
DORT - Loop Transport Carrier Calculation, MFP source; 25GWD/MTu
63** 0.0 1.39+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      8.19-03 1.73-01 1.46-01 2.53-01 1.18+00 3.49+00 1.04+01 8.08+01
      1.93+03 2.25+04 6.36+06 1.59+08 2.52+08 6.96+09 5.85+07 9.24+07
      1.41+08 4.43+08 5.22+08 5.16+08 8.70+08 2.15+09 1.72+09
```

***** DORT Input Changes for 50GWD/MTU LWR MFP Source *****

```
DORT - Loop Transport Carrier Calculation, MFP source; 50GWD/MTu
63** 0.0 1.47+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      3.10-02 6.53-01 5.53-01 9.54-01 4.44+00 1.32+01 3.91+01 1.73+02
      4.33+03 2.37+04 8.85+06 2.28+08 3.71+08 7.23+09 8.13+07 9.71+07
      1.46+08 4.66+08 5.95+08 5.45+08 8.81+08 2.26+09 1.81+09
```

***** DORT Input Changes for Cs-137 Source *****

```
DORT - Loop Transport Carrier Calculation, Cs-137 source
63** 0.0 3.467+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0 13r0.0 1.0 9r0.0   / fg(g), g=1,igm
```

***** DORT Input Changes for ORR MFP Source; 20% U235 *****

```
DORT - Loop Transport Carrier Calculation, ORR MFP Source; 20% U235
63** 0.0 1.71+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      4.52-05 9.59-04 8.15-04 1.41-03 6.60-03 1.98-02 5.93-02 2.85+01
      3.75+02 3.57+04 3.07+06 6.03+07 1.29+08 7.86+09 4.62+07 1.36+08
      2.23+08 6.67+08 6.48+08 7.68+08 1.13+09 2.92+09 2.48+09
```

***** DORT Input Changes for ORR MFP Source; 40% U235 *****

```
DORT - Loop Transport Carrier Calculation, ORR MFP Source; 40% U235
63** 0.0 1.78+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      4.91-02 1.04+00 8.78-01 1.51+00 7.04+00 2.09+01 6.20+01 2.26+02
      1.41+04 3.27+04 8.35+06 2.20+08 5.37+08 8.06+09 1.35+08 1.33+08
      2.07+08 6.40+08 7.33+08 7.37+08 1.07+09 2.86+09 2.46+09
```

***** DORT Input Changes for ORR MFP Source; 93% U235 *****

```
DORT - Loop Transport Carrier Calculation, ORR MFP Source; 93% U235
63** 0.0 1.83+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      1.53-03 3.23-02 2.74-02 4.72-02 2.20-01 6.55-01 1.95+00 2.69+01
      8.68+03 3.43+04 8.45+06 2.18+08 5.09+08 8.03+09 1.28+08 1.43+08
      2.25+08 6.92+08 7.78+08 7.93+08 1.15+09 3.02+09 2.57+09
```

Figure E.11 Card Input Data Changes for the DORT Calculation of the Other Sources Packaged in the Loop Transport Carrier SNF Shipping Cask.

```
 1$$  24  25  26  / ntdso,ntf,ntzf
 2$$  34  61  12 e  / ndet,neut,noa
   t
26**  f1.0
27**  61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s-cm2)
        1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
        5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
        1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
        3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
42**  / detector radial locations
          0.00    0.00  10.00   10.00   20.00   20.00  30.00   30.00
         34.30   34.30  34.30   34.30   34.30   34.30  34.30   34.30
        130.49  130.49 130.49  130.49  130.49  130.49 130.49  130.49
          0.00    0.00   5.00    5.00   10.00   10.00  15.00   15.00
         30.00   30.00
44**  / detector axial locations
         -3.81 -100.00  -3.81 -100.00   -3.81 -100.00  -3.81 -100.00
         20.00   30.00  70.00  120.00  170.00  206.00 215.00  225.00
         20.00   30.00  70.00  120.00  170.00  206.00 215.00  225.00
        242.90  339.09 242.90  339.09  242.90  339.09 233.06  329.25
        233.06  329.25
    t
   Loop Transport Carrier Spent Nuclear Fuel Shipping Cask
 Gamma-Ray ANSI Dose Response (rem/hour)/(gamma/second-cm**2)
 Dose Calculated at 3.81 cm and 100 cm above the cask surface
```

Figure E.12 Card Input Data for the FALSTF Calculations of the Surface and One Meter Distance Dose Rates at the Detector Locations Used in the Loop Transport Carrier SNF Shipping Cask Shielding Analysis.

```
Loop Transport Carrier DORT Geometry Model
0$$ 22 1 0 e / nflsv,irflx,irfly
1$$ 53 259 7 0 0 / imx,jm,izm,imap,itip
     84 25 400 1 0 / igm,nlvmx,nbuf,igeom,ivol
     0 0 0 0 0 / ishd,irsp,ihm,nmat,igx
     0 e / ilvck
2** 0.0 8.5 11.0 1.0 1.0 / size,xpage,ypage,xscl,yscl
     0.0 0.0 0.0 0.0 0.0 / xstp,ystp,xmin,xmax,ymin
     0.0 0.25 e / ymax,eps
     t
3$$ 53 f0
4$$ f1 t
5** /axii (jm+1)
  4i0.0 3i3.81 1i6.35 8i7.30 16i13.98 2i28.59 30.81 1i31.45
  167i33.35 4i200.99 205.43 206.07 11i206.71 8i218.13 2i226.07
  1i228.30 1i229.25 1i230.52 9i231.52 238.45 239.09
6** /radii (im+1)
  2i0.0 1i1.33 4i2.41 5.08 3i5.40 7.30 3i7.62 1i9.36 1i10.16
  10.80 5i11.12 1i14.29 1i15.24 14i16.83 2i28.73 30.48
8$$ / zone numbers by interval
  35r2 18r1 4q53 /j-ints 1-5
  33r2 20r4 3q53 /j-ints 6-9
  20r2 33r4 1q53 /j-ints 10-11
  24r2 26r3 3r4 8q53 /j-ints 12-20
  15r5 9r2 26r3 3r4 16q53 /j-ints 21-37
  24r2 26r3 3r4 2q53 /j-ints 38-40
  10r1 14r2 26r3 3r4 /j-int 41
  10r1 6r2 34r3 3r4 1q53 /j-ints 42-43
  15r1 1r2 34r3 3r4 167q53 /j-ints 44-211
  10r1 6r2 34r3 3r4 4q53 /j-ints 212-216
  10r1 12r2 28r3 3r4 /j-int 217
  3r6 19r2 28r3 3r4 /j-int 218
  3r6 17r7 2r2 28r3 3r4 11q53 /j-ints 219-230
  5r6 15r7 2r2 28r3 3r4 8q53 /j-ints 231-239
  5r6 15r7 11r2 19r3 3r4 2q53 /j-ints 240-242
  5r6 15r7 11r2 22r4 1q53 /j-ints 243-244
  5r6 26r2 22r1 1q53 /j-ints 245-246
  11r6 13r1 7r2 22r1 1q53 /j-ints 247-248
  24r1 1r2 28r1 9q53 /j-ints 249-258
  25r2 28r1 /j-int 259
9$$ 1 7 13 19 13 7 13 / mat by zone
     t
Radius (cm)$
Height (cm)$
Loop Transport Carrier Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0 / iga,igb,nlvl,iplt,ipos
     0 0 e / imat,ichk
14** 1.0 -1.0 -1.0 e t / fac,fmin,fmax
```

Figure E.13. Card Input Data for the ISOPLOT Isodose Contour Maps for the Loop Transport Carrier SNF Shipping Cask Shielding Analysis.

```
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
  t
last
Loop Transport Carrier DORT Geometry Model
1$$  53 259 7 2 0  / imx,jm,izm,imap,itip
      84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 20.0 0.0  / xstp,ystp,xmin,xmax,ymin
      35.0 0.25 e  / ymax,eps
      t
Radius (cm)$
Height (cm)$
Loop Transport Carrier Door Plug Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
      0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e t  / fac,fmin,fmax
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
  t
last
Loop Transport Carrier DORT Geometry Model
1$$  53 259 7 2 0  / imx,jm,izm,imap,itip
      84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 15.0 200.0  / xstp,ystp,xmin,xmax,ymin
      240.0 0.25 e  / ymax.eps
      t
Radius (cm)$
Height (cm)$
Loop Transport Carrier End Plug Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
      0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e t  / fac,fmin,fmax
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
  t
last
```

Figure E.13 Continued.

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation, Co-60 source
' VELM61 61n-23g, P-5, endf/b-v, mm = 240 (sym)
61$$  0 21 4 0 23  / ntflx,ntfog,ntsig,ntbsi,ntdsi
       0  0 0 0  0   / ntfci,ntibi,ntibo,ntnpr,ntdir
      24 e          / ntdso
62$$ 0 5 10 43 385   / iadj,isctm,izm,im,jm
      84 3 4 87 0   / igm,iht,ihs,ihm,mixl
      0 54 54 0 240   / mmesh,mtp,mtm,idfac,mm
      1 1 0 0 0   / ingeom,ibl,ibr,ibb,ibt
      1 -1 0 4 0   / isrmx,ifxmi,ifxmf,mode,ktype
      2 0 0 0 3  / iacc,kalf,igtype,inpfxm,inpsrm
      0 0 0 0 -4  / njntsr,nintsr,njntfx,nintfx,iact
      3 0 1 1 0   / ired,ipdb2,ifxprt,icsprt,idirf
      0 0 120 11 0   / jdirf,jdirl,nbuf,iepsbz,minblk
      0 1 1 1 1   / maxblk,isbt,msbt,msdm,ibfscl
      4 50 1 0 4  / intscl,itmscl,nofis,ifdb2z,iswp
      357 1 0 0 0   / keyjn,keyin,nsigtp,norpos,normat
      0 1 1500 0 -10   / mstmax,negfix,locobj,lcmobj,nkeyfx
      4 61 0 0 0   / ncndin,neut,itally,isp1,isp2
      e
63** 0.0 7.4+10 1-4 1-3 1-3   / tmax,xnf,eps,epp,epv
      1-3 1.0 0.2 1.5 10.0   /epf,ekobj,evth,evchm,evmax
      1.0 1.0 -1.0 0.3 10.0   /evkmx,evi,devdki,evdelk,sormin
      1.0 1-4 1-2 0.0 -1.5   /conacc,conscl,coneps,wsolmn,wsolii
      1.5 0.6 0.0 1-30 0.0   /wsolcn,orf,fsnacc,flxmin,smooth
      1-2 0.2 0.9   / epo,extrcv,theta
      e  t
      t
81**      / wts mm240
    0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
    2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
    714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
    480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
    310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
    745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
    n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
    394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
    378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
    517107-8 408094-8 542534-8 384965-8 n4 q120
82**      / mus mm240
    -641230-7 -421582-7 m1 -142963-6 -939923-7 m1 -229252-6
    -150724-6 m1 -315291-6 -207291-6 m1 -399349-6 -262555-6 m1
    -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
    -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
    -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
    -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
    -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
    -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
```

Figure E.14 Card Input Data for the DORT Calculation of the ^{60}Co Source Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask.

```
     -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
     -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
     -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
     -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
     -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
     -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120
83**     / etas mm240
     3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
     5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
     7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
     9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120
84$$ 1 2 3 3 3 2 2 2 2 2 / reg nos by zone
       t
1** f0   / fission spectrum
2**  /axii (jm+1)
   1i0.0 1.27 1.91 23i2.55 17.79 18.43 324i19.07 262.91 263.55
   23i264.19 279.43 280.07 1i280.71 281.98
4**  /radii (im+1)
   16i0.0 10.64 10.95 11.43 1i12.06 19i13.34 26.19 26.83
5** f1   / energy group boundaries
8$$  / zone numbers by interval
' zone 1-air, 2-ss347, 3-lead
   19r1 23r2 1r6 1q43  /j-ints 1-2
   18r1 4r2 20r3 1r6  /j-int 3
   22r2 20r3 1r6  /j-int 4
   20r4 2r7 20r3 1r6 23q43  /j-ints 5-28
   22r9 20r3 1r6  /j-int 29
   17r1 5r9 20r3 1r6  /j-int 30
   17r1 1r9 24r3 1r6 324q43  /j-ints 31-355
   17r1 5r9 20r3 1r6  /j-int 356
   22r9 20r3 1r6  /j-int 357
   20r5 2r8 20r3 1r6 23q43  /j-ints 358-381
   22r10 20r3 1r6  /j-int 382
   18r1 4r10 20r3 1r6  /j-int 383
   19r1 23r10 1r6 1q43  /j-ints 384-385
9$$ 1 7 13 13 13 7 7 7 7 7  / mat by zone
24** f1  / importance by zone
25$$ -31 -37 -43 -49  / mats for activity calcs
26$$   1   1   1   1  / x-sec positions for activity calcs
27** 1.0 1.0 1.0 1.0  / activity multipliers
28$$ 61r0 23r25  / inners by grp
29$$  1  1  1  1  4  4 29 84 138 193  / j-pos key fluxes
30$$ 21 28 34 42  1 10 43 43  43  43  / i-pos key fluxes
       t
96**  17r1.0 26r0.0   /fi(i), i=1,im
       t
97**  29r0.0 327r1.0 29r0.0   /  fj(j), j=1,jm
       t
98**  61r0.0 11r0.0 1.0 11r0.0    / fg(g), g=1,igm
       t
```

Figure E.14 Continued.

----- Input Changes for 25GWD/MTU LWR MFP Source -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation. MFP source: 25GWD/MTu
63** 0.0 1.39+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        8.19-03 1.73-01 1.46-01 2.53-01 1.18+00 3.49+00 1.04+01 8.08+01
        1.93+03 2.25+04 6.36+06 1.59+08 2.52+08 6.96+09 5.85+07 9.24+07
        1.41+08 4.43+08 5.22+08 5.16+08 8.70+08 2.15+09 1.72+09
```

----- Input Changes for 50GWD/MTU LWR MFP Source -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation. MFP source; 50GWD/MTu
63** 0.0 1.47+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        3.10-02 6.53-01 5.53-01 9.54-01 4.44+00 1.32+01 3.91+01 1.73+02
        4.33+03 2.37+04 8.85+06 2.28+08 3.71+08 7.23+09 8.13+07 9.71+07
        1.46+08 4.66+08 5.95+08 5.45+08 8.81+08 2.26+09 1.81+09
```

----- Input Changes for Cs-137 Source -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation. Cs-137 source
63** 0.0 3.467+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0 13r0.0 1.0 9r0.0  / fg(g), g=1,igm
```

----- Input Changes for ORR MFP Source; 20% U235 -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation, ORR MFP Source: 20% U235
63** 0.0 1.71+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.52-05 9.59-04 8.15-04 1.41-03 6.60-03 1.98-02 5.93-02 2.85+01
        3.75+02 3.57+04 3.07+06 6.03+07 1.29+08 7.86+09 4.62+07 1.36+08
        2.23+08 6.67+08 6.48+08 7.68+08 1.13+09 2.92+09 2.48+09
```

----- Input Changes for ORR MFP Source; 40% U235 -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation, ORR MFP Source; 40% U235
63** 0.0 1.78+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.91-02 1.04+00 8.78-01 1.51+00 7.04+00 2.09+01 6.20+01 2.26+02
        1.41+04 3.27+04 8.35+06 2.20+08 5.37+08 8.06+09 1.35+08 1.33+08
        2.07+08 6.40+08 7.33+08 7.37+08 1.07+09 2.86+09 2.46+09
```

----- Input Changes for ORR MFP Source; 93% U235 -----

```
 DORT - In-Pile Loop LITR HB-2 Carrier Calculation, ORR MFP Source; 93% U235
63** 0.0 1.83+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        1.53-03 3.23-02 2.74-02 4.72-02 2.20-01 6.55-01 1.95+00 2.69+01
        8.68+03 3.43+04 8.45+06 2.18+08 5.09+08 8.03+09 1.28+08 1.43+08
        2.25+08 6.92+08 7.78+08 7.93+08 1.15+09 3.02+09 2.57+09
```

Figure E.15 Card Input Data Changes for the DORT Calculation of the Other Sources Packaged in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask.

```
 1$$  24  25  26  / ntdso,ntf,ntzf
 2$$  34  61  12 e   / ndet,neut,noa
   t
26**  f1.0
27**  61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s-cm2)
        1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
        5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
        1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
        3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
42**  / detector radial locations
          0.00    0.00   0.00   0.00    6.00    6.00   6.00   6.00
         12.00   12.00  12.00  12.00   18.00   18.00  18.00  18.00
         24.00   24.00  24.00  24.00   30.64   30.64  30.64  30.64
         30.64   30.64  30.64 126.83  126.83  126.83 126.83 126.83
        126.83  126.83
44**  / detector axial locations
         -3.81 -100.00 285.79 381.98  -3.81 -100.00 285.79 381.98
         -3.81 -100.00 285.79 381.98  -3.81 -100.00 285.79 381.98
         -3.81 -100.00 285.79 381.98   9.00   18.00  60.00 140.00
        220.00  264.00 273.00   9.00  18.00   60.00 140.00 220.00
        264.00  273.00
    t
In-Pile Loop LITR HB-2 Carrier Spent Nuclear Fuel Shipping Cask
  Gamma-Ray ANSI Dose Response (rem/hour)/(gamma/second-cm**2)
  Dose Calculated at 3.81 cm and 100 cm above the cask surface
```

Figure E.16 Card Input Data for the FALSTF Calculations of the Surface and One Meter Distance Dose Rates at the Detector Locations Used in the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask Shielding Analysis.

```
In-Pile Loop LITR HB-2 Carrier DORT Geometry Model
0$$  22 1 0 e  / nflsv,irflx,irfly
1$$  43 385 10 0 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 0.0 0.0  / xstp,ystp,xmin,xmax,ymin
       0.0 0.25 e  / ymax,eps
       t
3$$  43 f0
4$$  f1
       t
5**  /axii (jm+1)
   1i0.0 1.27 1.91 23i2.55 17.79 18.43 324i19.07 262.91 263.55
   23i264.19 279.43 280.07 1i280.71 281.98
6**  /radii (im+1)
   16i0.0 10.64 10.95 11.43 1i12.06 19i13.34 26.19 26.83
8$$  / zone numbers by interval
   19r1 23r2 1r6 1q43  /j-ints 1-2
   18r1 4r2 20r3 1r6  /j-int 3
   22r2 20r3 1r6  /j-int 4
   20r4 2r7 20r3 1r6 23q43  /j-ints 5-28
   22r9 20r3 1r6  /j-int 29
   17r1 5r9 20r3 1r6  /j-int 30
   17r1  1r9 24r3 1r6 324q43  /j-ints 31-355
   17r1 5r9 20r3 1r6  /j-int 356
   22r9 20r3 1r6  /j-int 357
   20r5 2r8 20r3 1r6 23q43  /j-ints 358-381
   22r10 20r3 1r6  /j-int 382
   18r1 4r10 20r3 1r6  /j-int 383
   19r1 23r10 1r6 1q43  /j-ints 384-385
9$$ 1 7 13 13 13 7 7 7 7 7  / mat by zone
       t
Radius (cm)$
Height (cm)$
In-Pile Loop LITR HB-2 Carrier Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
```

Figure E.17 Card Input Data for the ISOPLOT Isodose Contour Maps for the In-Pile Loop LITR HB-2 Carrier SNF Shipping Cask Shielding Analysis.

```
In-Pile Loop LITR HB-2 Carrier DORT Geometry Model
1$$  43 385 10 2 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 15.0 -2.0  / xstp,ystp,xmin,xmax,ymin
       22.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
LITR HB-2 Carrier Double Door Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
           1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
           5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
           1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
           3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
In-Pile Loop LITR HB-2 Carrier DORT Geometry Model
1$$  43 385 10 2 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 15.0 260.0  / xstp,ystp,xmin,xmax,ymin
       284.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
LITR HB-2 Carrier Large Door Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
           1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
           5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
           1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
           3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
```

Figure E-17. Continued.

```
DORT - 6.5 inch HRLEL Carrier Calculation, Co-60 source
' VELM61 61n-23g, P-5, endf/b-v, mm = 240 (sym)
61$$ 0 21 4 0 23 / ntflx,ntfog,ntsig,ntbsi,ntdsi
     0 0 0 0 0 / ntfci,ntibi,ntibo,ntnpr,ntdir
     24 e        / ntdso
62$$ 0 5 12 46 269 / iadj,isctm,izm,im,jm
     84 3 4 87 0 / igm,iht,ihs,ihm,mixl
     0 54 54 0 240 / mmesh,mtp,mtm,idfac,mm
     1 1 0 0 0 / ingeom,ibl,ibr,ibb,ibt
     1 -1 0 4 0 / isrmx,ifxmi,ifxmf,mode,ktype
     2 0 0 0 3 / iacc,kalf,igtype,inpfxm,inpsrm
     0 0 0 0 -4 / njntsr,nintsr,njntfx,nintfx,iact
     4 0 1 1 0 / ired,ipdb2,ifxprt,icsprt,idirf
     0 0 120 11 0 / jdirf,jdirl,nbuf,iepsbz,minblk
     0 1 1 1 1 / maxblk,isbt,msbt,msdm,ibfscl
     4 50 1 0 4 / intscl,itmscl,nofis,ifdb2z,iswp
     41 1 0 0 0 / keyjn,keyin,nsigtp,norpos,normat
     0 1 1500 0 -12 / mstmax,negfix,locobj,lcmobj,nkeyfx
     4 61 0 0 0 / ncndin,neut,itally,isp1,isp2
     e
63** 0.0 7.4+10 1-4 1-3 1-3 / tmax,xnf,eps,epp,epv
     1-3 1.0 0.2 1.5 10.0 /epf,ekobj,evth,evchm,evmax
     1.0 1.0 -1.0 0.3 10.0 /evkmx,evi,devdki,evdelk,sormin
     1.0 1-4 1-2 0.0 -1.5 /conacc,conscl,coneps,wsolmn,wsolii
     1.5 0.6 0.0 1-30 0.0 /wsolcn,orf,fsnacc,flxmin,smooth
     1-2 0.2 0.9 / epo,extrcv,theta
     e t
     t
81**    / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
82**    / mus mm240
   -641230-7 -421582-7 m1 -142963-6 -939923-7 m1 -229252-6
   -150724-6 m1 -315291-6 -207291-6 m1 -399349-6 -262555-6 m1
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
   -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
```

Figure E.18 Card Input Data for the DORT Calculation of the ^{60}Co Source Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask.

```
   -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
   -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
   -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
   -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
   -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120
83**    / etas mm240
   3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
   5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
   7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
   9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120
84$$ 1 2 3 4 3 3 2 4 2 2 2 2 / reg nos by zone
     t
1** f0  / fission spectrum
2**  /axii (jm+1)
  2i0.0 4i2.54 1i6.35 7.94 2i8.89 25i10.80 29.80 5i30.44 34.57
  35.52 134i36.47 1i132.04 7i133.31 139.98 140.99 13i141.88
  152.68 5i153.63 10i158.39 5i166.65 171.74 13i172.36 183.16
  184.11 7i185.06 2i191.09 3i193.00 2i195.86 198.40
4**  /radii (im+1)
  5i0.0 4.12 4.76 4i5.40 8.89 3i9.84 2i12.70 2i14.92 2i17.15
  10i19.37 28.26 4i29.21 1i33.66 34.93
5** f1  / energy group boundaries
8$$  / zone numbers by interval
' zone 1-air, 2-ss347, 3-lead, 4-aluminum
  38r4 8r1 2q46  /j-ints 1-3
  18r1 28r2 4q46  /j-ints 4-8
  18r1 3r2 17r3 1r9 7r1 1q46  /j-ints 9-10
  8r7 10r1 3r2 17r3 1r9 7r1  /j-int 11
  6r7 15r2 17r3 1r9 7r1 2q46  /j-ints 12-14
  6r7 12r5 3r2 17r3 1r9 7r1 25q46  /j-ints 15-40
  6r7 2r2 10r5 3r2 17r3 1r9 7r1  /j-int 41
  7r1 1r2 10r5 3r2 17r3 1r9 7r1 5q46  /j-ints 42-47
  7r1 14r2 17r3 1r9 7r1  /j-int 48
  13r1 8r2 17r3 1r9 7r1  /j-int 49
  13r1 1r2 24r3 1r9 7r1 134q46  /j-ints 50-184
  13r1 1r2 24r3 8r9 1q46  /j-ints 185-186
  13r1 1r2 30r3 2r9 7q46  /j-ints 187-194
  13r1 14r2 17r3 2r9  /j-int 195
  27r2 17r3 2r9  /j-int 196
  24r6 3r2 17r3 2r9 13q46  /j-ints 197-210
  14r11 10r6 3r2 17r3 2r9  /j-int 211
  13r1 1r10 10r6 3r2 17r3 2r9 5q46  /j-ints 212-217
  13r1 1r10 10r6 3r2 17r3 2r9 10q46  /j-ints 218-228
  13r1 1r10 10r6 3r2 17r3 2r9 5q46  /j-ints 229-234
  14r12 10r6 3r2 17r3 2r9  /j-int 235
  24r6 3r2 17r3 2r9 13q46  /j-ints 136-249
  27r2 17r3 2r9  /j-int 250
  13r1 14r2 17r3 2r9  /j-int 251
  13r1 1r2 30r3 2r9 7q46  /j-ints 252-259
  13r1 33r2 2q46  /j-ints 260-262
```

Figure E.18 Continued.

```
  13r1 33r2 3q46  /j-ints 263-266
  38r8 8r1 2q46  /j-ints 267-269
9$$ 1 7 13 25 13 13 7 25 7 7 7 7  / mat by zone
24** f1  / importance by zone
25$$ -31 -37 -43 -49  / mats for activity calcs
26$$  1  1  1  1  / x-sec positions for activity calcs
27** 1.0 1.0 1.0 1.0  / activity multipliers
28$$ 61r0 23r25  / inners by grp
29$$ 2 2  2 48 184 117 196 223 250 268 268 268 / j-pos key fluxes
30$$ 1 6 20 39  39  39  46  46  46   1  14  37 / i-pos key fluxes
     t
96**  13r1.0 33r0.0  /fi(i), i=1,im
     t
97**  48r0.0 147r1.0 74r0.0   /  fj(j), j=1,jm
     t
98**  61r0.0 11r0.0 1.0 11r0.0    / fg(g), g=1,igm
     t
```

Figure E.18 Continued.

```
----- Input Changes for 25GWD/MTU LWR MFP Source -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, MFP source; 25GWD/MTu
63** 0.0 1.39+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        8.19-03 1.73-01 1.46-01 2.53-01 1.18+00 3.49+00 1.04+01 8.08+01
        1.93+03 2.25+04 6.36+06 1.59+08 2.52+08 6.96+09 5.85+07 9.24+07
        1.41+08 4.43+08 5.22+08 5.16+08 8.70+08 2.15+09 1.72+09

----- Input Changes for 50GWD/MTU LWR MFP Source -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, MFP source; 50GWD/MTu
63** 0.0 1.47+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        3.10-02 6.53-01 5.53-01 9.54-01 4.44+00 1.32+01 3.91+01 1.73+02
        4.33+03 2.37+04 8.85+06 2.28+08 3.71+08 7.23+09 8.13+07 9.71+07
        1.46+08 4.66+08 5.95+08 5.45+08 8.81+08 2.26+09 1.81+09

----- Input Changes for Cs-137 Source -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, Cs-137 source
63** 0.0 3.467+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0 13r0.0 1.0 9r0.0  / fg(g), g=1,igm

----- Input Changes for ORR MFP Source; 20% U235 -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, ORR MFP Source; 20% U235
63** 0.0 1.71+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.52-05 9.59-04 8.15-04 1.41-03 6.60-03 1.98-02 5.93-02 2.85+01
        3.75+02 3.57+04 3.07+06 6.03+07 1.29+08 7.86+09 4.62+07 1.36+08
        2.23+08 6.67+08 6.48+08 7.68+08 1.13+09 2.92+09 2.48+09

----- Input Changes for ORR MFP Source; 40% U235 -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, ORR MFP Source; 40% U235
63** 0.0 1.78+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.91-02 1.04+00 8.78-01 1.51+00 7.04+00 2.09+01 6.20+01 2.26+02
        1.41+04 3.27+04 8.35+06 2.20+08 5.37+08 8.06+09 1.35+08 1.33+08
        2.07+08 6.40+08 7.33+08 7.37+08 1.07+09 2.86+09 2.46+09

----- Input Changes for ORR MFP Source; 93% U235 -----
 DORT - 6.5 Inch HRLEL Carrier Calculation, ORR MFP Source; 93% U235
63** 0.0 1.83+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        1.53-03 3.23-02 2.74-02 4.72-02 2.20-01 6.55-01 1.95+00 2.69+01
        8.68+03 3.43+04 8.45+06 2.18+08 5.09+08 8.03+09 1.28+08 1.43+08
        2.25+08 6.92+08 7.78+08 7.93+08 1.15+09 3.02+09 2.57+09
```

Figure E.19 Card Input Data Changes for the DORT Calculation of the Other Sources Packaged in the 6.5-Inch HRLEL Carrier SNF Shipping Cask.

```
 1$$  24  25  26  / ntdso,ntf,ntzf
 2$$  34  61   12 e   / ndet,neut,noa
   t
26**  f1.0
27**  61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s-cm2)
        1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
        5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
        1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
        3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
42**  / detector radial locations
          0.00    0.00   3.00    3.00    9.00    9.00  14.00   14.00
         25.00   25.00  33.02   33.02   33.02   33.02  33.02  129.21
        129.21  129.21 129.21  129.21   38.74   38.74  38.74   38.74
        134.93  134.93 134.93  134.93    0.00    0.00  10.00   10.00
         20.00   20.00
44**  / detector axial locations
         -3.81 -100.00  -3.81 -100.00   -3.81 -100.00  -3.81 -100.00
         -3.81 -100.00  20.00   35.00   75.00  110.00 130.00   20.00
         35.00   75.00 110.00  130.00  141.00  162.00 184.00  190.00
        141.00  162.00 184.00  190.00  202.21  298.40 202.21  298.40
        202.21  298.40
    t
   6.5 Inch HRLEL Carrier Spent Nuclear Fuel Shipping Cask
  Gamma-Ray ANSI Dose Response (rem/hour)/(gamma/second-cm**2)
  Dose Calculated at 3.81 cm and 100 cm above the cask surface
```

Figure E.20 Card Input Data for the FALSTF Calculations of the Surface and One Meter Distance Dose Rates at the Detector Locations Used in the 6.5-Inch HRLEL Carrier SNF Shipping Cask Shielding Analysis.

```
6.5 Inch HRLEL Carrier DORT Geometry Model
0$$  22 1 0 e  / nflsv,irflx,irfly
1$$  46 269 12 0 0  / imx,jm,izm,imap,itip
     84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
     0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
     0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
     0.0 0.0 0.0 0.0 0.0  / xstp,ystp,xmin,xmax,ymin
     0.0 0.25 e  / ymax,eps
     t
3$$  46 f0
4$$  f1
     t
5**  /axii (jm+1)
  2i0.0 4i2.54 1i6.35 7.94 2i8.89 25i10.80 29.80 5i30.44 34.57
  35.52 134i36.47 1i132.04 7i133.31 139.98 140.99 13i141.88
  152.68 5i153.63 10i158.39 5i166.65 171.74 13i172.36 183.16
  184.11 7i185.06 2i191.09 3i193.00 2i195.86 198.40
6**  /radii (im+1)
  5i0.0 4.12 4.76 4i5.40 8.89 3i9.84 2i12.70 2i14.92 2i17.15
  10i19.37 28.26 4i29.21 1i33.66 34.93
8$$  / zone numbers by interval
  38r4 8r1 2q46  /j-ints 1-3
  18r1 28r2 4q46  /j-ints 4-8
  18r1 3r2 17r3 1r9 7r1 1q46  /j-ints 9-10
  8r7 10r1 3r2 17r3 1r9 7r1  /j-int 11
  6r7 15r2 17r3 1r9 7r1 2q46  /j-ints 12-14
  6r7 12r5 3r2 17r3 1r9 7r1 25q46  /j-ints 15-40
  6r7 2r2 10r5 3r2 17r3 1r9 7r1  /j-int 41
  7r1 1r2 10r5 3r2 17r3 1r9 7r1 5q46  /j-ints 42-47
  7r1 14r2 17r3 1r9 7r1  /j-int 48
  13r1 8r2 17r3 1r9 7r1  /j-int 49
  13r1 1r2 24r3 1r9 7r1 134q46  /j-ints 50-184
  13r1 1r2 24r3 8r9 1q46  /j-ints 185-186
  13r1 1r2 30r3 2r9 7q46  /j-ints 187-194
  13r1 14r2 17r3 2r9  /j-int 195
  27r2 17r3 2r9  /j-int 196
  24r6 3r2 17r3 2r9 13q46  /j-ints 197-210
  14r11 10r6 3r2 17r3 2r9  /j-int 211
  13r1 1r10 10r6 3r2 17r3 2r9 5q46  /j-ints 212-217
  13r1 1r10 10r6 3r2 17r3 2r9 10q46  /j-ints 218-228
  13r1 1r10 10r6 3r2 17r3 2r9 5q46  /j-ints 229-234
  14r12 10r6 3r2 17r3 2r9  /j-int 235
  24r6 3r2 17r3 2r9 13q46  /j-ints 136-249
  27r2 17r3 2r9  /j-int 250
  13r1 14r2 17r3 2r9  /j-int 251
  13r1 1r2 30r3 2r9 7q46  /j-ints 252-259
  13r1 33r2 2q46  /j-ints 260-262
  13r1 33r2 3q46  /j-ints 263-266
```

Figure E.21 Card Input Data for the ISOPLOT Isodose Contour Maps for the 6.5-Inch HRLEL Carrier SNF Shipping Cask Shielding Analysis.

```
   38r8 8r1 2q46 /j-ints 267-269
9$$ 1 7 13 25 13 13 7 25 7 7 7 7 /·mat by zone
      t
Radius (cm)$
Height (cm)$
6.5 Inch HRLEL Carrier Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0 / iga,igb,nlvl,iplt,ipos
      0 0 e / imat,ichk
14** 1.0 -1.0 -1.0 e / fac,fmin,fmax
      t
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
         1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
         5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
         1.7563-6 1.4417-6 1.2797-6 1.0845-6 8.7594-7 5.6676-7
         3.2767-7 2.6817-7 2.7185-7 5.7760-7 2.1439-6
   t
last
6.5 Inch HRLEL Carrier DORT Geometry Model
1$$ 46 269 12 2 0 / imx,jm,izm,imap,itip
      84 25 400 1 0 / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0 / ishd,irsp,ihm,nmat,igx
      0 e / ilvck
2** 0.0 8.5 11.0 1.0 1.0 / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 16.0 0.0 / xstp,ystp,xmin,xmax,ymin
      38.0 0.25 e / ymax,eps
      t
Radius (cm)$
Height (cm)$
6.5 Inch HRLEL Carrier End Plug Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0 / iga,igb,nlvl,iplt,ipos
      0 0 e / imat,ichk
14** 1.0 -1.0 -1.0 e / fac,fmin,fmax
      t
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
         1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
         5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
         1.7563-6 1.4417-6 1.2797-6 1.0845-6 8.7594-7 5.6676-7
         3.2767-7 2.6817-7 2.7185-7 5.7760-7 2.1439-6
   t
last
6.5 Inch HRLEL Carrier DORT Geometry Model
1$$ 46 269 12 2 0 / imx,jm,izm,imap,itip
      84 25 400 1 0 / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0 / ishd,irsp,ihm,nmat,igx
      0 e / ilvck
2** 0.0 8.5 11.0 1.0 1.0 / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 20.0 135.0 / xstp,ystp,xmin,xmax,ymin
      200.0 0.25 e / ymax,eps
      t
```

Figure E.21 Continued.

```
Radius (cm)$
Height (cm)$
6.5 Inch HRLEL Carrier Door Gamma-Ray Dose Rate$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
      0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
      t
15**   61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
         1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
         5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
         1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
         3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
```

Figure E.21 Continued.

```
DORT - HIFR Hot Scrap Shipping Cask Calculation, Co-60 source
' VELM61 61n-23g, P-5, endf/b-v, mm = 240 (sym)
61$$ 0 21 4 0 23 / ntflx,ntfog,ntsig,ntbsi,ntdsi
     0 0 0 0 0 / ntfci,ntibi,ntibo,ntmpr,ntdir
     24 e        / ntdso
62$$ 0 5 14 64 243  / iadj,isctm,izm,im,jm
     84 3 4 87 0  / igm,iht,ihs,ihm,mixl
     0 54 54 0 240  / mmesh,mtp,mtm,idfac,mm
     1 1 0 0 0  / ingeom,ibl,ibr,ibb,ibt
     1 -1 0 4 0  / isrmx,ifxmi,ifxmf,mode,ktype
     2 0 0 0 3  / iacc,kalf,igtype,inpfxm,inpsrm
     0 0 0 0 -4  / njntsr,nintsr,njntfx,nintfx,iact
     3 0 1 1 0  / ired,ipdb2,ifxprt,icsprt,idirf
     0 0 120 11 0  / jdirf,jdirl,nbuf,iepsbz,minblk
     0 1 1 1 1  / maxblk,isbt,msbt,msdm,ibfscl
     4 50 1 0 4  / intscl,itmscl,nofis,ifdb2z,iswp
     124 60 0 0 0  / keyjn,keyin,nsigtp,norpos,normat
     0 1 1500 0 -10  / mstmax,negfix,locobj,lcmobj,nkeyfx
     4 61 0 0 0  / ncndin,neut,itally,isp1,isp2
     e
63** 0.0 7.40+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
     1-3 1.0 0.2 1.5 10.0  /epf,ekobj,evth,evchm,evmax
     1.0 1.0 -1.0 0.3 10.0  /evkmx,evi,devdki,evdelk,sormin
     1.0 1-4 1-2 0.0 -1.5  /conacc,conscl,coneps,wsolmn,wsolii
     1.5 0.6 0.0 1-30 0.0  /wsolcn,orf,fsnacc,flxmin,smooth
     1-2 0.2 0.9  / epo,extrcv,theta
     e  t
     t
81**    / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
82**    / mus mm240
   -641230-7 -421582-7 m1 -142963-6 -939923-7 m1 -229252-6
   -150724-6 m1 -315291-6 -207291-6 m1 -399349-6 -262555-6 m1
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
   -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
```

Figure E.22 Card Input Data for the DORT Calculation of the ^{60}Co Source Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask.

```
    -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
    -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
    -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
    -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
    -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120
83**    / etas mm240
    3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
    5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
    7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
    9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120
84$$ 1 2 3 2 2 2 3 3 3 2 2 2 2 2 / reg nos by zone
      t
1** f0  / fission spectrum
2**  /axii (jm+1)
   1i0.0 6i0.95 5i5.39 9i9.52 21i16.19 30.16 30.80 149i31.44
   2i121.93 1i123.83 34i124.78 1i146.69 1i147.64 148.91
4**  /radii (im+1)
   1i0.0 1.33 20i2.06 15.56 15.88 16.51 17.15 1i17.46 2i18.73
   2i20.32 4i22.23 20i25.40 1i39.06 40.01
5** f1  / energy group boundaries
8$$  / zone numbers by interval
   3r2 61r1 1q64  /j-ints 1-2
   3r2 38r10 23r1 6q64 /j-ints 3-9
   3r2 25r3 34r11 2r4 5q64  /j-ints 10-15
   3r2 25r3 2r11 32r7 2r4 9q64  /j-ints 16-25
   2r2 26r3 2r11 32r7 2r4 21q64  /j-ints 26-47
   30r2 32r7 2r4  /j-int 48
   24r1 1r12 1r1 4r13 32r7 2r4  /j-int 49
   24r1 1r12 1r1 1r13 35r7 2r4 149q64  /j-ints 50-199
   24r1 1r12 1r1 36r13 2r4 2q64  /j-ints 200-202
   62r5 2r4 1q64  /j-ints 203-204
   33r8 3r14 26r9 2r4 34q64  /j-ints 205-239
   36r14 26r9 2r4 1q64  /j-ints 240-241
   35r1 29r6 1q64  /j-ints 242-243
9$$  1  7 13  7  7  7 13 13 13  7  7  7  7  7 / mat by zone
24** f1  / importance by zone
25$$ -31 -37 -43 -49  / mats for activity calcs
26$$  1   1   1   1  / x-sec positions for activity calcs
27** 1.0 1.0 1.0 1.0  / activity multipliers
28$$ 61r0 23r25  / inners by grp
29$$ 1  3  3 10 48 124 202 243 241 241 / j-pos key fluxes
30$$ 1 17 30 50 64  64  64  50  35   1 / i-pos key fluxes
      t
96**  24r1.0 40r0.0   /fi(i), i=1,im
      t
97**  48r0.0 154r1.0 41r0.0   /  fj(j), j=1,jm
      t
98**  61r0.0 11r0.0 1.0 11r0.0   / fg(g), g=1,igm
      t
```

Figure E.22 Continued.

```
----- Input Changes for 25GWD/MTU LWR MFP Source -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, MFP source; 25GWD/MTu
63** 0.0 1.39+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        8.19-03 1.73-01 1.46-01 2.53-01 1.18+00 3.49+00 1.04+01 8.08+01
        1.93+03 2.25+04 6.36+06 1.59+08 2.52+08 6.96+09 5.85+07 9.24+07
        1.41+08 4.43+08 5.22+08 5.16+08 8.70+08 2.15+09 1.72+09

----- Input Changes for 50GWD/MTU LWR MFP Source -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, MFP source; 50GWD/MTu
63** 0.0 1.47+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        3.10-02 6.53-01 5.53-01 9.54-01 4.44+00 1.32+01 3.91+01 1.73+02
        4.33+03 2.37+04 8.85+06 2.28+08 3.71+08 7.23+09 8.13+07 9.71+07
        1.46+08 4.66+08 5.95+08 5.45+08 8.81+08 2.26+09 1.81+09

----- Input Changes for Cs-137 Source -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, Cs-137 source
63** 0.0 3.467+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0 13r0.0 1.0 9r0.0  / fg(g), g=1,igm

----- Input Changes for ORR MFP Source; 20% U235 -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, ORR MFP Source; 20% U235
63** 0.0 1.71+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.52-05 9.59-04 8.15-04 1.41-03 6.60-03 1.98-02 5.93-02 2.85+01
        3.75+02 3.57+04 3.07+06 6.03+07 1.29+08 7.86+09 4.62+07 1.36+08
        2.23+08 6.67+08 6.48+08 7.68+08 1.13+09 2.92+09 2.48+09

----- Input Changes for ORR MFP Source; 40% U235 -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, ORR MFP Source; 40% U235
63** 0.0 1.78+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        4.91-02 1.04+00 8.78-01 1.51+00 7.04+00 2.09+01 6.20+01 2.26+02
        1.41+04 3.27+04 8.35+06 2.20+08 5.37+08 8.06+09 1.35+08 1.33+08
        2.07+08 6.40+08 7.33+08 7.37+08 1.07+09 2.86+09 2.46+09

----- Input Changes for ORR MFP Source; 93% U235 -----
DORT - HIFR Hot Scrap Shipping Cask Calculation, ORR MFP Source; 93% U235
63** 0.0 1.83+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
        1.53-03 3.23-02 2.74-02 4.72-02 2.20-01 6.55-01 1.95+00 2.69+01
        8.68+03 3.43+04 8.45+06 2.18+08 5.09+08 8.03+09 1.28+08 1.43+08
        2.25+08 6.92+08 7.78+08 7.93+08 1.15+09 3.02+09 2.57+09
```

Figure E.23 Card Input Data Changes for the DORT Calculation of the Other Sources Packaged in the HFIR Hot Scrap Carrier SNF Shipping Cask.

```
 1$$  24  25  26  / ntdso,ntf,ntzf
 2$$  34  61  12 e  / ndet,neut,noa
   t
26**  f1.0
27**  61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s-cm2)
        1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
        5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
        1.7563-6 1.4417-6 1.2797-6 1.0845-6 8.7594-7 5.6676-7
        3.2767-7 2.6817-7 2.7185-7 5.7760-7 2.1439-6
42**  / detector radial locations
          0.00   9.00  18.00  28.00  38.00  43.82  43.82  43.82
         43.82  43.82  43.82  43.82  43.82  32.00  21.25  11.00
          0.00   0.00   9.00  18.00  28.00  38.00 140.01 140.01
        140.01 140.01 140.01 140.01 140.01 140.01  32.00  21.25
         11.00   0.00
44**  / detector axial locations
         -3.81  -2.86  -2.86  -2.86  -2.86  16.00  31.00  54.00
         77.00 100.00 123.00 134.00 145.00 152.72 152.72 151.45
        151.45 -100.00 -99.05 -99.05 -99.05 -99.05  16.00  31.00
         54.00  77.00 100.00 123.00 134.00 145.00 248.91 248.91
        247.64 247.64
     t
     HIFR Hot Scrap And Spent Nuclear Fuel Shipping Carrier
   Gamma-Ray ANSI Dose Response (rem/hour)/(gamma/second-cm**2)
   Dose Calculated at 3.81 cm and 100 cm above the cask surface
```

Figure E.24 Card Input Data for the FALSTF Calculations of the Surface and One Meter Distance Dose Rates at the Detector Locations Used in the HFIR Hot Scrap Carrier SNF Shipping Cask Shielding Analysis.

```
HIFR Hot Scrap Shipping Carrier DORT Geometry Model
0$$  22 1 0 e  / nflsv,irflx,irfly
1$$  64 243 14 0 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck -
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 0.0 0.0  / xstp,ystp,xmin,xmax,ymin
       0.0 0.25 e  / ymax,eps
       t
3$$  64 f0
4$$  f1
       t
5**  /axii (jm+1)
   1i0.0 6i0.95 5i5.39 9i9.52 21i16.19 30.16 30.80 149i31.44
   2i121.93 1i123.83 34i124.78 1i146.69 1i147.64 148.91
6**  /radii (im+1)
   1i0.0 1.33 20i2.06 15.56 15.88 16.51 17.15 1i17.46 2i18.73
   2i20.32 4i22.23 20i25.40 1i39.06 40.01
8$$  / zone numbers by interval
   3r2 61r1 1q64  /j-ints 1-2
   3r2 38r10 23r1 6q64 /j-ints 3-9
   3r2 25r3 34r11 2r4 5q64  /j-ints 10-15
   3r2 25r3 2r11 32r7 2r4 9q64  /j-ints 16-25
   2r2 26r3 2r11 32r7 2r4 21q64  /j-ints 26-47
   30r2 32r7 2r4  /j-int 48
   24r1 1r12 1r1 4r13 32r7 2r4  /j-int 49
   24r1 1r12 1r1 1r13 35r7 2r4 149q64  /j-ints 50-199
   24r1 1r12 1r1 36r13 2r4 2q64  /j-ints 200-202
   62r5 2r4 1q64  /j-ints 203-204
   33r8 3r14 26r9 2r4 34q64  /j-ints 205-239
   36r14 26r9 2r4 1q64  /j-ints 240-241
   35r1 29r6 1q64  /j-ints 242-243
9$$  1  7 13  7  7  7 13 13 13  7  7  7  7  7 / mat by zone
       t
Radius (cm)$
Height (cm)$
HIFR Hot Scrap SNF Shipping Cask$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**   61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
           1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
           5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
           1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
           3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
```

Figure E.25 Card Input Data for the ISOPLOT Isodose Contour Maps for the HFIR Hot Scrap Carrier SNF Shipping Cask Shielding Analysis.

```
HIFR Hot Scrap Shipping Carrier DORT Geometry Model
1$$  64 243 14 2 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 25.0 110.0  / xstp,ystp,xmin,xmax,ymin
       155.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
HIFR Hot Scrap SNF Shipping Carrier Bottom Door$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
            1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
            5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
            1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
            3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
HIFR Hot Scrap Shipping Carrier DORT Geometry Model
1$$  64 243 14 2 0  / imx,jm,izm,imap,itip
       84 25 400 1 0  / igm,nlvmx,nbuf,igeom,ivol
       0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
       0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
       0.0 0.0 0.0 30.0 -5.0  / xstp,ystp,xmin,xmax,ymin
       45.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
HIFR Hot Scrap SNF Shipping Carrier Top Plug$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
            1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
            5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
            1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
            3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
    t
last
```

Figure E.25 Continued.

```
DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.. Co-60 source
' VELM61 61n-23g, P-5, endf/b-v, mm = 240 (sym)
61$$ 0 21 4 0 23 / ntflx,ntfog,ntsig,ntbsi,ntdsi
      0 0 0 0 0 / ntfci,ntibi,ntibo,ntnpr,ntdir
      24 e       / ntdso
62$$ 0 5 9 63 641 / iadj,isctm,izm,im,jm
      84 3 4 87 0 / igm,iht,ihs,ihm,mixl
      0 54 54 0 240 / mmesh,mtp,mtm,idfac,mm
      1 1 0 0 0 / ingeom,ibl,ibr,ibb,ibt
      1 -1 0 4 0 / isrmx,ifxmi,ifxmf,mode,ktype
      2 0 0 0 3 / iacc,kalf,igtype,inpfxm,inpsrm
      0 0 0 0 -4 / njntsr,nintsr,njntfx,nintfx,iact
      3 0 1 1 0 / ired,ipdb2,ifxprt,icsprt,idirf
      0 0 120 11 0 / jdirf,jdirl,nbuf,iepsbz,minblk
      0 1 1 1 1 / maxblk,isbt,msbt,msdm,ibfscl
      4 50 1 0 4 / intscl,itmscl,nofis,ifdb2z,iswp
      8 53 0 0 0 / keyjn,keyin,nsigtp,norpos,normat
      0 1 1500 0 -10 / mstmax,negfix,locobj,lcmobj,nkeyfx
      4 61 0 0 0 / ncndin,neut,itally,isp1,isp2
      e
63** 0.0 7.40+10 1-4 1-3 1-3 / tmax,xnf,eps,epp,epv
      1-3 1.0 0.2 1.5 10.0 /epf,ekobj,evth,evchm,evmax
      1.0 1.0 -1.0 0.3 10.0 /evkmx,evi,devdki,evdelk,sormin
      1.0 1-4 1-2 0.0 -1.5 /conacc,conscl,coneps,wsolmn,wsolii
      1.5 0.6 0.0 1-30 0.0 /wsolcn,orf,fsnacc,flxmin,smooth
      1-2 0.2 0.9 / epo,extrcv,theta
      e t
      t
81**     / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
82**     / mus mm240
   -641230-7 -421582-7 m1 -142963-6 -939923-7 m1 -229252-6
   -150724-6 m1 -315291-6 -207291-6 m1 -399349-6 -262555-6 m1
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
```

Figure E.26 Card Input Data for the DORT Calculation of the ^{60}Co Source Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask.

```
     -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
     -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
     -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
     -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
     -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
     -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120
83**     / etas mm240
     3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
     5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
     7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
     9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120
84$$ 1 2 3 3 3 3 3 3 2  t  / reg nos by zone
1** f0  / fission spectrum
2**  /axii (jm+1)
   4i0.0 2i3.81 26i5.72 2i25.40 3i27.31 259i29.85 5i211.46
   144i215.91 5i331.48 144i335.93 5i451.50 2i455.95 19i457.86
   2i472.46 4i474.37 477.55
4**  /radii (im+1)
   21i0.0 1i13.97 1i15.24 2i16.51 3i18.42 13i20.96 2i29.84
   4i31.74 2i34.92 4i36.82 40.01
5** f1  / energy group boundaries
8$$  / zone numbers by interval
   24r1 39r9 4q63  /j-ints 1-5
   33r2 22r3 3r9 5r1 2q63  /j-ints 6-8
   26r4 7r2 22r3 3r9 5r1 26q63  /j-ints 9-35
   33r2 22r3 3r9 5r1 2q63  /j-ints 36-38
   22r1 11r2 22r3 3r9 5r1 3q63  /j-ints 39-42
   22r1 2r2 31r3 3r9 5r1 259q63  /j-ints 43-302
   22r1 2r2 39r9 5q63  /j-ints 303-308
   22r1 2r2 23r5 3r9 13r1 144q63  /j-ints 309-453
   22r1 2r2 39r9 5q63  /j-ints 454-459
   22r1 2r2 23r6 3r9 13r1 144q63  /j-ints 460-604
   22r1 2r2 39r9 5q63  /j-ints 605-610
   33r2 14r7 3r9 13r1 2q63  /j-ints 611-613
   26r8 7r2 14r7 3r9 13r1 19q63  /j-ints 614-633
   33r2 14r7 3r9 13r1 2q63  /j-ints 634-636
   24r1 39r9 4q63  /j-ints 637-641
9$$  1  7 13 13 13 13 13 13  7 / mat by zone
24** f1  / importance by zone
25$$ -31 -37 -43 -49  / mats for activity calcs
26$$   1   1   1   1  / x-sec positions for activity calcs
27** 1.0 1.0 1.0 1.0  / activity multipliers
28$$ 61r0 23r25  / inners by grp
29$$ 6  1 37 170 305 380 456 607 641 636 /  j-pos key fluxes
30$$ 1 30 58  58  63  50  63  63  30   1  t /  i-pos key fluxes
96**  22r1.0 41r0.0   /fi(i), i=1,im
      t
97**  38r0.0 572r1.0 31r0.0   /  fj(j), j=1,jm
      t
98**  61r0.0 11r0.0 1.0 11r0.0   / fg(g), g=1,igm
      t
```

Figure E.26 Continued.

```
----- Input Changes for 25GWD/MTU LWR MFP Source -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,MFP source;25GWD/MTu
63** 0.0 1.39+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      8.19-03 1.73-01 1.46-01 2.53-01 1.18+00 3.49+00 1.04+01 8.08+01
      1.93+03 2.25+04 6.36+06 1.59+08 2.52+08 6.96+09 5.85+07 9.24+07
      1.41+08 4.43+08 5.22+08 5.16+08 8.70+08 2.15+09 1.72+09

----- Input Changes for 50GWD/MTU LWR MFP Source -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,MFP source;50GWD/MTu
63** 0.0 1.47+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0   / fg(g), g=1,igm
      3.10-02 6.53-01 5.53-01 9.54-01 4.44+00 1.32+01 3.91+01 1.73+02
      4.33+03 2.37+04 8.85+06 2.28+08 3.71+08 7.23+09 8.13+07 9.71+07
      1.46+08 4.66+08 5.95+08 5.45+08 8.81+08 2.26+09 1.81+09


----- Input Changes for Cs-137 Source -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,Cs-137 source
63** 0.0 3.467+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0 13r0.0 1.0 9r0.0  / fg(g), g=1,igm


----- Input Changes for ORR MFP Source; 20% U235 -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,ORR MFP Source;20% U235
63** 0.0 1.71+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0  / fg(g), g=1,igm
      4.52-05 9.59-04 8.15-04 1.41-03 6.60-03 1.98-02 5.93-02 2.85+01
      3.75+02 3.57+04 3.07+06 6.03+07 1.29+08 7.86+09 4.62+07 1.36+08
      2.23+08 6.67+08 6.48+08 7.68+08 1.13+09 2.92+09 2.48+09

----- Input Changes for ORR MFP Source; 40% U235 -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,ORR MFP Source;40% U235
63** 0.0 1.78+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0  / fg(g), g=1,igm
      4.91-02 1.04+00 8.78-01 1.51+00 7.04+00 2.09+01 6.20+01 2.26+02
      1.41+04 3.27+04 8.35+06 2.20+08 5.37+08 8.06+09 1.35+08 1.33+08
      2.07+08 6.40+08 7.33+08 7.37+08 1.07+09 2.86+09 2.46+09

----- Input Changes for ORR MFP Source; 93% U235 -----
 DORT - 10 Inch Expt. Removal Shield-ORR Cask Calc.,ORR MFP Source;93% U235
63** 0.0 1.83+10 1-4 1-3 1-3  / tmax,xnf,eps,epp,epv
98**  61r0.0  / fg(g), g=1,igm
      1.53-03 3.23-02 2.74-02 4.72-02 2.20-01 6.55-01 1.95+00 2.69+01
      8.68+03 3.43+04 8.45+06 2.18+08 5.09+08 8.03+09 1.28+08 1.43+08
      2.25+08 6.92+08 7.78+08 7.93+08 1.15+09 3.02+09 2.57+09
```

Figure E.27 Card Input Data Changes for the DORT Calculation of the Other Sources Packaged in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask.

```
 1$$  24  25  26  / ntdso,ntf,ntzf
 2$$  34  61  12 e  / ndet,neut,noa
   t
26**  f1.0
27**  61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s-cm2)
        1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
        5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
        1.7563-6 1.4417-6 1.2797-6 1.0845-6 8.7594-7 5.6676-7
        3.2767-7 2.6817-7 2.7185-7 5.7760-7 2.1439-6
42**  / detector radial locations
          0.00    9.00   18.00   26.00   40.64   40.64   40.64   43.82
         35.56   43.82   35.56   43.82   35.56   24.00   18.00    9.00
          0.00    0.00    9.00   18.00   26.00  136.83  136.83  136.83
        140.01  131.75  140.01  131.75  140.01  131.75   24.00   18.00
          9.00    0.00
44**  / detector axial locations
          0.00    0.00   -3.81   -3.81   27.00   89.00  151.00  213.00
        273.00  333.00  393.00  453.00  465.00  481.36  481.36  478.18
        478.18  -96.19  -96.19 -100.00 -100.00   27.00   89.00  151.00
        213.00  273.00  333.00  393:00  453.00  465.00  577.55  577.55
        574.37  574.37
   t
10 Inch Experimental Removal Shield-ORR Spent Fuel Shipping Cask
  Gamma-Ray ANSI Dose Response (rem/hour)/(gamma/second-cm**2)
  Dose Calculated at 3.81 cm and 100 cm above the cask surface
```

Figure E.28 Card Input Data for the FALSTF Calculations of the Surface and One Meter Distance Dose Rates at the Detector Locations Used in the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask Shielding Analysis.

```
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
0$$ 22 1 0 e / nflsv,irflx,irfly
1$$ 63 641 9 0 0 / imx,jm,izm,imap,itip
     84 25 500 1 0 / igm,nlvmx,nbuf,igeom,ivol
     0 0 0 0 0 / ishd,irsp,ihm,nmat,igx
     0 e / ilvck
2** 0.0 8.5 11.0 1.0 1.0 / size,xpage,ypage,xscl,yscl
     0.0 0.0 0.0 0.0 0.0 / xstp,ystp,xmin,xmax,ymin
     0.0 0.25 e / ymax,eps
     t
3$$ 63 f0
4$$ f1
     t
5** /axii (jm+1)
  4i0.0 2i3.81 26i5.72 2i25.40 3i27.31 259i29.85 5i211.46
  144i215.91 5i331.48 144i335.93 5i451.50 2i455.95 19i457.86
  2i472.46 4i474.37 477.55
6** /radii (im+1)
  21i0.0 1i13.97 1i15.24 2i16.51 3i18.42 13i20.96 2i29.84
  4i31.74 2i34.92 4i36.82 40.01
8$$ / zone numbers by interval
  24r1 39r9 4q63 /j-ints 1-5
  33r2 22r3 3r9 5r1 2q63 /j-ints 6-8
  26r4 7r2 22r3 3r9 5r1 26q63 /j-ints 9-35
  33r2 22r3 3r9 5r1 2q63 /j-ints 36-38
  22r1 11r2 22r3 3r9 5r1 3q63 /j-ints 39-42
  22r1 2r2 31r3 3r9 5r1 259q63 /j-ints 43-302
  22r1 2r2 39r9 5q63 /j-ints 303-308
  22r1 2r2 23r5 3r9 13r1 144q63 /j-ints 309-453
  22r1 2r2 39r9 5q63 /j-ints 454-459
  22r1 2r2 23r6 3r9 13r1 144q63 /j-ints 460-604
  22r1 2r2 39r9 5q63 /j-ints 605-610
  33r2 14r7 3r9 13r1 2q63 /j-ints 611-613
  26r8 7r2 14r7 3r9 13r1 19q63 /j-ints 614-633
  33r2 14r7 3r9 13r1 2q63 /j-ints 634-636
  24r1 39r9 4q63 /j-ints 637-641
9$$ 1 7 13 13 13 13 13 13 7 / mat by zone
     t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR SNF Shipping Cask$
13$$ 62 84 1001 2 0 / iga,igb,nlvl,iplt,ipos
     0 0 e / imat,ichk
14** 1.0 -1.0 -1.0 e / fac,fmin,fmax
     t
15**  61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
        1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
        5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
```

Figure E.29 Card Input Data for the ISOPLOT Isodose Contour Maps for the 10-Inch ORR Experiment Removal Shield SNF Shipping Cask Shielding Analysis.

```
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
1$$  63 641 9 2 0  / imx,jm,izm,imap,itip
      84 25 500 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 0.0 0.0  / xstp,ystp,xmin,xmax,ymin
      220.0 0.25 e  / ymax,eps
      t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR Carrier Heavy Shield$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
      0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
      t
15**   61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
1$$  63 641 9 2 0  / imx,jm,izm,imap,itip
      84 25 500 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 0.0 190.0  / xstp,ystp,xmin,xmax,ymin
      350.0 0.25 e  / ymax,eps
      t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR Carrier Light Shield$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
      0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
      t
15**   61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
          5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
          1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
          3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
```

Figure E.29 Continued.

```
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
1$$  63 641 9 2 0  / imx,jm,izm,imap,itip
      84 25 500 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  /-ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 0.0 320.0  / xstp,ystp,xmin,xmax,ymin
      480.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR Carrier Light Shield$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
           1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
           5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
           1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
           3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
1$$  63 641 9 2 0  / imx,jm,izm,imap,itip
      84 25 500 1 0  / igm,nlvmx,nbuf,igeom,ivol
      0 0 0 0 0  / ishd,irsp,ihm,nmat,igx
      0 e  / ilvck
2**  0.0 8.5 11.0 1.0 1.0  / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 25.0 -5.0  / xstp,ystp,xmin,xmax,ymin
      35.0 0.25 e  / ymax,eps
       t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR Carrier Heavy Door$
13$$ 62 84 1001 2 0  / iga,igb,nlvl,iplt,ipos
       0 0 e  / imat,ichk
14** 1.0 -1.0 -1.0 e  / fac,fmin,fmax
       t
15**    61r0.0  / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
           1.1020-5  8.7716-6  7.8468-6  7.4783-6  6.9265-6  6.1909-6
           5.1436-6  4.6220-6  3.9596-6  3.4686-6  2.9270-6  2.3156-6
           1.7563-6  1.4417-6  1.2797-6  1.0845-6  8.7594-7  5.6676-7
           3.2767-7  2.6817-7  2.7185-7  5.7760-7  2.1439-6
   t
last
10 Inch Expt. Removal Shield-ORR Carrier DORT Geometry Model
1$$  63 641 9 2 0  / imx,jm,izm,imap,itip
      84 25 500 1 0  / igm,nlvmx,nbuf,igeom,ivol
```

Figure E.29 Continued.

```
      0 0 0 0 0 / ishd,irsp,ihm,nmat,igx
      0 e / ilvck
2**  0.0 8.5 11.0 1.0 1.0 / size,xpage,ypage,xscl,yscl
      0.0 0.0 0.0 25.0 445.0 / xstp,ystp,xmin,xmax,ymin
      485.0 0.25 e / ymax,eps
      t
Radius (cm)$
Height (cm)$
10 Inch Expt. Removal Shield-ORR Carrier Light Door$
13$$ 62 84 1001 2 0 / iga,igb,nlvl,iplt,ipos
      0 0 e / imat,ichk
14** 1.0 -1.0 -1.0 e / fac,fmin,fmax
      t
15**   61r0.0 / Gamma-Ray ANSI Dose Response (rem/hr)/(g/s.cm2)
          1.1020-5 8.7716-6 7.8468-6 7.4783-6 6.9265-6 6.1909-6
          5.1436-6 4.6220-6 3.9596-6 3.4686-6 2.9270-6 2.3156-6
          1.7563-6 1.4417-6 1.2797-6 1.0845-6 8.7594-7 5.6676-7
          3.2767-7 2.6817-7 2.7185-7 5.7760-7 2.1439-6
   t
last
```

Figure E.29 Continued.

INTERNAL DISTRIBUTION

1. D. R. Brown
2. R. H. Cooper
3. C. E. DeVores
4. J. D. Drischler
5. T. A. Gabriel
6. D. T. Ingersoll
7-11. J. O. Johnson
12. M. A. Kuliasha
13. G. R. Larson
14. B. C. McClelland
15. R. N. Morris
16. C. E. Oliver
17. N. H. Packan
18-22. J. V. Pace III
23. C. H. Shappert
24. D. W. Turner
25. L. R. Williams
26. Central Research Section
27. Document Reference Section
28. Laboratory Records
29. ORNL Patent Section

EXTERNAL DISTRIBUTION

30. Office of the Assistant Manager for Energy
Research and Development
DOE-ORO
P.O. Box 2008
Oak Ridge, TN 37831-6269

31-32. Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37830