5. SHIELDING EVALUATION

This Chapter describes the RT-100 shielding evaluation under the RT Quality Assurance Program [Ref. 1] and summarizes the results to demonstrate compliance with the shielding requirements of 10 CFR 71 [Ref. 2]. The RT-100 cask package is designed to transport contaminated resin and filter media from nuclear power plant operation. The RT-100 has a robust gamma shielding design comprised of a steel/lead/steel body with a steel primary lid and a steel/lead/steel secondary lid. The primary lid is bolted onto the body, and the secondary lid is bolted into the primary lid. Both lids, along with their O-ring seals provide secure containment of the radioactive material contents. Analyses presented in this chapter demonstrate that the shielding design produces dose rates below the external radiation requirements of 10 CFR 71 [Ref. 2] under Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC). The package and vehicle radiation limits are for exclusive use of an open (flat-bed) transport vehicle. Operating limits are established for the specific activities of individual radionuclides (Ci/g) allowed in the contents of the package.

The RT-100 is designed in compliance with the external radiation standards that are specified in 10 CFR Part 71 [Ref. 2] as:

- The RT-100 is designed, constructed, and prepared for shipment so that the external radiation levels will not significantly increase under the tests specified in 10 CFR 71.71 (Normal Conditions of Transport) in accordance with 10 CFR 71.43(f) and 10 CFR 71.51(a)(1).
- Under NCT tests specified in 10 CFR 71.71, the external radiation levels meet the requirements of 10 CFR 71.47(b) for exclusive-use shipments.
- Under HAC tests specified in 10 CFR 71.73, the external radiation level does not exceed 10 mSv/hr (1 rem/hr) at one meter from the surface of the package in accordance with 10 CFR 71.51(a)(2).

The shielding evaluation is based on the descriptions and evaluations presented in the General Information, Structural Evaluation and Thermal Evaluation sections of the application. Results of the shielding evaluation are considered in the preparation of Operating Procedures and the Acceptance Tests and Maintenance Program. An example of information flow for the shielding evaluation is shown in Figure 5-1 .

The approach used to calculate the maximum allowable limits is intended to assure that the maximum activity of each radionuclide includes sufficient margin to ensure that the maximum dose rates of a loaded RT-100 cask will comply with regulatory dose rate limits. The process used to calculate the radionuclide-specific source strength densities (Ci/g) is summarized as:

1. Shielding Model package geometry, materials, source definition, tallies
   An MCNP6 shielding model is constructed using the minimum shielding material thicknesses, and assumes that the maximum activity concentration of a specific radionuclide completely fills the cask cavity with no credit given for attenuation provided by secondary containers. Separate tallies are defined in the shielding model to determine the peak external dose rate at all locations required by the regulations (i.e. package surface, 1m, 2m). The input file for MCNP6 is a shielding model that represents the package geometry, materials, source definition, and tallies as described in Section 5.3 and 5.4.1.1.

2. External dose rates for package transport conditions
   The shielding analysis, to determine external dose rates for the RT-100 package, is performed with MCNP6 [Ref. 3]. The output from MCNP6 is a dose rate response in mrem/hr/Ci for each of the generic source energies that has been modified by fluence-to-dose conversion factors and is normalized per 1 Curie of activity. A detailed description of the shielding analysis method is provided in Section 5.4.1.2.

   The actual dose rate associated with a particular radionuclide in the cask contents is a function of the package shielding configuration, the interaction of emitted radiation with the cask contents, and the spectrum of radiation emitted from decay of the radionuclides. Since there are numerous potential radionuclides in the cask contents (as discussed in Section 5.2) with each radionuclide having an emission spectrum containing multiple energy levels, it is impractical to explicitly analyze each energy level for each potential radionuclide separately. Rather, a finite number of energy levels are selected that are representative of the expected range of radiation energies from all radionuclides. The shielding analysis is performed for each of these representative energy levels, referred to in this evaluation as *generic energies*. The generic energy source term used for the calculation assumes the probability of particle emission is 100 percent per disintegration, and the actual emission probability (i.e. intensity) is accounted for in the dose rate response calculation for individual nuclides.

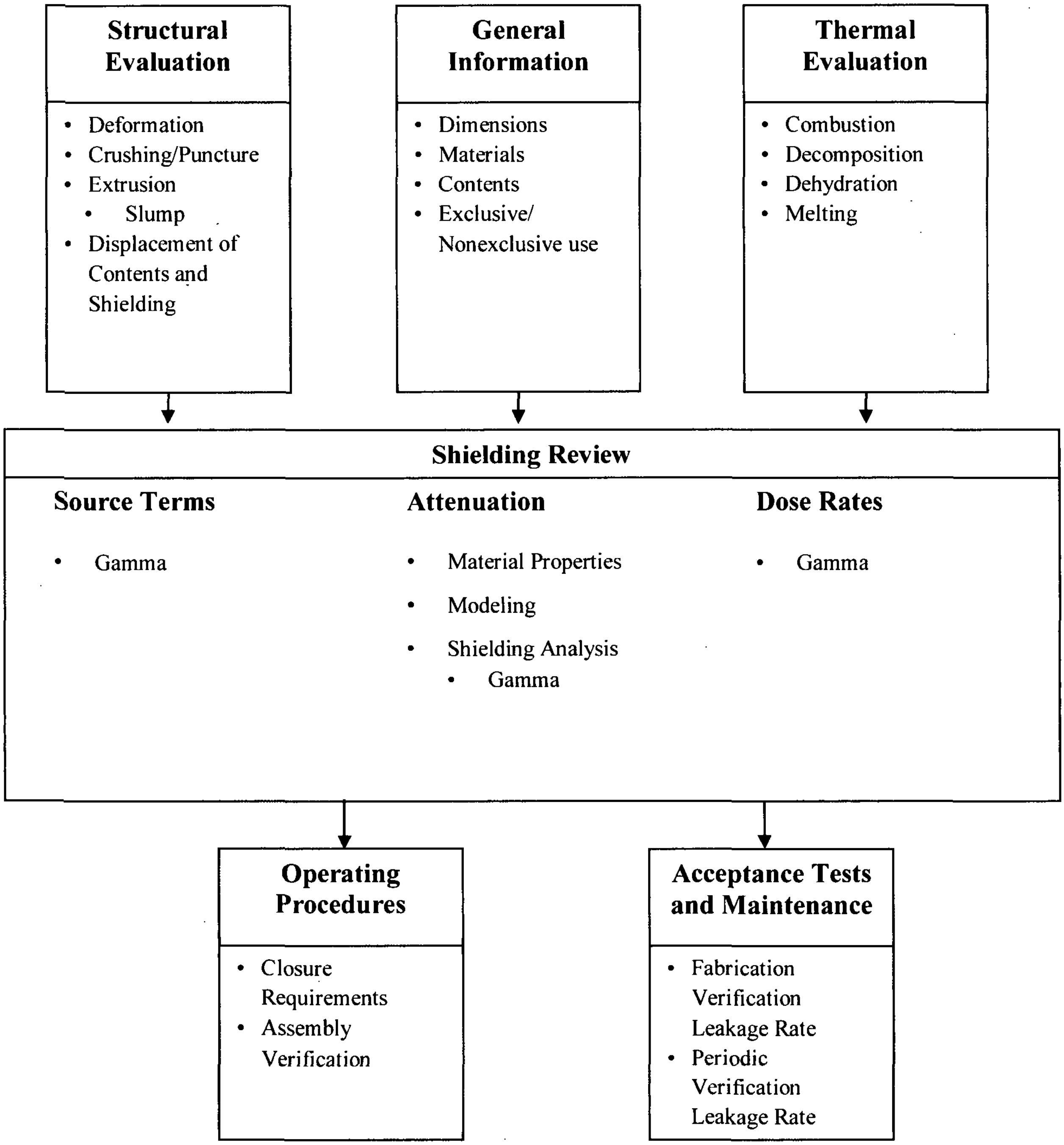
3. Dose rate response for individual radionuclides
   The MCNP6 shielding evaluation calculates the dose rate responses for a finite set of generic source energies, independent of the radionuclide responsible for the particle emission. In this evaluation, 26 discrete generic energies were analyzed. The generic energy dose rate responses from MCNP6 are processed and used as input to calculate the dose rate response for individual radionuclides. The method utilized to determine the dose rates from 1 Curie of a specific radionuclide uses the calculated responses of the generic energy lines to determine the response at each energy line of the respective radionuclide. A radionuclide dose rate response in mrem/hr/Ci is calculated by summing the determined dose rate responses for all energy lines of the respective radionuclide.

The dose rates for the most significant radionuclides are calculated separately from the generic energy line response method, with individual MCNP6 inputs modeling the actual source spectrum of each radionuclide. The radionuclides considered individually in this analysis are: Co-60, Zn-65, Fe-59, Mn-54, Co-58, Ag-110m, Cs-134, and Cs-137. A detailed description of the method used to calculate radionuclide dose rate responses is provided in Section 5.4.1.2.

4. Calculate the maximum allowable source strength density
   Based on the maximum possible mass of resin material in the RT-100, the regulatory dose rate at a given location, and the calculated radionuclide dose rate response at the respective regulatory location, a maximum quantity of each radionuclide allowed to be transported in the cask is specified in the form of specific activities (Ci/g), also referred to as the *source strength density*. The radionuclide-specific source strength densities are used to verify that the actual contents being shipped will comply with the regulatory requirements for external radiation levels. The maximum allowed source strength densities calculated in the shielding evaluation are used in an operating procedure, referred to as the *loading table*, which is used for mixtures of radionuclides. A detailed description of the method used to calculate the maximum allowable source strength is provided in Section 5.4.1.3.

The actual contents can vary significantly for shipments; therefore, it is not practical to explicitly evaluate the actual contents that are shipped. This methodology is used to imply a dose rate associated with a particular mixture of radionuclides in the contents by calculating an effective source strength density that is a sum of the fraction of the maximum allowable source strength densities for the individual radionuclides. A sum of the fractions for radionuclide-specific maximum allowable source strength densities that is less than or equal to 1.0 implies that the external radiation levels meet the regulatory limits. Further description of the loading table operating procedure is provided in Chapter 7, Section 7.6.1 of this SAR.

Figure 5-1 Information Flow for the Shielding Evaluation



5.1 Description of Shielding Design

A description of the shielding design, as well as a summary of the results of the analysis for this design is provided below.

5.1.1 Design Features

The RT-100 body is a right circular cylinder 2060 mm in diameter and 2324 mm in height without the impact limiters attached. The cavity of the RT-100 is 1730 mm in diameter and 1956 mm in height. Surrounding the cavity are the cask radial wall, cask bottom wall, primary lid and a secondary lid embedded in the primary lid. The cask radial wall comprises 30 mm of steel, 90 mm of lead and 35 mm of steel for gamma shielding. The cask bottom wall comprises 50 mm of steel, 75 mm of lead and 30 mm of steel for gamma shielding. The primary lid comprises 210 mm of steel for gamma shielding. Embedded in the primary lid is a secondary lid that comprises 100 mm of steel, 60 mm of lead and 10 mm of steel for gamma shielding. The primary lid is 2016 mm in diameter and the secondary lid is 1000 mm in diameter. Under transport conditions, the top and bottom impact limiters provide additional gamma shielding from the 10 mm inner steel shell, polyurethane foam and 4 mm outer steel shell.

Dimensional tolerances and material densities used in the shielding evaluations are given in Section 5.3.1 and Section 5.3.2, respectively.

During normal conditions of transport, shielding evaluations assume that the RT-100 is transported on a truck trailer that is 2438.4 mm wide and 12801.6 mm long with the cask tied down in the center. Thus, the 2 meter radial surface is 3219.2 mm from the cask centerline and the distance to the cab, taking into account the trailer hookup and the distance to back of cab, is 8915.4 mm from the cask centerline. This is a conservative assumption since the actual occupied position is at least 1828.8 mm forward from the back of the cab. A visual representation of the dose locations is provided in Figure 5.4.4-4.

5.1.2 Summary Table of Maximum Radiation Levels

The transport regulations provide dose limits in 10 CFR 71.47 and 71.51 at locations external to the package for rates for both Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC). A full discussion of the methods employed to analyze the RT-100 cask design and results of applying these methods that demonstrate compliance with the regulatory limits are presented in the sections that follow. Table 5.1.2-1 shown below summarizes the calculated results for the maximum radiation levels allowed for exclusive use shipment using an open (flat-bed) transport vehicle under NCT and HAC for the worst-case loading of radionuclides. These results represent the maximum dose rates for the worst-case allowable contents as presented in Section 5.4.4.

Table 5.1.2-1 Summary Table of External Radiation Levels (Exclusive Use)

Normal Conditions of Transport (NCT)	Package Surface[1] mSv/hr (mrem/hr)						2 Meter from Edge of Vehicle mSv/hr (mrem/hr)		Vehicle Occupied Position mSv/hr (mrem/hr)	
Radiation[2]	Side		Bottom		Top		Side		Cab	
Gamma	1.13	(113.2)	0.47	(47.2)	0.87	(86.7)	0.095	(9.5)	0.01	(1.3)
10 CFR 71.47 (b) Limit	2.0	(200.0)	2.0	(200.0)	2.0	(200.0)	0.1	(10.0)	0.02	(2.0)

Hypothetical Accident Conditions (HAC)	1 Meter from Package Surface[1] mSv/hr (mrem/hr)					
Radiation[2]	Side		Bottom		Top	
Gamma	9.5	(950)	1.16	(115.9)	2.36	(235.7)
10 CFR 71.51 (a)(2) Limit	10	(1000)	10	(1000)	10	(1000)

Note 1: The gamma dose rates are each calculated for a contents limit corresponding to a limiting regulatory dose rate. These values are the maximum of all the radionuclides that were evaluated in Section 5.4.4.5.

Note 2: Typical contents will not contain a significant neutron source term.

5.2 Source Specification

The RT-100 is designed to transport nuclear plant radioactive resins and filters. This content is described in Chapter 1, Section 1.2.2. The radionuclides in these resins and filters produce primarily gamma emissions and trace neutron emissions from actinide spontaneous fission and alpha-n reactions in the media.

The shielding evaluation for the RT-100 calculates a dose rate response that is normalized to one Curie (mrem/hr/Ci) for each radionuclide with a half-life greater than 1 day. Thus, the gamma dose rate responses are specified on a per Curie basis. The total dose rate will be based on the loaded activity, in Curies, of the resin or filter media. In general, the gamma source terms decrease over time.

5.2.1 Gamma Source

Gamma spectra, i.e. the photon lines, are explicitly evaluated in the RT-100 shielding evaluation for radionuclides with greater than 1 day half-life. The radionuclide gamma spectra and intensities are taken from the SCALE 6.0 ORIGEN-S data libraries: *origen.rev02.mpdkxgam.dat* [Ref. 4]. This data file was reformatted into an excel file for use in the generic energy dependent response approach to compute radionuclide dose rates from a one Curie source for each radionuclide.

The ORIGEN-S radionuclide data library *origen.rev04.endfdec.data* [Ref. 5] was read to determine all radionuclides with greater than 1 day half-life for use in the generic approach to compute radionuclide specific gamma dose rates. The list of 281 radionuclides with greater than

1 day half-life is given in Table 5.5.1-1. The selection details and associated spectra data file are provided in the "ORIGEN-S: Data Libraries" [Ref. 4]. Due to the magnitude of the data, all gamma source terms cannot be provided in the SAR, but the gamma spectra for 1 Curie Co-60 is shown in Table 5.2.1-1. Co-60 is the dominant gamma emitter and dose rate contributor from resins and filter media.

Table 5.2.1-1 One Curie Co-60 Gamma Source Term

Photon Energy[1]	Intensity	1 Curie	
(MeV)	Photon/dis	Photon/s	MeV/s
1.17E+00	1.00E+00	3.70E+10	4.34E+10
1.33E+00	1.00E+00	3.70E+10	4.93E+10
	Total	7.40E+10	9.27E+10

Note 1: Only the prominent photon lines are considered for Co-60 in the individual analysis.

Beta Emitter/ Bremsstrahlung source

Another source of gamma radiation is from radionuclide beta emission Bremsstrahlung (braking radiation). Contributions from Bremsstrahlung gamma radiation have been evaluated by explicit mode e-p (electron-photon) transport calculation. The following radionuclides with beta $E_{max} > 2$ MeV were evaluated, as well as Cs-137, due to its typical high activity in resins and filters:

Y-90 $E_{max} = 2.281$ MeV
Sb-124 $E_{max} = 2.302$ MeV
Cs-137 $E_{max} = 1.175$ MeV
La-140 $E_{max} = 2.165$ MeV
Ce-144 $E_{max} = 2.996$ MeV

Binned radionuclide beta source spectra are compiled in Calculation Package RTL-001-CALC-SH-0101, Rev. 1 [Ref. 6]. As discussed in Section 5.4.4.3, an assessment of the contribution to exterior dose rates from Bremsstrahlung due to these fission product beta emitting radionuclides is evaluated for the RT-100 NCT configuration and found to contribute less than 1.0 percent of the total dose due to gamma radiation. Therefore, gamma radiation from Bremsstrahlung is not included in the determination of maximum allowed source strength densities.

5.2.2 Neutron Source

The RT-100 cask is not designed for shielding neutrons, thus neutron emitters in the contents are limited to trace amounts that may be present in the activated resin and filter media. For this packaging, any neutron source is limited to 3.5E-06 Ci/g, based on Class C burial limits.

5.3 Shielding Model

MCNP6 [Ref. 3] is used to perform the shielding evaluation of the RT-100. Two sets of MCNP6 shielding models are created for the evaluations of the RT-100 for NCT and HAC. In both cases, the model geometry was developed from the drawings provided in Appendix 1.4. For evaluation purposes, the thicknesses of shielding materials that comprise the package (steel shells, lead shielding, and lids) are reduced by subtracting the manufacturing tolerance from the nominal dimensions. Using minimum thicknesses of shielding materials in the model bounds any effect that a variation in thickness due to fabrication tolerances may have on external dose rates. A summary of the nominal and minimum shield thicknesses is given in Table 5.3-1. For the NCT

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rate responses. The shielding from the high integrity container (HIC) used to store and transfer resin into the RT-100 cavity is neglected in the shielding evaluations. The effects of resin and filter density changes and redistribution of the content media due to NCT and HAC are modeled by decreasing the volume occupied by the source term.

Table 5.3-1 Model Shielding Thicknesses

Component	Nominal (mm)	Model (mm)
Interior Barrel	30	29.7
Lead	90	85
Exterior Barrel	35	34.7
Bottom Forging	50	49.7
Bottom Lead	75	70
Bottom Wall	30	29.7
Primary Lid	210	209.5
Secondary Lid	170	169.5
Secondary Lid Lead	60	58

5.3.1 Configuration of Source and Shielding

The RT-100 is designed to transport resins and filters that are contaminated with radioactive material. Due to the physical form of these contents, the resins and filters are packaged within a secondary container placed in the cask cavity. Except for close fitting contents, the secondary container is positioned within the cavity using shoring. Additional details regarding physical form of the contents, including the secondary container and shoring, are provided in Chapter 1, Section 1.2.2.3. The volume of the radioactive source term within the RT-100, as modeled in the analyses that follow, does not take credit for the reduction in available volume associated with a secondary container or any shoring. As described below, the source term is assumed to uniformly fill the

entire cavity (i.e., fill-volume) and no credit is taken for radiation attenuation provided by a secondary container or shoring materials.

5.3.1.1 Source Term

The NCT and HAC shielding models consider the photon source uniformly distributed throughout the geometry cell representing the resin/filter media. With this approach the source strength density limit is based on the maximum specific activity evenly distributed throughout the entire cask cavity. In the actual operation of the cask, the contents will not be homogeneously distributed. However, the contents of a liner are characterized by the shipper prior to cask loading. The maximum specific activity determined in the characterization for a given nuclide is used in the loading table, and thus is considered as the source strength density throughout the entire contents. This ensures that while the source distribution will be inhomogeneous, the source strength density used in the loading tables to show compliance with regulatory limits will be bounding of the contents for that shipment.

5.3.1.2 NCT Model

For the shielding analysis, there is one NCT shielding model. In the NCT model, for the dose rate response calculation for all generic energies, the resin material filling the RT-100 cavity is considered as void, neglecting all photon attenuation in the resin and filter media of the contents. For the dose rate response calculation for the eight radionuclides that are considered individually, the RT-100 cask cavity is filled with carbon at 1 g/cm^3. This case takes credit for some photon attenuation in the resin material, but with the most restrictive condition. It is established in CN-13039-502 [Ref. 8] that Carbon at 1 g/cm^3, produces the most restrictive Ci/g limits for all radionuclides (also discussed in Section 5.3.2). The NCT models are shown in Figure 5.3.1-1.

The tally surfaces for dose rate response estimation in accordance with 10 CFR 71.47(b) [Ref. 2], are shown in Figure 5.3.1-2, where the 2 meter surface is the vertical plane projected from the outer side edge of an open (flat-bed) transport vehicle. The radial tally surfaces are segmented into 10 cm increments by planes perpendicular to the z axis. The maximum segment dose rate response is determined by post processing the MCNP6 output files.

5.3.1.3 HAC Model

The HAC configuration assumes the following damage from the 9 meter drop, 1 meter puncture drop, and fire:

1. Loss of impact limiters
2. One inch puncture depth in the lead
3. Lead slump

For the shielding analysis, two HAC shielding models are developed. Both HAC models include an annular void at the top from the postulated end drop and a 1 inch x 6 inch diameter indentation from the postulated pin puncture. The annular void is a 5 mm lead slump at the top of the lead column. This value is based on the lead slump calculation provided in Section 2.7.1.1.2. The two different HAC models differ in how the resin and filter material and source are modeled inside the cavity of each. As is the case with the NCT model, for the first HAC model, used for the dose rate response calculation for all generic energies, the RT-100 cavity is considered full, with the resin material considered as void for the generic energy dose calculations and as carbon at 1 g/cm³ for the individual radionuclides considered. This first HAC model is only used for the bottom 1 meter dose rate response calculations. For the second HAC model, used for the side and top 1 meter dose rate calculations, the resin material is compacted to the top of the RT-100 cavity providing a more restrictive source geometry for these cases. Once again, the resin material in the RT-100 cavity is considered void for the generic energy line dose rate response calculations and as carbon at 1 g/cm³ for the individual nuclide calculations. The location of the pin puncture is moved between the two models such that it remains at the axial midplane of the resin material. The HAC models are shown in Figure 5.3.1-3 and Figure 5.3.1-4.

The tally surfaces and for dose rate response estimation in accordance with 10 CFR 71.51(a)(2) [Ref. 2] are shown in Figure 5.3.1-5 and Figure 5.3.1-6, respectively. Note that the arrangement of tallies shown in these two figures is used for both HAC models. Figure 5.3.1-5 shows the general tally surfaces that are segmented with axial planes for the side and cylinders for the top and bottom tallies. A set spacing of 10 cm between axial planes and concentric cylinders is utilized in order to determine the maximum dose rate response as a function of elevation and radius, respectively. A comparison with 5 cm segmentation provided in Calculation Package RTL-001-CALC-SH-0201, Rev. 5 [Ref. 7] shows nearly identical results for the maximum dose rate response and location, particularly for the limiting NCT 2 meter dose rate response and the limiting HAC 1 meter response. Figure 5.3.1-5 shows a three-dimensional view of a RT-100 HAC model and the tally segments used to calculate the dose rate response 1 meter from the side surface at the lead slump and pin puncture locations. These tallies are formed by segmenting the 1 meter cylindrical tally surface. The lead slump segment is formed by two segmenting planes that are 1 cm apart, centered around the lead slump. The pin puncture segment is formed by a segmenting cylinder with a diameter equal to the pin puncture (6 inches) at the axial location of the puncture.

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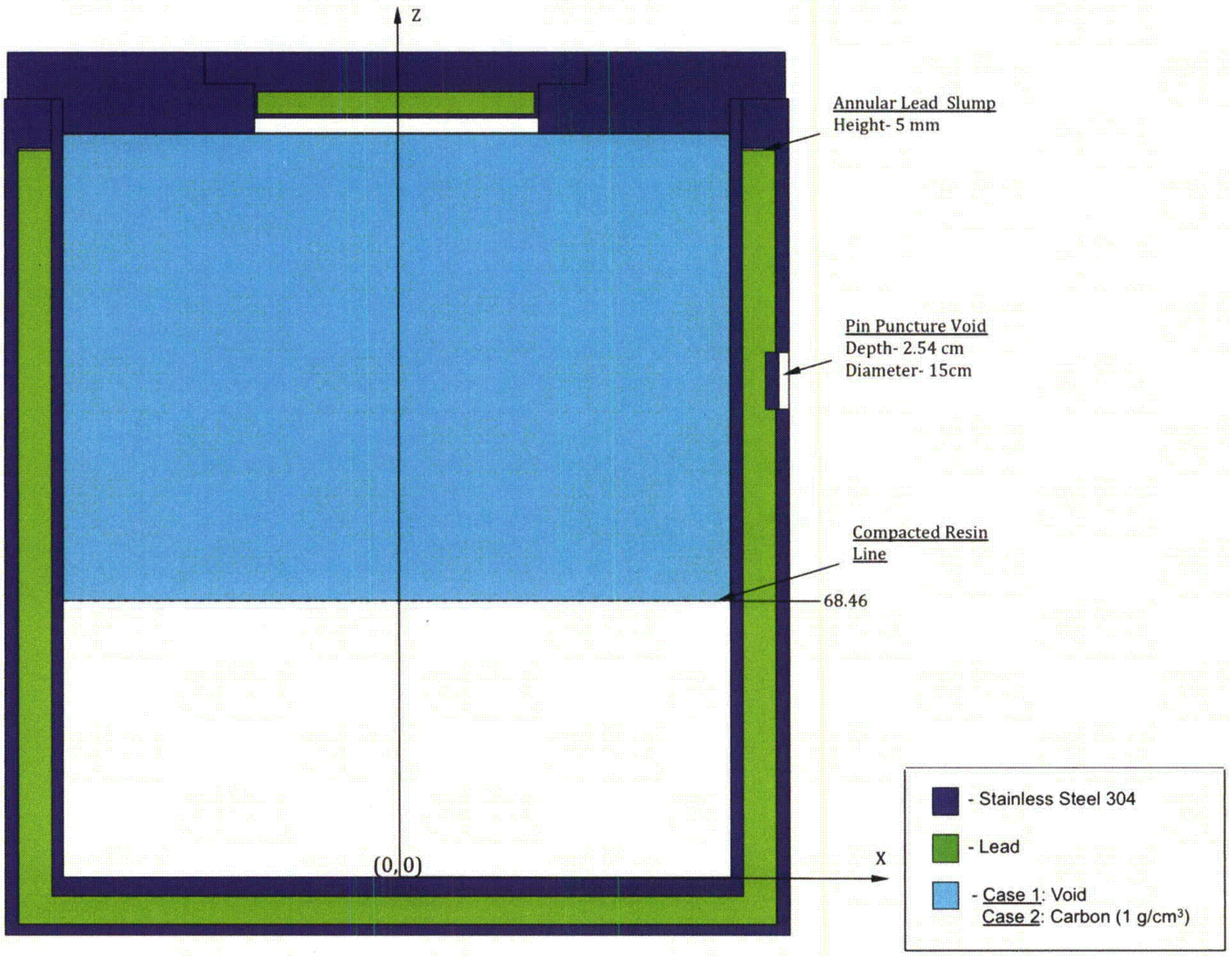

Figure 5.3.1-4 HAC Model 2

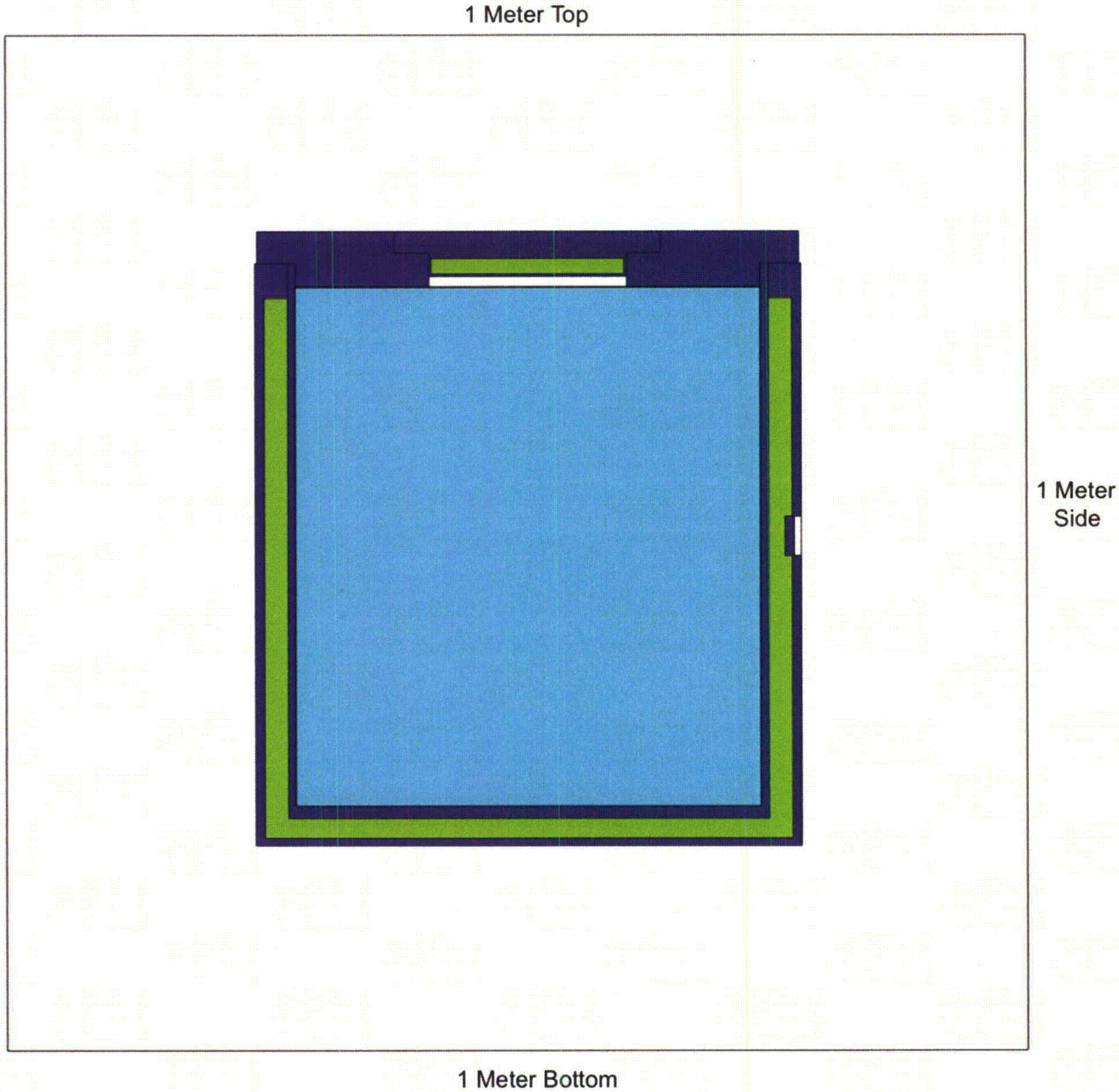

Figure 5.3.1-5 HAC Model General Tally Surfaces

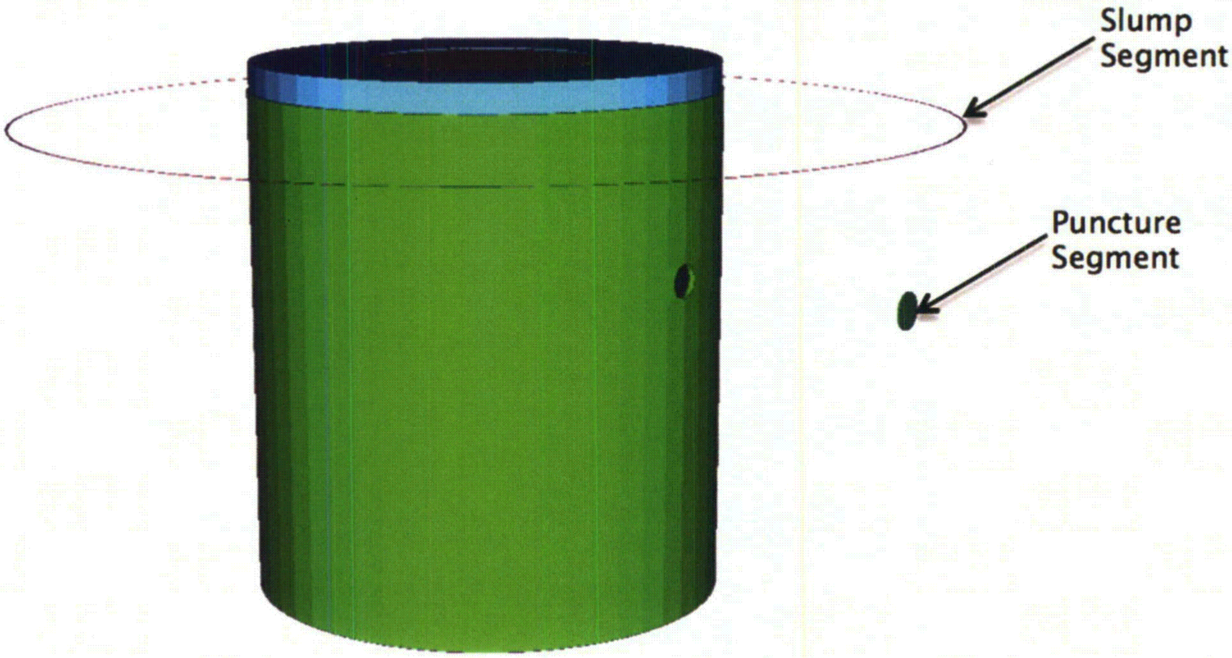

Figure 5.3.1-6 HAC Model Surface Tally

5.3.2 Material Properties

Materials used for the fabrication of the RT-100 are stainless steel and lead in the body, and for the fabrication of the impact limiters the materials used are polyurethane and stainless steel. The material properties used in the shielding evaluations are shown in Table 5.3.2-1. No changes in material properties are expected under Normal Conditions of Transport or Hypothetical Accident Conditions. Melting of the lead will not occur based on the thermal evaluation in Chapter 3. Also, the shielding properties of these materials will not degrade during the service life of the RT-100.

Contents transported in the RT-100 are resins and filter media. The following four materials, typical of resins and filter media, are considered as the cask contents:

- Polystyrene based resins such as Duralite
- Activated Charcoal
- Nylon filter media
- Zeolite - hydrated aluminosilicates such as Faujasite

In the case of nylon filter media, any steel cartridge structure is neglected and the cavity is assumed to be completely filled with nylon material at a reduced density. It is established in CN-13039-502 [Ref. 8] that carbon (activated charcoal) is the least effective shielding material between the four materials considered, and thus calculates the most restrictive specific activity (Ci/g) limits for all radionuclides, so in the shielding analysis the contents are modeled as carbon for both NCT and HAC.

The densities for resin and filter materials can vary quite a lot depending on the size of the particles, configuration of the filter media (i.e. tubes or fiber sheets) and the theoretical density of the material. The theoretical densities of polystyrene, carbon, Faujasite and nylon are 1.04, 2.2, 1.93 and 1.08 g/cm^3, respectively, but resin media bulk densities for all the typical material compositions can vary from 0.3 to 1.0 g/cm^3. It is established in CN-13039-502 [Ref. 8] that a contents density of 1 g/cm^3 calculates the most restrictive specific activity (Ci/g) limits for all radionuclides, so the shielding analysis uses this density for the modeled contents media for both NCT and HAC.

For all bottom dose rate response calculations, a 10% compaction of the resin is considered, and the results from the shielding analysis are adjusted to consider this variation, though the bottom dose rate locations are never the limiting case.

Table 5.3.2-1 RT-100 Material Composition Summary

Material	Density (g/cm^3)	Element	Nuclide ID	Weight Fraction
Stainless Steel 304 [Ref. 9]	7.94	Fe	26000	0.68375
		Ni	28000	0.09500
		Cr	24000	0.19000
		Mn	25055	0.02000
		Si	14000	0.01000
		C	6000	0.00080
		P	15000	0.00045
Lead [Ref. 9]	11.35	Pb	82000	1.0000

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Polystyrene [Ref. 10]	0.3 – 1.0	H	1001	0.0774
		C	6000	0.9226
Activated Carbon [Ref. 9]	0.3 – 1.0	C	6000	1.0000
Nylon [Ref. 10]	0.3 – 1.0	H	1001	0.0980
		C	6000	0.6369
		N	7014	0.1238
		O	8016	0.1414
Zeolite (Faujasite-Na) [Ref. 11]	0.3 – 1.0	O	8016	0.6067
		Si	14000	0.2263
		Al	13027	0.0895
		H	1001	0.0306
		Na	11023	0.0229
		Ca	20000	0.0199
		Mg	12000	0.0040

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5.4 Shielding Evaluation

Section 5.4 describes the shielding evaluation for the RT-100 using industry accepted methods.

5.4.1 Methods

5.4.1.1 MCNP6 Analysis

MCNP6 [Ref. 3] is used to perform the shielding evaluation of the RT-100. The ENDF/B-VI Release 8 Photo-atomic Data gamma cross section library, and MCPLIB84 [Ref. 12], are utilized in the transport computations.

MCNP6 is a Monte Carlo transport code that offers a full three-dimensional combinatorial geometry modeling capability. This type of modeling means that no gross approximations are required to represent the RT-100 Cask in the shielding analysis. However as stated in Section 5.3, bounding shielding material thicknesses are used in the MCNP6 models. The mesh based weight windows approach was utilized as the primary variance reduction technique in the shielding evaluation of the RT 100 and is further described in Section 5.4.1.4.

5.4.1.2 Dose Rate Response Calculation

The dose rate response calculations between the Generic Energy Line Method and those for the individual nuclides of interest differ slightly as described below.

<u>Generic Energy Line Calculation</u>

For the generic energy line outputs, the dose rate responses reported by each tally are binned by the emission energies, so a dose rate response is reported for each generic energy line separately. The MCNP6 calculated dose rate response (***R***) is calculated for the gamma flux at a distance (***r***) originating as source particles at a generic energy ($\boldsymbol{E_s}$). Interactions in the contents and packaging media result in particles at a continuous spectrum of energies ($\boldsymbol{E_i}$). The dose rate response from the flux $\boldsymbol{\Phi(r,E_i)}$ of particles is binned using MCNP6 special tally treatment, which bins the response based on the source energy ($\boldsymbol{E_s}$). The dose rate response (***R***) is obtained by multiplying the tally flux for each energy ($\boldsymbol{E_i}$) in the segment by the source emission rate (***S***), a flux-to-dose conversion factor for each energy $\mathcal{R}(\boldsymbol{E_i})$ and a source term normalization constant (***N***). The response function is defined by the flux-to-dose conversion factors provided in ANSI 6.1.1-1977 [Ref. 13], and the source emission rate (***S***) equivalent to 1 Curie (3.7E+10 disintegrations/second), such that the modified tally normalized per 1 Curie, and the source term normalization constant (***N***) is equal to the number of energy lines in the MCNP6 source term in the respective input,

$$R(r,E_s)\left[\frac{\frac{mrem}{hr}}{Ci}\cdot\frac{disintegration}{emitted\ photons}\right]$$

$$=\sum_i \Phi(r,E_i)\left[\frac{\frac{photons}{cm^2}}{emitted\ photon}\right]\cdot S\left[\frac{\frac{disintegration}{sec}}{Ci}\right]\cdot \mathcal{R}(E_i)\left[\frac{\frac{mrem}{hr}}{\frac{photons}{cm^2\cdot sec}}\right]\cdot N$$

For gamma emitting radionuclides, the dose rate responses (mrem/hr/Ci) are computed for each tally segment or detector at the following 26 discrete emission energies (***E_s***) in a range from 0.5 MeV to 8.0 MeV that are grouped into MCNP6 files as follows:

Low Energies (N=2)
0.5, 0.6

Middle Energies (N=4)
0.7, 0.8, 0.9, 1.0

High Energies (N=18)
1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0

Additional Energy Lines (N=2)
7.0, 8.0

The energy lines for any given radionuclide that are above 0.1 MeV are rounded up to the next generic energy line and summed to create a grouped spectrum for each radionuclide, where photon emission energies are binned by the generic energy lines. All energy lines below 0.1 MeV are considered insignificant and are neglected. An example of the energy grouping is shown for Fe-59 in Figure 5.4.1-1, as the 12 radionuclide specific energy lines are grouped into 4 generic energy bins (0.5, 1.1, 1.3, and 1.5 MeV).

ORIGEN-S Spectrum (Fe-59)	
E (MeV)	I(E)
7.91E-04	2.83E-06
6.92E-03	6.12E-05
6.93E-03	1.21E-04
7.65E-03	2.46E-05
1.43E-01	1.02E-02
1.89E-01	1.30E-04
1.92E-01	3.08E-02
3.35E-01	2.70E-03
3.82E-01	1.80E-04
1.10E+00	5.65E-01
1.29E+00	4.32E-01
1.48E+00	5.90E-04

Rounded Up Spectrum (Fe-59)	
E (MeV)	I(E)
0	2.83E-06
0	6.12E-05
0	1.21E-04
0	2.46E-05
0.5	1.02E-02
0.5	1.30E-04
0.5	3.08E-02
0.5	2.70E-03
0.5	1.80E-04
1.1	5.65E-01
1.3	4.32E-01
1.5	5.90E-04

Grouped Spectrum (Fe-59)	
E (MeV)	I(E)
0.5	4.40E-02
0.6	0
0.7	0
0.8	0
0.9	0
1	0
1.1	5.65E-01
1.2	0
1.3	4.32E-01
1.4	0
1.5	5.90E-04
1.6	0
1.7	0
1.8	0
1.9	0
2	0
2.5	0
3	0
3.5	0
4	0
4.5	0
5	0
5.5	0
6	0
7	0
8	0

Figure 5.4.1-1 Fe-59 Spectrum Grouped into Generic Energy Lines

The photon emission intensities $I_X(E_s)$ of the grouped energy spectrum for a given radionuclide ***X*** are used, along with the radionuclide branching ratio ***BR*** and the MCNP6 calculated responses, to calculate the contribution to the total dose rate from generic energy line Es for the respective nuclide ($D_X(r,E_s)$). Note that the only nuclides with dose rates calculated incorporating branching ratios are listed in Table 5.5.1-1, labeled with a 'br' in the 'Branch' column of the table. For nuclides with dose rates calculated using the Generic Energy Line this includes the long lived beta emitters Mo-99, Sr-90, and Ru-106 that have the short lived gamma emitting daughters Tc-99m (BR=0.88), Y-90 (BR=1.0), and Rh-106 (BR=1.0), respectively.

$$D_X(r,E_s)\left[\frac{\frac{mrem}{hr}}{Ci}\right] = BR_X \cdot I_X(E_s)\left[\frac{emitted\ photons}{disintegration}\right] \cdot R(r,E_s)\left[\frac{\frac{mrem}{hr}}{Ci} \cdot \frac{disintegration}{emitted\ photons}\right]$$

The uncertainty from the MCNP6 calculated response $\sigma_R(r,E)$ translates to an uncertainty in the dose rate contribution from the generic energy line $\sigma_{DX}(r,E)$ as:

$$\sigma_{D_X}(r,E_s)^2 = \left(BR_X \cdot I_X(E_s)\right)^2 \cdot \sigma_R(r,E_s)^2$$

The total dose rate, in mrem/hr/Ci, from nuclide ***X*** at regulatory dose rate location ***r*** can then be calculated by summing the contributions (plus 2 sigma) from each of the 26 generic energies:

$$D_X(r)\left[\frac{\frac{mrem}{hr}}{Ci}\right] = \sum_{s=1}^{26} D_X(r, E_s) + 2 \cdot \sqrt{\sum_{s=1}^{26} \sigma_{D_X}(r, E_s)^2}$$

Individual Radionuclides

For the 8 radionuclides that are calculated individually all nuclide specific energy lines above 0.1 MeV are included in the MCNP6 model source, so the calculated dose rate response at location ***r*** for radionuclide ***X*** is calculated as,

$$R_X(r)\left[\frac{\frac{mrem}{hr}}{Ci} \cdot \frac{disintegration}{emitted\ photons}\right] = \sum_i \Phi(r)\left[\frac{\frac{photons}{cm^2}}{emitted\ photon}\right] \cdot S\left[\frac{\frac{disintegration}{s}}{Ci}\right] \cdot \mathcal{R}(E_i)\left[\frac{\frac{mrem}{h}}{\frac{photons}{cm^2 \cdot sec}}\right]$$

With the dose rate from radionuclide ***X*** at dose rate location ***r*** determined, the total dose rate for the given nuclide is calculated by incorporating the MCNP6 calculated statistical uncertainty (plus 2 sigma), the total number of emitted photons per disintegration, and the branching ratio. Note that the only nuclide with dose rates calculated individually, that incorporates a branching ratio is the long lived beta emitters Cs-137 that has the short lived gamma emitting daughter Ba-137m (BR=0.95).

$$D_X(r)\left[\frac{\frac{mrem}{hr}}{Ci}\right] = \left(R_X(r) + 2 \cdot \sigma_{R_X}(r)\right)\left[\frac{\frac{mrem}{hr}}{Ci} \cdot \frac{disintegration}{emitted\ photons}\right] \cdot \sum_{s=1}^{n} I_X(E_s)\left[\frac{emitted\ photons}{disintegration}\right] \cdot BR_X$$

Beta Emitter Dose Rate Contribution

NCT beta/Bremsstrahlung dose rate responses are computed on a radionuclide basis for a set of limiting radionuclides as defined in RTL-001-CALC-SH-0101, Rev. 1 [Ref. 6]. Based on major beta emitting radionuclides (E_{max}>2MeV) ORIGEN-S: Data Libraries [Ref. 4], shielding calculations provided in Calculation Package RTL-001-CALC-SH-0201 [Ref. 7] show negligible Bremsstrahlung contribution to exterior dose rate for the current resin/filter contents to be shipped in the RT-100.

5.4.1.3 Maximum allowed source strength density

The radionuclide-specific activity limit $A_X(r)$ is calculated as,

$$A_X(r)[Ci] = \frac{\dot{D}(r)\left[\frac{mrem}{hr}\right]}{D_X(r)\left[\frac{mrem/hr}{Ci}\right]}$$

Where, the regulatory dose rate limit for a given location $\dot{D}(r)$ that is specified in 10 CFR 71 is reduced by 5% to account for uncertainty representing the actual packaging and characterization of the contents.

More specifically, the regulatory NCT limit for the package surface is reduced from 200 mrem/hr to 190 mrem/hr, the limit at 2 meters from the transport vehicle is reduced from 10 mrem/hr to 9.5 mrem/hr, and the cab limit is reduced from 2 mrem/hr to 1.9 mrem/hr. Similarly, the HAC limit at 1 meter is reduced from 1000 mrem/hr to 950 mrem/hr.

For example, the activity limit of Co-60 for NCT as a function of the dose rate limit at 2 meters is calculated as,

$$A_{Co60}(2m) = \frac{9.5}{D_{Co60}(2m)}$$

The radionuclide-specific maximum allowable source strength density a_X is calculated by dividing the minimum activity limit from all regulatory dose rate locations of the given nuclide by the maximum resin and filter mass m allowed in the RT-100 packaging (at 1 g/cm³ m=4597809.127 g).

$$a_X\left[\frac{Ci}{g}\right] = \frac{A_X(r)_{min}[Ci]}{m[g]}$$

For example, because the minimum activity limit calculated for Co-60 is based on the 2 meter dose rate location, the maximum allowable source strength density is calculated as,

$$a_{Co60} = \frac{A_{Co60}(2m)}{4597809.127}$$

For a mixture of radionuclides, the source strength density for each radionuclide (Ci/g) is divided by the source strength density limit from the shielding evaluations, and the results summed for all radionuclides must be less than 100% to be acceptable for shipment. Further details of the

loading table construction are given in Section 7.6.1.

5.4.1.4 Variance Reduction

The primary variance reduction technique used is the mesh based weight windows approach. The cards used in the MCNP6 input file to implement the weight windows include: WWG and MESH for generating mesh based weight window files, and WWP for calling in the generated weight window mesh file. Pages 3-43 through 3-50 of the MCNP6 manual provide additional details on weight window card development [Ref. 3].

A cylindrical spatial mesh is superimposed over the geometry with the MESH card. This mesh defines a cylindrical grid of cells independent of the MCNP6 geometry that extends slightly beyond the boundaries of the model geometry. Multiple iterations are performed in order to generate an effective importance map. The term iteration in this case means that a run has been performed and a mesh importance map is generated and then the mesh importance map is used in a subsequent MCNP6 run on the same model. The importance map generated in the previous run is fed back into the model and run again with the intent of generating a new importance map with the old map improving the performance and results of the subsequent run. The weight windows estimated by the MCNP6 WWG card are subject to statistical fluctuations, thus some manual refining of the generated weight window mesh may be necessary.

Once a reasonable weight window mesh is obtained through this iterative process, production runs are executed with sufficient histories, such that the statistical errors for most tallies meet the 0.10 fractional standard deviation (fsd) criterion, and all statistical tests are passed for every tally in every MCNP6 output. Using an effective set of weight windows is the key to achieving statistical convergence for all tallies in a reasonable runtime.

5.4.2 Input and Output Data

All relevant inputs and outputs for the gamma shielding analysis are provided with calculation package CN-13039-502. Post processing of the energy dependent responses into detailed dose rate responses (mrem/hr/Ci) is performed for all radionuclides and is shown in Tables 5.5.2-1 and 5.5.2-2. Using these responses and the content activity loading, the total dose rate in mrem/hr can be computed for NCT and HAC conditions. This is demonstrated in Section 5.4.4.5 for the maximum source strength density of Co-60. A guide is provided in Appendix 5.5.4 that relates the process steps to the input and output files used for the shielding evaluation.

5.4.3 Flux-to-Dose Rate Conversion

MCNP6 [Ref. 3] calculates a photon flux (particles/s-cm^2) at a particular tally or detector location given the source magnitude. These values are converted into dose by use of flux-to-dose response functions. This conversion is done internally in MCNP6 [Ref. 3] by

associating dose response functions to each tally in the input file. Gamma flux-to-dose response functions used in these calculations are listed in Table 5.4.3-1.

Table 5.4.3-1 ANSI/ANS 6.1.1-1977 – Gamma Flux-to-Dose Conversion Factors

Gamma Energy (MeV)	(rem/hr)/ (photon/cm^2-s)
0.01	3.96E-06
0.03	5.82E-07
0.05	2.90E-07
0.07	2.58E-07
0.10	2.83E-07
0.15	3.79E-07
0.20	5.01E-07
0.25	6.31E-07
0.30	7.59E-07
0.35	8.78E-07
0.40	9.85E-07
0.45	1.08E-06
0.50	1.17E-06
0.55	1.27E-06
0.60	1.36E-06
0.65	1.44E-06
0.70	1.52E-06
0.80	1.68E-06
1.00	1.98E-06
1.40	2.51E-06
1.80	2.99E-06
2.20	3.42E-06
2.60	3.82E-06
2.80	4.01E-06
3.25	4.41E-06
3.75	4.83E-06
4.25	5.23E-06
4.75	5.60E-06
5.00	5.80E-06
5.25	6.01E-06
5.75	6.37E-06
6.25	6.74E-06
6.75	7.11E-06
7.50	7.66E-06
9.00	8.77E-06
11.0	1.03E-05
13.0	1.18E-05
15.0	1.33E-05

5.4.4 External Radiation Levels

The maximum external radiation levels are determined by the quantity of each radionuclide in the resin and filter media that is to be shipped. This limiting quantity of each radionuclide is determined by the respective source strength density limit of each. For the radionuclides considered, the source strength density is always limited by either the NCT 2 meter or the HAC side 1 meter regulatory limits. Thus, the maximum dose rate that can be measured at any regulatory location can only be equal to the regulatory limit at the NCT 2 meter or the HAC side 1 meter locations. For example, for radionuclides whose source strength density is limited by the NCT 2 meter location, the maximum dose rate at 2 meters from the edge of the vehicle is 9.5 mrem/hr and the dose rate at all other regulatory locations will be some amount less than the regulatory limit for that location because the source strength density is based on the NCT 2 meter location. Likewise, for radionuclides whose source strength density is limited by the HAC side 1 meter location, the maximum dose rate at 1 meter from the package surface is 950 mrem/hr and the dose rate at all other regulatory locations will be some amount less than the regulatory limit at that location.

Table 5.5.2-1 and Table 5.5.2-2 give the complete list of gamma radionuclide responses. Using these responses and the respective source strength density limits in Table 5.5.3-1, the total dose rate in mrem/hr at each regulatory location can be computed for any radionuclide as described in Section 5.4.4.5. The maximum dose rates under NCT and HAC from each radionuclide individually are shown in Table 5.4.4-5 and Table 5.4.4-6. Table 5.4.4-1 provides a summary of the maximum calculated dose rate at each regulatory location, and the radionuclide responsible for each maximum dose rate. Combining contributions from multiple radionuclides, as is done in the loading table, can only result in a dose rate at each regulatory location that is equal to or less than the maximum values reported below in Table 5.4.4-1.

Table 5.4.4-1 Maximum Dose Rates and Responsible Radionuclides

Normal Conditions of Transport	Package Surface (mrem/hr)			2 Meters from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
Source	Side	Bottom	Top	Side	Cab
Gamma	113.2 Pm-144	47.2 Cs-144	86.7 Pm-144	9.50 MULTIPLE	1.21 MULTIPLE

Hypothetical Accident Conditions	1 Meter from Package Surface (mrem/hr)		
Source	Side	Bottom	Top
Gamma	950.0 MULTIPLE	115.93 Mn-54	235.7 Mn-54

5.4.4.1 MCNP6 Statistics Evaluation

5.4.4.1.1 Tally Statistics Diagnostics

MCNP6 produces information about a simulation to allow the user to assess the precision (not the accuracy) of the result. MCNP6 provides 10 statistical tests performed on the tally for assessing the reliability of results. If any of the 10 tests are not met, they are recorded as "NO". MCNP6 automatically produces additional output to aid the user in interpreting the cause of the failed tests. The 10 tests are summarized as,

Tally Mean, x

1. The mean must exhibit, for the last half of the problem, only random fluctuations as N increases. No up or down trends must be exhibited.

Relative Error, R

2. R must be less than 0.1 (0.05 for point/ring detectors).
3. R must decrease monotonically with N for the last half of the problem.
4. R must decrease as $1/\sqrt{N}$ for the last half of the problem.

Variance of the Variance, VOV:

5. The magnitude of the VOV must be less than 0.1 for all types of tallies.
6. VOV must decrease monotonically for the last half of the problem.
7. VOV must decrease as 1/N for the last half of the problem.

Figure of Merit, FOM:

8. FOM must remain statistically constant for the last half of the problem.
9. FOM must exhibit no monotonic up or down trends in the last half of the problem.

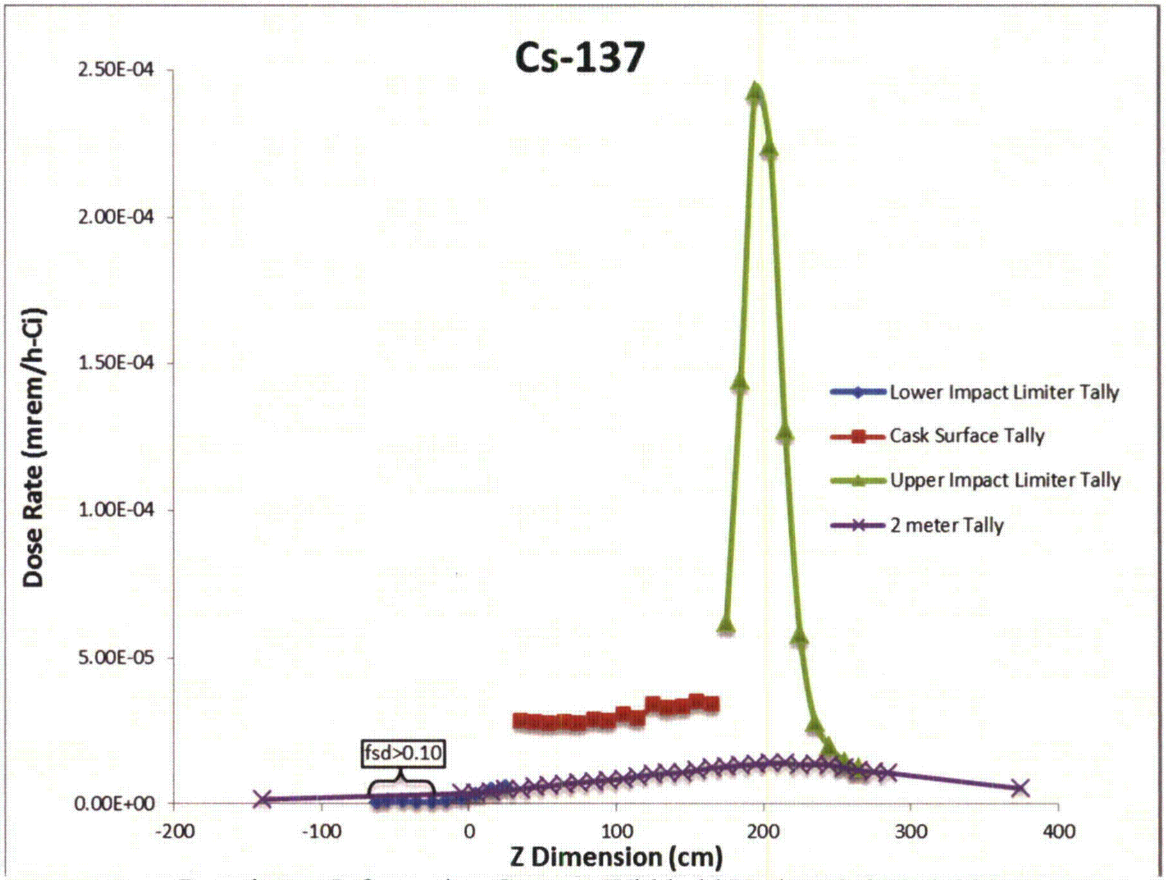
Tally PDF, f(x)

10. The SLOPE determined from the 201 largest scoring events must be greater than 3.

The MCNP Manual states that "A tally is considered to be converged with high confidence only when it passes all ten statistical checks" [Ref. 3]. Every tally in all MCNP6 outputs in the shielding analysis passes all 10 statistical tests, indicating that the reported results are reliable.

5.4.4.1.2 Fractional Standard Deviation of Individual Tally Segments

Of all tally bins included in the 72 MCNP outputs for the gamma shielding analysis, there are a total of 17 bins with reported fractional standard deviations larger than the MCNP6 requirement for reliable results (fsd<0.10). These tally segment bins with a fractional standard deviation greater than 0.1 are far from the maximum segment, with a calculated dose rate that is orders of magnitude less than the value reported at the maximum segment. This is shown for Cs-137 in Figure 5.4.1-1, where it can be noted that the tally segments that don't meet the fsd requirement are on the bottom impact limiter, with reported dose rates that are multiple orders of magnitude less than the segments at the axial location of the streaming peak. All maximum dose rate segments have an fsd of 0.05 or less, most being significantly lower.



Proprietary Information Content Withheld Under 10 CFR 2.390

Figure 5.4.4-1 Fluctuation in Radial Dose Rates (Cs-137)

5.4.4.2 Media Composition and Density

The effect of the media composition is addressed in calculation RTL-001-CALC-SH-0201 Section 7.7.2 *"Content Density and Material Variation"* [Ref. 7]. The MCNP calculations for the final dose rate response functions of the 8 radionuclides considered individually are performed using carbon at a density of 1.00 g/cm^3 as the material composition and density. Parametric studies were performed to evaluate the effect of other media compositions (polystyrene, nylon, and zeolite) and media densities in the range from 0.65 to 1.0 g/cm^3 on the dose rate response. The maximum allowable source strength density (Ci/g) decreases slightly with increasing material density and carbon material composition results in the most limiting source strength density. The final dose rate responses used to calculate the maximum source strength densities are calculated modeling the resin media as carbon at 1 g/cm^3, instead of adjusting the calculated dose rate responses for polystyrene at 0.65 g/cm^3 using correction factors as originally discussed in Section 7.7.2 of the calculation RTL-001-CALC-SH-0201 [Ref. 7].

5.4.4.2.1 Effect of Media Composition

The effect of media composition was evaluated by calculating the dose rate response for the generic energies using the typical resin and filter material compositions at a fixed material density, 0.65 g/cc. The ratio $\Re_X(r,\chi)$ between the dose rate calculated for each media composition χ and the base case (polystyrene) is determined for each radionuclide X at each regulatory dose rate limit location r. A comparison of the average of the calculated ratios is presented in Table 5.4.4-2, where it is shown that modeling activated carbon as the attenuating media results in the highest calculated dose rates.

$$\Re_X(r,\chi) = \frac{D_X(r,\chi)\left[\frac{mrem/hr}{Ci}\right]}{D_X(r,\chi = Polystyrene)\left[\frac{mrem/hr}{Ci}\right]}$$

$$\Re(\chi) = avg\{\Re_X(r,\chi)\}$$

Table 5.4.4-2 Media Composition Comparison

χ	$\Re(\chi)$		
	Side	**Bottom**	**Top**
Polystyrene	1.00	1.00	1.00
Activated Carbon	1.07	1.10	1.09
Nylon	0.98	1.02	1.05
Zeolite [10]	1.04	1.03	1.06

5.4.4.2.2 Effect of Media Density

The effect of media density was evaluated by calculating the specific activity limit a_X for the generic energies using the material compositions for a range of material densities for one material composition, polystyrene. The ratio $\Re_X(r,\rho)$ between the specific activity limit calculated for each density ρ and the base case (0.65 g/cm³) is determined for each radionuclide X at each regulatory dose rate limit location r. A comparison of the maximum calculated ratios is presented in Table 5.4.4-3, where it shown that modeling the content media at 1 g/cm³ results in the most restrictive calculated specific activity limits.

$$\Re_X(r,\rho) = \frac{a_X(r,\rho)[{}^{Ci}/_{g}]}{a_X(r,\rho = 1.00)[{}^{Ci}/_{g}]}$$

$$\Re(\rho) = max\{\Re_X(r,\rho)\}$$

Table 5.4.4-3 Media Density Comparison

ρ [g/cm³]	$\Re(\rho)$
0.65	1.053
0.75	1.041
0.85	1.035
1.00	1.000

5.4.4.3 Shielding Evaluation Uncertainty

Accurate results from the shielding analysis of transport casks are important to ensure that loading limits yield doses that do not exceed the regulatory limits for external radiation levels. Content loading limits (i.e. specific source strength densities) for the RT-100 are determined using regulatory dose rate limits. These regulatory limits are reduced by 5 percent to account for any uncertainty in representing the packaging and the characterization of the contents. The uncertainties and margins are summarized in Figure 5.4.4-2.

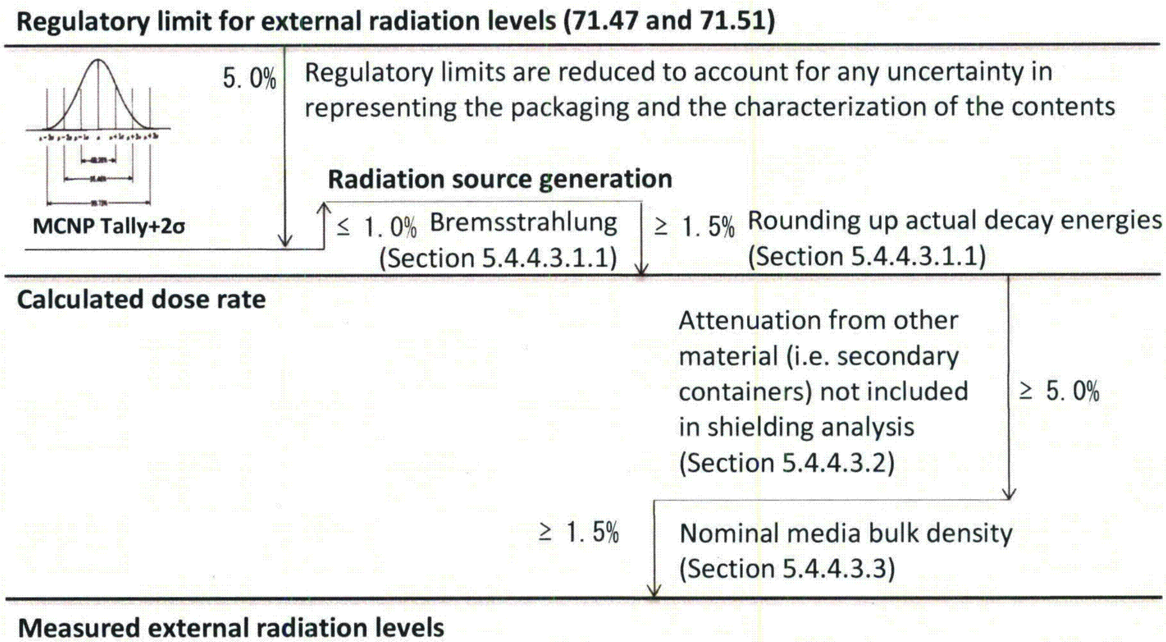


Figure 5.4.4-2 Summary of Calculated Dose Rate Margins

5.4.4.3.1 Calculation of Dose Rates

Uncertainty in calculated dose rates arises from three major analysis areas: radiation source generation, use of cross-section data, and the radiation transport codes used to evaluate doses.

5.4.4.3.1.1 Radiation Source Generation

Generation of the source specification is discussed in detail in Section 5.2.

<u>Bremsstrahlung</u>

The dose rate from Bremsstrahlung is not included, as this source term accounts for less than 1% of the regulatory dose rate limit, and there is no significant uncertainty associated with the radiation source definition for gammas.

An evaluation of the contribution of Beta/Bremsstrahlung radiation to external dose rates was performed in the calculation report RTL-001-CALC-SH-0201. The NCT results for this analysis

are presented for Y-90, Sb-124, Cs-137, La-140 and Ce-144 in Table 5.4.4-4. Based on this assessment, the contribution of Beta/Bremsstrahlung to exterior doses on the RT-100 can be neglected as long as the beta activity is well below 60,000 Curies (the Curie content of Ce-144 that would produce 1% of the chosen dose rate limit for two meters, or 0.095 mrem/hr). The 3000 A_2 limit precludes the shipment of sufficient Curies of the beta/bremsstrahlung emitting isotopes to exceed the 1% of the total dose rate limit at two meters, and the bremsstrahlung gamma response functions are therefore omitted from the loading tables.

Table 5.4.4-4 NCT Dose Rate Responses Due to Bremsstrahlung

Maximum Response + 2σ (mrem/hr/Ci) for Side Dose Locations					
Radionuclide	Top Surface	Side Surface	Bottom Surface	2 Meter	Cab
Y-90	2.80E-06	6.00E-06	3.78E-06	6.60E-07	1.88E-07
SB-124	2.00E-06	1.43E-06	4.49E-07	1.59E-07	4.38E-08
CS-137	0.00E+00	3.37E-11	0.00E+00	1.45E-11	5.89E-12
LA-140	6.13E-08	4.46E-07	3.94E-07	3.88E-08	1.25E-08
CE-144	4.76E-06	1.23E-05	1.80E-05	1.95E-06	5.49E-07
CE-144-void	1.16E-04	2.75E-04	2.43E-04	3.64E-05	1.04E-05
CE-144-4	1.16E-05	2.37E-05	1.25E-05	3.12E-06	8.18E-07

Rounding up actual decay energies

The use of a generic energy spectrum method as described in Section 5.4.1 overestimates the dose rate from specific radionuclides. Rounding up the gamma energies of the specific radionuclides to the nearest generic energy line may result in a 1.5% to 40% increase in dose rates depending on the radionuclide.

5.4.4.3.1.2 Cross Section Data

The use of continuous pointwise energy cross section data libraries in MCNP6 eliminates any uncertainty due to the choice of energy-collapsing spectrum and parent fine-group data.

5.4.4.3.1.3 Radiation Transport Codes

The use of MCNP6 to calculate the dose rate responses is discussed in detail in Section 5.4.1.2. The mean tally value plus two standard deviations as calculated by MCNP6 is used to calculate the limiting dose rate responses. Adding two standard deviations to the calculated average value means that there is at least a 95% confidence that the calculated dose rate response will be less than the limiting dose rate response.

5.4.4.3.2 Attenuation from other material (i.e. secondary containers) not included in shielding analysis

The secondary container is fabricated using approximately 1.27 cm thickness polyethylene. The half-value layer (HVL) for polyethylene for 1 MeV for gammas is approximately 15 cm. The

secondary container provides a reduction in external dose levels of approximately 6%.

5.4.4.3.3 Nominal Media Bulk Density

The bulk density of dewatered resins is typically less than 1 g/cm^3. Compliance with the regulatory dose rate limits is demonstrated using the limiting source strength density values for a bulk density of 1 g/cm^3. When the maximum allowed source strength density (i.e. the value at 1 g/cm^3) is used to estimate the expected dose rate for media densities less than 1 g/cm^3, the calculated dose rate is greater than the estimated dose rate using the source strength density (Ci/g) for 1 g/cm^3, and the actual media density (g/cm^3) and associated dose rate response (mrem/hr/Ci). An example of this conservatism is shown in Figure 5.4.4-3.

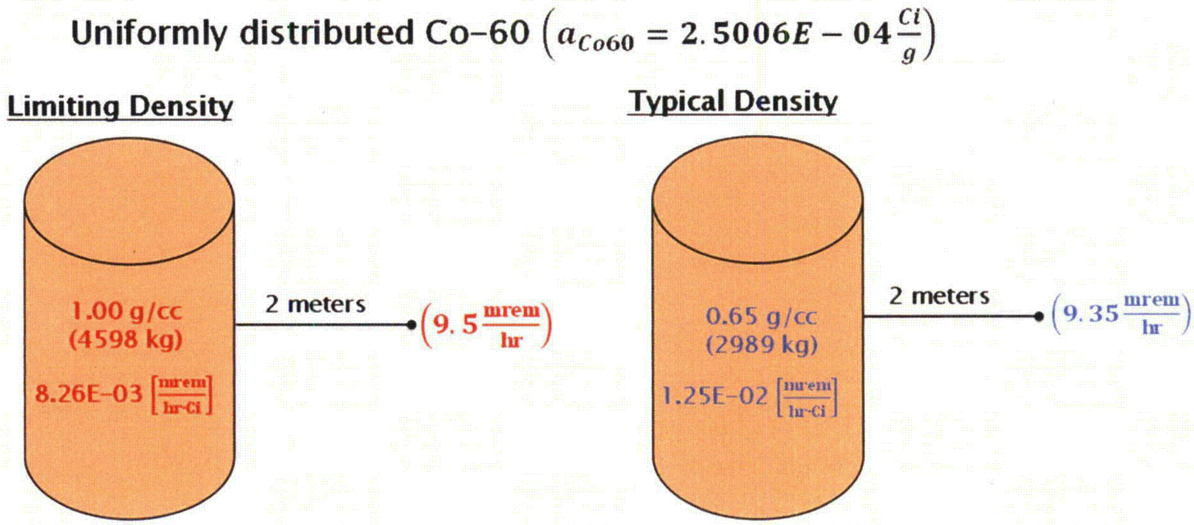


Figure 5.4.4-3 Example of Media Density Effect

5.4.4.4 Loading Table

Ultimately, a loading table specifying the maximum Curies per gram of each radionuclide is developed. The maximum Curies per gram are defined as the minimum specific activity at which the regulatory dose rate limit for either NCT or HAC is met. For conservatism 5% lower than the regulatory limits is assumed, thus the NCT limit at the package surface is taken as 190 mrem/hr, at 2 meters from the transport vehicle as 9.5 mrem/hr and the cab limit is taken as 1.9 mrem/hr. Similarly, the HAC limit at 1 meter is evaluated at 950 mrem/hr.

For NCT, the maximum source strength density (Ci/g) is computed as the minimum of the following:

$$a_X(Package\ Surface)\left[\frac{Ci}{g}\right] = \frac{190\left[\frac{mrem}{hr}\right]}{D_X(Package\ surface)\left[\frac{mrem/hr}{Ci}\right]\cdot m\left(1.00\ {}^{g}/_{cm^3}\right)[g]}$$

$$a_X(2\ meter)\left[\frac{Ci}{g}\right] = \frac{9.5\left[\frac{mrem}{hr}\right]}{D_X(2\ meter)\left[\frac{mrem/hr}{Ci}\right]\cdot m\left(1.00\ {}^{g}/_{cm^3}\right)[g]}$$

$$a_X(Cab)\left[\frac{Ci}{g}\right] = \frac{1.9\left[\frac{mrem}{hr}\right]}{D_X(Cab)\left[\frac{mrem/hr}{Ci}\right]\cdot m\left(1.00\ {}^{g}/_{cm^3}\right)[g]}$$

For HAC, the maximum source strength density (Ci/g) is computed as the minimum of the following:

$$a_X(1\ meter)\left[\frac{Ci}{g}\right] = \frac{950\left[\frac{mrem}{hr}\right]}{D_X(1\ meter)\left[\frac{mrem/hr}{Ci}\right]\cdot m\left(1.00\ {}^{g}/_{cm^3}\right)[g]}$$

Whichever condition is more limiting, either NCT or HAC determines the maximum Curies per gram of a particular radionuclide ***X***. Section 5.5, Appendix 5.5.3 gives the complete list of the maximum allowable source strength density (Ci/g) limits for each of the gamma emitting radionuclides and for each of the predominant neutron emitting radionuclides. These limits are based on resin or filter material at a density of 1.0 g/cm^3 filling the entire cavity of the RT-100 (4597809 total grams).

In the loading table, the actual source strength density for each radionuclide is divided by the maximum allowable source strength density from the shielding evaluations, and the results summed for all radionuclides must be less than 1.0 to be acceptable for shipment.

5.4.4.5 Dose Rates for Maximum Radionuclide Loading

External radiation levels at a given dose rate location $\mathcal{D}_X(r)$ are computed for the maximum radionuclide loadings in the RT-100 by using the calculated nuclide-specific dose rate per Curie responses $D_X(r)$ along with the source strength density limit set for the respective radionuclide a_X to demonstrate the dose rates produced for a given content isotopic loading as follows:

$$\mathcal{D}_X(r)\left[\frac{mrem}{hr}\right] = a_X\left[\frac{Ci}{g}\right]\cdot D_X(r)\left[\frac{mrem/hr}{Ci}\right]\cdot m\,[g]$$

An example of the maximum does rates and their corresponding measurement locations are

shown in Figure 5.4.4-4 for Co-60 (assuming the maximum mass of 4597809 grams).

Dose rates for other radionuclides with a greater than one (1) day half-life can also be computed in the same manner using radionuclide gamma dose rate per Ci responses in Table 5.5.2-1 for NCT and Table 5.5.2-2 for HAC, and the source strength densities in Table 5.5.3-1. The estimated dose rates due to the maximum allowed loading of each radionuclide considered individually is shown in Table 5.4.4-5 and Table 5.4.4-6. Any mixture of radionuclides can be evaluated with a characterization of the actual source strength density (Ci/g) of each radionuclide, using the loading table.

The RT-100 loading table procedure as outlined in Chapter 7, Section 7.6.1 provides the guidance on the acceptability of a mixture of radionuclides in resin and filter material based on the maximum Ci/g for each radionuclide in the mixture. This loading table procedure, based on sum of the fractions of contributions, determines whether the radionuclide mixture meets or exceeds 10 CFR 71.47(b) or 10 CFR 71.51(a) (2) [*both* Ref. 2] radiation limits. In addition, the loading table determines whether the combined A_2 and mixture heat load meets or exceeds licensed limits.

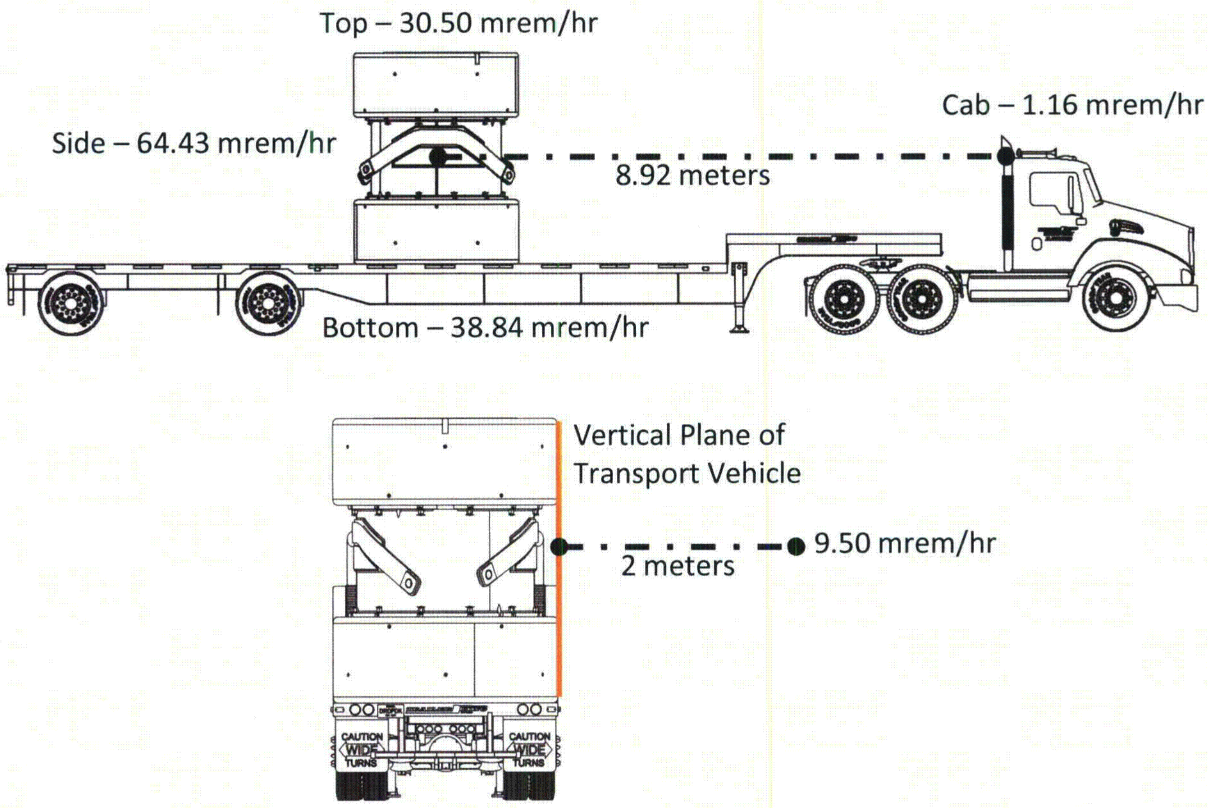


Figure 5.4.4-4 NCT Maximum Gamma Dose Rates for Co-60 Content at 1.00 g/cc

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
na24	3.38E-06	65.9	46.7	33.6	9.5	1.2
bi208	3.76E-06	65.9	47.1	34.2	9.5	1.2
cs144	5.27E-06	65.2	47.2	35.1	9.5	1.2
y88	1.02E-05	67.0	44.3	29.1	9.5	1.2
la140	1.63E-05	66.5	43.5	29.6	9.5	1.2
sb124	2.19E-05	66.9	43.5	29.9	9.5	1.2
eu156	2.26E-05	65.8	45.1	30.9	9.5	1.2
sc48	2.67E-05	66.2	43.4	30.8	9.5	1.2
la138	3.87E-05	67.0	42.7	29.6	9.5	1.2
tb156	4.10E-05	67.1	43.7	30.4	9.5	1.2
ag106m	4.45E-05	67.2	43.3	30.9	9.5	1.2
lu169	4.55E-05	66.5	43.6	30.1	9.5	1.2
na22	5.38E-05	68.3	43.9	31.7	9.5	1.2
sb120m	5.51E-05	66.6	43.9	33.4	9.5	1.2
i124	5.54E-05	66.9	44.0	30.5	9.5	1.2
br82	5.93E-05	67.4	43.0	31.5	9.5	1.2
lu172	6.68E-05	66.4	44.2	32.9	9.5	1.2
ta182	6.93E-05	67.3	43.6	31.5	9.5	1.2
ca47	7.23E-05	67.8	44.0	31.5	9.5	1.2
sc46	7.66E-05	66.3	43.6	33.9	9.5	1.2
te131m	7.96E-05	66.7	44.6	32.4	9.5	1.2
eu152	8.35E-05	67.0	43.1	31.0	9.5	1.2
as72	8.49E-05	66.1	46.0	35.0	9.5	1.2
tm172	9.32E-05	66.7	42.9	29.1	9.5	1.2
eu154	9.69E-05	67.5	44.0	32.5	9.5	1.2
cs136	1.09E-04	66.5	44.9	36.3	9.5	1.2
pm148	1.10E-04	66.9	42.8	29.9	9.5	1.2
ge69	1.25E-04	66.8	43.5	31.4	9.5	1.2
tb160	1.56E-04	66.4	44.0	34.3	9.5	1.2
sn125	1.82E-04	65.7	45.5	32.3	9.5	1.2
rh102m	1.88E-04	69.2	43.7	36.8	9.5	1.2
gd147	1.93E-04	67.4	43.8	33.9	9.5	1.2
tc96	2.23E-04	66.4	45.2	46.3	9.5	1.2
sr83	2.25E-04	67.4	43.8	31.9	9.5	1.2
k40	2.42E-04	66.9	42.7	29.3	9.5	1.2
co60	2.50E-04	64.4	38.8	30.5	9.5	1.2
as76	2.84E-04	67.2	44.6	31.5	9.5	1.2
nb92	3.41E-04	66.3	45.6	42.5	9.5	1.2
np238	3.49E-04	65.7	45.6	38.4	9.5	1.2
am240	4.09E-04	64.7	46.1	43.0	9.5	1.2
tb158	4.32E-04	65.4	45.5	40.2	9.5	1.2
pm148m	4.79E-04	74.0	43.8	46.2	9.5	1.2
ag110m	4.84E-04	64.5	38.7	30.6	9.5	1.2
ho166m	5.45E-04	69.8	44.7	49.8	9.5	1.2
pa232	5.96E-04	65.0	46.0	44.8	9.5	1.2
sb126	6.14E-04	83.0	42.1	56.4	9.5	1.2

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
nb94	6.40E-04	68.4	46.6	60.1	9.5	1.2
rb84	6.41E-04	66.0	45.2	42.9	9.5	1.2
tm168	6.65E-04	67.8	45.2	49.0	9.5	1.2
pr144	6.75E-04	65.7	45.5	31.1	9.5	1.2
fe59	7.11E-04	64.5	39.0	31.7	9.5	1.2
rh99	7.83E-04	69.1	42.7	32.1	9.5	1.2
tm165	8.21E-04	68.0	43.0	34.4	9.5	1.2
zr89	1.18E-03	69.6	42.5	30.4	9.5	1.2
rh102	1.23E-03	69.8	42.5	33.5	9.5	1.2
as71	1.37E-03	72.7	42.5	37.6	9.5	1.2
ru106	1.57E-03	69.1	43.9	34.2	9.5	1.2
tc95m	1.59E-03	69.2	44.8	51.4	9.5	1.2
rb86	1.82E-03	66.3	45.4	36.7	9.5	1.2
tc98	1.97E-03	99.9	42.0	86.1	9.5	1.2
ag108m	2.12E-03	102.2	40.9	86.4	9.5	1.2
ho166	2.17E-03	66.5	42.8	28.5	9.5	1.2
ir194m	2.25E-03	109.2	34.4	71.0	9.5	1.2
zn65	2.34E-03	64.3	39.2	35.1	9.5	1.2
cs132	2.34E-03	87.1	39.7	51.4	9.5	1.2
lu171	2.56E-03	80.4	44.7	65.0	9.5	1.2
nb95	2.59E-03	87.3	45.3	79.1	9.5	1.3
zr95	2.62E-03	87.3	45.3	79.1	9.5	1.3
tb153	2.83E-03	70.3	43.5	41.2	9.5	1.2
te121m	3.15E-03	71.1	41.9	34.3	9.5	1.2
ag105	3.32E-03	76.6	42.6	45.3	9.5	1.2
sb127	3.61E-03	89.3	40.5	60.3	9.5	1.2
sb122	3.62E-03	80.2	40.0	41.3	9.5	1.2
pm144	3.14E-03	113.2	25.8	86.7	7.8	1.0
cd115m	4.17E-03	67.0	44.4	33.7	9.5	1.2
kr79	4.27E-03	74.5	41.2	38.7	9.5	1.2
pm146	4.35E-03	92.1	43.4	80.2	9.5	1.3
gd149	4.88E-03	83.2	41.9	59.0	9.5	1.2
i126	5.10E-03	88.0	39.3	53.7	9.5	1.2
cs134	6.03E-03	62.4	37.2	44.7	9.5	1.2
os185	6.57E-03	64.9	46.8	56.3	9.5	1.2
cu64	6.61E-03	77.3	39.5	37.1	9.5	1.2
pm143	6.71E-03	87.3	45.3	79.1	9.5	1.3
co58	6.96E-03	64.3	37.8	43.3	9.5	1.2
as74	7.27E-03	106.9	32.1	61.5	9.5	1.1
ba131	7.28E-03	82.8	39.8	46.8	9.5	1.2
br77	9.13E-03	86.3	39.3	55.7	9.5	1.2
ce143	9.23E-03	82.9	40.8	53.2	9.5	1.2
pm151	1.27E-02	95.0	38.8	70.3	9.5	1.2
mn54	1.65E-02	79.8	38.6	73.6	9.5	1.3
y91	1.80E-02	67.8	44.0	31.3	9.5	1.2
sb125	1.29E-02	96.2	17.8	69.8	6.2	0.8

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
sr85	1.15E-02	85.0	4.8	54.9	4.5	0.5
rb83	1.23E-02	86.8	6.6	57.0	4.8	0.6
te121	1.15E-02	84.6	4.7	54.6	4.5	0.5
sn123	2.46E-02	66.3	45.4	36.7	9.5	1.2
i131	1.71E-02	72.2	10.5	46.8	4.6	0.5
ag110	3.68E-02	81.2	41.4	46.1	9.5	1.2
cm241	1.16E-02	55.4	1.3	29.6	2.8	0.3
lu176	1.12E-02	52.6	0.2	26.9	2.6	0.3
au198	2.01E-02	66.5	10.1	35.3	4.6	0.5
se75	1.14E-02	52.7	0.3	27.0	2.6	0.3
y87	1.16E-02	52.8	0.3	27.0	2.6	0.3
rh101	1.30E-02	52.6	0.2	26.9	2.6	0.3
in114m	4.87E-02	106.1	37.7	84.3	9.5	1.2
hf181	1.36E-02	53.0	0.4	27.3	2.6	0.3
ru103	1.83E-02	63.4	4.3	37.3	3.5	0.4
cs129	2.97E-02	71.4	13.0	40.2	5.2	0.6
xe127	1.73E-02	52.7	0.3	27.0	2.6	0.3
bi210m	2.20E-02	61.0	3.5	35.1	3.3	0.4
ru97	2.01E-02	54.7	1.5	29.0	2.9	0.3
yb169	1.97E-02	52.6	0.3	26.9	2.6	0.3
co57	1.99E-02	52.9	0.4	27.2	2.6	0.3
ta183	2.04E-02	52.6	0.2	26.9	2.6	0.3
np239	2.04E-02	52.6	0.2	26.9	2.6	0.3
ba133	2.04E-02	52.6	0.2	26.9	2.6	0.3
zr88	2.05E-02	52.6	0.2	26.9	2.6	0.3
zn72	2.06E-02	52.6	0.2	26.9	2.6	0.3
rh101m	2.23E-02	55.4	0.6	29.3	2.8	0.3
cd115	3.40E-02	79.4	4.0	50.0	4.2	0.5
pt191	3.21E-02	71.7	4.6	43.7	3.9	0.4
te132	2.17E-02	52.6	0.2	26.9	2.6	0.3
cf249	2.18E-02	52.7	0.3	27.0	2.6	0.3
ba140	3.43E-02	76.6	3.5	47.6	4.0	0.4
hf182	2.22E-02	52.6	0.2	26.9	2.6	0.3
tc99m	2.24E-02	52.6	0.2	26.9	2.6	0.3
sn117m	2.25E-02	52.6	0.2	26.9	2.6	0.3
te129m	8.36E-02	94.3	40.6	70.6	9.5	1.2
hf175	2.30E-02	52.6	0.2	26.9	2.6	0.3
u235	2.32E-02	52.6	0.3	26.9	2.6	0.3
te123m	2.37E-02	52.6	0.2	26.9	2.6	0.3
hg203	2.45E-02	52.6	0.2	26.9	2.6	0.3
cm247	2.45E-02	52.6	0.2	26.9	2.6	0.3
cf251	2.48E-02	52.6	0.2	26.9	2.6	0.3
ce139	2.50E-02	52.6	0.2	26.9	2.6	0.3
pu246	2.54E-02	52.6	0.2	26.9	2.6	0.3
mo99	9.03E-03	100.0	38.4	76.0	9.5	1.2
ar37	4.49E-02	70.4	7.1	43.9	4.1	0.5

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
sc47	2.93E-02	52.6	0.2	26.9	2.6	0.3
in113m	3.11E-02	52.6	0.2	26.9	2.6	0.3
u237	3.13E-02	52.6	0.2	26.9	2.6	0.3
cm243	3.16E-02	52.6	0.2	26.9	2.6	0.3
pa233	3.22E-02	52.6	0.2	26.9	2.6	0.3
ga67	4.31E-02	57.0	4.3	31.2	3.4	0.4
tb155	3.46E-02	53.0	0.3	27.3	2.6	0.3
er172	3.72E-02	53.1	0.4	27.4	2.6	0.3
nd147	6.37E-02	82.2	5.6	52.9	4.5	0.5
lu177m	3.73E-02	52.6	0.2	26.9	2.6	0.3
cm245	3.76E-02	52.6	0.2	26.9	2.6	0.3
np236	3.88E-02	52.6	0.2	26.9	2.6	0.3
cs137	7.95E-02	94.2	9.4	65.9	5.3	0.6
cu67	4.00E-02	52.6	0.2	26.9	2.6	0.3
au199	4.09E-02	52.6	0.2	26.9	2.6	0.3
ce141	4.14E-02	52.6	0.2	26.9	2.6	0.3
tm167	4.47E-02	54.7	0.5	28.7	2.7	0.3
th227	5.64E-02	53.3	0.8	27.5	2.7	0.3
ra223	5.77E-02	53.4	0.5	27.6	2.6	0.3
pu237	6.27E-02	52.6	0.2	26.9	2.6	0.3
sm153	6.61E-02	53.1	0.3	27.3	2.6	0.3
sn126	6.59E-02	52.6	0.2	26.9	2.6	0.3
os191	6.88E-02	52.6	0.2	26.9	2.6	0.3
nb95m	7.52E-02	53.0	0.5	27.3	2.6	0.3
rh105	8.17E-02	52.6	0.2	26.9	2.6	0.3
os193	1.08E-01	61.0	3.1	34.4	3.3	0.4
re189	9.10E-02	55.6	0.6	29.5	2.8	0.3
pm149	3.21E-01	83.1	39.9	61.4	9.5	1.2
eu155	9.11E-02	52.6	0.2	26.9	2.6	0.3
gd153	9.29E-02	52.6	0.2	26.9	2.6	0.3
th229	9.61E-02	52.6	0.2	26.9	2.6	0.3
lu177	1.12E-01	52.6	0.2	26.9	2.6	0.3
hf172	1.20E-01	52.6	0.2	26.9	2.6	0.3
ba135m	1.28E-01	52.6	0.2	26.9	2.6	0.3
eu149	1.91E-01	58.6	1.0	32.0	2.9	0.3
yb175	1.69E-01	52.6	0.2	26.9	2.6	0.3
ce144	1.80E-01	52.6	0.2	26.9	2.6	0.3
be7	1.93E-01	52.6	0.2	26.9	2.6	0.3
re186	2.10E-01	54.4	1.4	28.8	2.8	0.3
cr51	1.98E-01	52.6	0.2	26.9	2.6	0.3
xe133m	1.99E-01	52.6	0.2	26.9	2.6	0.3
pa231	2.09E-01	52.7	0.3	27.0	2.6	0.3
ag111	2.47E-01	54.7	1.8	29.0	2.9	0.3
ir192	2.36E-01	52.9	0.5	27.3	2.6	0.3
xe129m	4.35E-01	52.6	0.2	26.9	2.6	0.3
ra224	4.99E-01	52.9	0.3	27.2	2.6	0.3

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
ac225	5.06E-01	52.9	0.3	27.2	2.6	0.3
kr81	5.11E-01	52.6	0.2	26.9	2.6	0.3
ra226	5.69E-01	52.7	0.3	27.0	2.6	0.3
np237	5.86E-01	52.6	0.2	26.9	2.6	0.3
as77	7.12E-01	61.5	1.4	34.5	3.1	0.3
pt195m	6.57E-01	52.6	0.2	26.9	2.6	0.3
ni59	3.30E+00	78.1	43.3	58.6	9.5	1.2
xe131m	1.02E+00	52.6	0.2	26.9	2.6	0.3
sn113	1.09E+00	52.7	0.3	27.0	2.6	0.3
kr85	2.62E+00	84.9	4.7	54.8	4.5	0.5
th231	1.60E+00	52.6	0.2	26.9	2.6	0.3
dy166	1.70E+00	52.6	0.2	26.9	2.6	0.3
nb91	3.47E+00	84.9	4.7	54.8	4.5	0.5
am243	2.81E+00	53.0	0.4	27.3	2.6	0.3
w188	3.13E+00	52.6	0.2	26.9	2.6	0.3
th228	3.85E+00	52.7	0.3	27.0	2.6	0.3
tb161	4.57E+00	58.6	1.0	32.0	2.9	0.3
es254	4.48E+00	52.6	0.2	26.9	2.6	0.3
u230	6.10E+00	52.7	0.3	27.0	2.6	0.3
la137	1.73E+01	106.0	21.8	79.6	7.1	0.9
te125m	7.07E+00	52.6	0.2	26.9	2.6	0.3
th234	7.08E+00	52.6	0.2	26.9	2.6	0.3
rn222	1.50E+01	84.9	4.7	54.8	4.5	0.5
am242m	1.20E+01	52.6	0.2	26.9	2.6	0.3
te127m	3.73E+01	101.1	18.7	74.2	6.5	0.8
es253	1.90E+01	55.8	2.5	29.0	3.1	0.3
w181	1.72E+01	52.6	0.2	26.9	2.6	0.3
pt193m	1.78E+01	52.6	0.2	26.9	2.6	0.3
po210	7.99E+01	62.2	47.0	53.8	9.5	1.2
u233	2.67E+01	55.1	2.0	28.2	3.0	0.3
u232	2.54E+01	52.7	0.3	27.0	2.6	0.3
xe133	2.72E+01	52.6	0.2	26.9	2.6	0.3
th230	2.84E+01	52.6	0.3	26.9	2.6	0.3
am241	6.02E+01	59.3	4.2	33.7	3.3	0.4
ac227	4.82E+01	52.6	0.2	26.9	2.6	0.3
u234	5.50E+01	52.7	0.3	27.0	2.6	0.3
pd103	6.91E+01	52.6	0.2	26.9	2.6	0.3
th232	7.27E+01	52.6	0.2	26.9	2.6	0.3
cd113m	8.69E+01	52.6	0.2	26.9	2.6	0.3
sr90	3.64E+02	65.5	45.8	31.2	9.5	1.2
u236	9.99E+01	52.6	0.2	26.9	2.6	0.3
v49	1.07E+02	53.8	0.4	27.9	2.7	0.3
pu239	1.14E+02	54.1	1.1	28.4	2.8	0.3
w185	1.07E+02	52.6	0.2	26.9	2.6	0.3
pu236	1.44E+02	57.2	1.7	31.2	2.9	0.3
cf252	1.34E+02	52.6	0.2	26.9	2.6	0.3

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
cm242	4.05E+02	79.1	18.2	46.2	6.3	0.7
u238	1.86E+02	52.6	0.2	26.9	2.6	0.3
cl36	3.35E+02	84.9	4.7	54.8	4.5	0.5
cm244	8.69E+02	88.5	38.3	64.5	9.5	1.2
pu240	2.60E+02	53.1	0.5	27.4	2.6	0.3
ca41	4.10E+02	52.6	0.2	26.9	2.6	0.3
pu238	1.62E+03	89.9	29.4	59.0	8.1	1.0
sm145	5.73E+02	52.6	0.2	26.9	2.6	0.3
pu242	6.96E+02	52.6	0.2	26.9	2.6	0.3
pm147	7.00E+02	52.6	0.2	26.9	2.6	0.3
er169	1.53E+03	52.6	0.2	26.9	2.6	0.3
fe55	1.63E+03	52.6	0.2	26.9	2.6	0.3
pu241	3.67E+03	52.6	0.2	26.9	2.6	0.3
bi210	1.96E+04	52.6	0.2	26.9	2.6	0.3
bk249	5.28E+04	52.6	0.2	26.9	2.6	0.3
pr143	2.15E+05	87.3	45.3	79.1	9.5	1.3
tc97	5.81E+05	52.6	0.2	26.9	2.6	0.3
ca45	5.83E+05	52.6	0.2	26.9	2.6	0.3
ge71	5.83E+05	52.6	0.2	26.9	2.6	0.3
nb93m	5.83E+05	52.6	0.2	26.9	2.6	0.3
mo93	5.83E+05	52.6	0.2	26.9	2.6	0.3
tc97m	5.83E+05	52.6	0.2	26.9	2.6	0.3
cd109	5.83E+05	52.6	0.2	26.9	2.6	0.3
sn113m	5.83E+05	52.6	0.2	26.9	2.6	0.3
sn119m	5.83E+05	52.6	0.2	26.9	2.6	0.3
sn121m	5.83E+05	52.6	0.2	26.9	2.6	0.3
te123	5.83E+05	52.6	0.2	26.9	2.6	0.3
i125	5.83E+05	52.6	0.2	26.9	2.6	0.3
i129	5.83E+05	52.6	0.2	26.9	2.6	0.3
cs131	5.83E+05	52.6	0.2	26.9	2.6	0.3
pm145	5.83E+05	52.6	0.2	26.9	2.6	0.3
sm151	5.83E+05	52.6	0.2	26.9	2.6	0.3
tb157	5.83E+05	52.6	0.2	26.9	2.6	0.3
dy159	5.83E+05	52.6	0.2	26.9	2.6	0.3
tm170	5.83E+05	52.6	0.2	26.9	2.6	0.3
tm171	5.83E+05	52.6	0.2	26.9	2.6	0.3
os194	5.83E+05	52.6	0.2	26.9	2.6	0.3
pt193	5.83E+05	52.6	0.2	26.9	2.6	0.3
tl204	5.83E+05	52.6	0.2	26.9	2.6	0.3
pb205	5.83E+05	52.6	0.2	26.9	2.6	0.3
pb210	5.83E+05	52.6	0.2	26.9	2.6	0.3
ra225	5.83E+05	52.6	0.2	26.9	2.6	0.3
ra228	5.83E+05	52.6	0.2	26.9	2.6	0.3
np235	5.83E+05	52.6	0.2	26.9	2.6	0.3
cm246	5.83E+05	52.6	0.2	26.9	2.6	0.3
cm248	5.83E+05	52.6	0.2	26.9	2.6	0.3

Table 5.4.4-5 NCT Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	Package Surface (mrem/hr)			2 Meter from Edge of Vehicle (mrem/hr)	Vehicle Occupied Position (mrem/hr)
X	a_X	Side	Bottom	Top	Side	Cab
cf250	5.83E+05	52.6	0.2	26.9	2.6	0.3
se72	5.83E+05	52.6	0.2	26.9	2.6	0.3
as73	5.83E+05	52.6	0.2	26.9	2.6	0.3
te118	5.83E+05	52.6	0.2	26.9	2.6	0.3
sb119	5.83E+05	52.6	0.2	26.9	2.6	0.3
nd140	5.83E+05	52.6	0.2	26.9	2.6	0.3
yb166	5.83E+05	52.6	0.2	26.9	2.6	0.3
h3	5.83E+05	52.6	0.2	26.9	2.6	0.3
ni63	5.83E+05	52.6	0.2	26.9	2.6	0.3
sr89	5.83E+05	52.6	0.2	26.9	2.6	0.3
tc99	5.83E+05	52.6	0.2	26.9	2.6	0.3
am242	5.83E+05	52.6	0.2	26.9	2.6	0.3
c14	5.83E+05	52.6	0.2	26.9	2.6	0.3

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
na24	3.38E-06	34.7	53.9	53.0
bi208	3.76E-06	33.4	53.7	53.1
cs144	5.27E-06	34.5	53.2	55.0
y88	1.02E-05	39.6	54.7	48.3
la140	1.63E-05	42.1	53.8	49.5
sb124	2.19E-05	42.4	54.5	48.3
eu156	2.26E-05	39.2	53.7	50.5
sc48	2.67E-05	60.2	58.7	58.9
la138	3.87E-05	48.2	57.0	51.4
tb156	4.10E-05	53.0	56.9	53.4
ag106m	4.45E-05	63.2	56.2	55.8
lu169	4.55E-05	48.4	56.0	52.3
na22	5.38E-05	62.5	59.8	57.2
sb120m	5.51E-05	76.6	60.8	64.9
i124	5.54E-05	45.6	54.0	49.9
br82	5.93E-05	71.3	57.8	59.0
lu172	6.68E-05	69.0	59.2	60.6
ta182	6.93E-05	62.0	59.4	58.7
ca47	7.23E-05	56.1	60.1	56.6
sc46	7.66E-05	82.3	60.2	67.2
te131m	7.96E-05	61.5	56.0	57.3
eu152	8.35E-05	60.6	58.2	56.3
as72	8.49E-05	63.9	54.5	59.4
tm172	9.32E-05	45.6	55.9	50.2
eu154	9.69E-05	68.0	60.0	60.0
cs136	1.09E-04	93.7	63.3	71.1
pm148	1.10E-04	51.2	57.2	52.5
ge69	1.25E-04	65.2	57.1	58.4
tb160	1.56E-04	86.0	61.1	68.3
sn125	1.82E-04	48.3	55.2	54.8
rh102m	1.88E-04	121.6	61.1	74.0
gd147	1.93E-04	93.3	59.0	65.5
tc96	2.23E-04	185.0	66.3	101.6
sr83	2.25E-04	69.2	55.0	56.2
k40	2.42E-04	46.0	56.9	50.7
co60	2.50E-04	70.0	97.6	81.7
as76	2.84E-04	54.5	54.9	53.4
nb92	3.41E-04	159.4	67.6	94.4
np238	3.49E-04	102.6	65.8	77.8
am240	4.09E-04	152.4	68.5	95.5
tb158	4.32E-04	128.3	66.4	87.1
pm148m	4.79E-04	229.9	64.0	98.9
ag110m	4.84E-04	84.9	93.4	80.5
ho166m	5.45E-04	250.0	66.0	110.6
pa232	5.96E-04	173.8	68.6	100.2
sb126	6.14E-04	372.3	62.5	127.2

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
nb94	6.40E-04	304.1	72.3	140.0
rb84	6.41E-04	167.5	63.1	90.3
tm168	6.65E-04	231.9	67.1	108.8
pr144	6.75E-04	36.0	52.6	49.7
fe59	7.11E-04	82.1	100.4	88.5
rh99	7.83E-04	100.7	55.2	58.5
tm165	8.21E-04	118.2	58.9	68.0
zr89	1.18E-03	80.2	53.6	53.0
rh102	1.23E-03	123.5	56.3	64.9
as71	1.37E-03	194.4	58.7	75.4
ru106	1.57E-03	96.4	55.1	61.7
tc95m	1.59E-03	281.8	67.1	115.2
rb86	1.82E-03	88.0	64.7	70.9
tc98	1.97E-03	663.3	68.0	208.2
ag108m	2.12E-03	733.4	66.3	209.9
ho166	2.17E-03	44.3	55.6	50.5
ir194m	2.25E-03	855.9	52.2	168.6
zn65	2.34E-03	104.8	103.1	102.3
cs132	2.34E-03	359.9	55.3	112.9
lu171	2.56E-03	390.4	68.8	151.2
nb95	2.59E-03	526.8	72.8	190.2
zr95	2.62E-03	526.8	72.8	190.2
tb153	2.83E-03	220.5	62.5	88.5
te121m	3.15E-03	186.3	57.2	69.7
ag105	3.32E-03	311.8	61.6	96.4
sb127	3.61E-03	469.1	60.1	138.4
sb122	3.62E-03	277.3	54.9	86.2
pm144	3.14E-03	950.0	43.6	213.8
cd115m	4.17E-03	73.8	61.8	64.6
kr79	4.27E-03	228.3	56.6	81.3
pm146	4.35E-03	644.9	69.8	194.6
gd149	4.88E-03	524.1	64.0	139.7
i126	5.10E-03	428.5	55.8	118.3
cs134	6.03E-03	263.9	104.3	138.8
os185	6.57E-03	266.8	72.1	130.4
cu64	6.61E-03	238.9	52.8	77.0
pm143	6.71E-03	526.8	72.8	190.2
co58	6.96E-03	218.0	100.1	128.3
as74	7.27E-03	747.3	43.2	141.1
ba131	7.28E-03	529.7	57.6	104.4
br77	9.13E-03	538.8	58.1	127.3
ce143	9.23E-03	458.4	59.6	121.5
pm151	1.27E-02	814.1	60.7	171.7
mn54	1.65E-02	483.9	115.9	235.7
y91	1.80E-02	54.9	60.0	56.3
sb125	1.29E-02	950.0	30.4	175.2

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
sr85	1.15E-02	950.0	8.6	140.9
rb83	1.23E-02	950.0	11.5	145.8
te121	1.15E-02	950.0	8.4	140.3
sn123	2.46E-02	87.8	64.6	70.8
i131	1.71E-02	950.0	17.6	121.7
ag110	3.68E-02	268.4	54.5	94.6
cm241	1.16E-02	950.0	2.6	82.0
lu176	1.12E-02	950.0	0.9	75.7
au198	2.01E-02	950.0	15.0	92.1
se75	1.14E-02	950.0	0.9	75.7
y87	1.16E-02	950.0	0.9	76.0
rh101	1.30E-02	950.0	0.9	75.7
in114m	4.87E-02	945.3	60.9	208.4
hf181	1.36E-02	950.0	1.1	76.5
ru103	1.83E-02	950.0	7.8	99.8
cs129	2.97E-02	950.0	20.0	104.8
xe127	1.73E-02	950.0	0.9	75.8
bi210m	2.20E-02	950.0	6.3	94.6
ru97	2.01E-02	950.0	2.9	80.4
yb169	1.97E-02	950.0	0.9	75.7
co57	1.99E-02	950.0	1.1	76.4
ta183	2.04E-02	950.0	0.9	75.7
np239	2.04E-02	950.0	0.9	75.7
ba133	2.04E-02	950.0	0.9	75.7
zr88	2.05E-02	950.0	0.9	75.7
zn72	2.06E-02	950.0	0.9	75.7
rh101m	2.23E-02	950.0	1.5	81.3
cd115	3.40E-02	950.0	7.2	129.6
pt191	3.21E-02	950.0	8.1	114.7
te132	2.17E-02	950.0	0.9	75.7
cf249	2.18E-02	950.0	1.0	75.9
ba140	3.43E-02	950.0	6.5	124.0
hf182	2.22E-02	950.0	0.9	75.7
tc99m	2.24E-02	950.0	0.9	75.7
sn117m	2.25E-02	950.0	0.9	75.7
te129m	8.36E-02	540.0	62.5	165.0
hf175	2.30E-02	950.0	0.9	75.7
u235	2.32E-02	950.0	0.9	75.7
te123m	2.37E-02	950.0	0.9	75.7
hg203	2.45E-02	950.0	0.9	75.7
cm247	2.45E-02	950.0	0.9	75.7
cf251	2.48E-02	950.0	0.9	75.7
ce139	2.50E-02	950.0	0.9	75.7
pu246	2.54E-02	950.0	0.9	75.7
mo99	9.03E-03	885.2	60.8	186.6
ar37	4.49E-02	950.0	12.2	115.2

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
sc47	2.93E-02	950.0	0.9	75.7
in113m	3.11E-02	950.0	0.9	75.7
u237	3.13E-02	950.0	0.9	75.7
cm243	3.16E-02	950.0	0.9	75.7
pa233	3.22E-02	950.0	0.9	75.7
ga67	4.31E-02	950.0	7.1	85.3
tb155	3.46E-02	950.0	1.1	76.5
er172	3.72E-02	950.0	1.1	76.7
nd147	6.37E-02	950.0	9.9	136.4
lu177m	3.73E-02	950.0	0.9	75.7
cm245	3.76E-02	950.0	0.9	75.7
np236	3.88E-02	950.0	0.9	75.7
cs137	7.95E-02	950.0	31.3	214.4
cu67	4.00E-02	950.0	0.9	75.7
au199	4.09E-02	950.0	0.9	75.7
ce141	4.14E-02	950.0	0.9	75.7
tm167	4.47E-02	950.0	1.4	79.9
th227	5.64E-02	950.0	1.7	76.9
ra223	5.77E-02	950.0	1.3	77.3
pu237	6.27E-02	950.0	0.9	75.7
sm153	6.61E-02	950.0	1.1	76.7
sn126	6.59E-02	950.0	0.9	75.7
os191	6.88E-02	950.0	0.9	75.7
nb95m	7.52E-02	950.0	1.3	76.7
rh105	8.17E-02	950.0	0.9	75.7
os193	1.08E-01	950.0	5.4	93.0
re189	9.10E-02	950.0	1.6	81.7
pm149	3.21E-01	716.4	61.5	149.1
eu155	9.11E-02	950.0	0.9	75.7
gd153	9.29E-02	950.0	0.9	75.7
th229	9.61E-02	950.0	0.9	75.7
lu177	1.12E-01	950.0	0.9	75.7
hf172	1.20E-01	950.0	0.9	75.7
ba135m	1.28E-01	950.0	0.9	75.7
eu149	1.91E-01	950.0	2.3	87.7
yb175	1.69E-01	950.0	0.9	75.7
ce144	1.80E-01	950.0	0.9	75.7
be7	1.93E-01	950.0	0.9	75.7
re186	2.10E-01	950.0	2.8	80.0
cr51	1.98E-01	950.0	0.9	75.7
xe133m	1.99E-01	950.0	0.9	75.7
pa231	2.09E-01	950.0	0.9	75.8
ag111	2.47E-01	950.0	3.3	80.3
ir192	2.36E-01	950.0	1.3	76.4
xe129m	4.35E-01	950.0	0.9	75.7
ra224	4.99E-01	950.0	1.1	76.3

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
ac225	5.06E-01	950.0	1.0	76.3
kr81	5.11E-01	950.0	0.9	75.7
ra226	5.69E-01	950.0	0.9	75.8
np237	5.86E-01	950.0	0.9	75.7
as77	7.12E-01	950.0	2.9	93.5
pt195m	6.57E-01	950.0	0.9	75.7
ni59	3.30E+00	408.4	66.1	136.6
xe131m	1.02E+00	950.0	0.9	75.7
sn113	1.09E+00	950.0	1.0	75.9
kr85	2.62E+00	950.0	8.5	140.8
th231	1.60E+00	950.0	0.9	75.7
dy166	1.70E+00	950.0	0.9	75.7
nb91	3.47E+00	950.0	8.5	140.8
am243	2.81E+00	950.0	1.2	76.6
w188	3.13E+00	950.0	0.9	75.7
th228	3.85E+00	950.0	1.0	75.8
tb161	4.57E+00	950.0	2.3	87.7
es254	4.48E+00	950.0	0.9	75.7
u230	6.10E+00	950.0	0.9	75.8
la137	1.73E+01	950.0	37.2	197.8
te125m	7.07E+00	950.0	0.9	75.7
th234	7.08E+00	950.0	0.9	75.7
rn222	1.50E+01	950.0	8.5	140.8
am242m	1.20E+01	950.0	0.9	75.7
te127m	3.73E+01	950.0	32.0	185.3
es253	1.90E+01	950.0	4.2	80.2
w181	1.72E+01	950.0	0.9	75.7
pt193m	1.78E+01	950.0	0.9	75.7
po210	7.99E+01	237.9	72.2	124.1
u233	2.67E+01	950.0	3.4	78.1
u232	2.54E+01	950.0	1.0	75.8
xe133	2.72E+01	950.0	0.9	75.7
th230	2.84E+01	950.0	0.9	75.7
am241	6.02E+01	950.0	7.3	91.3
ac227	4.82E+01	950.0	0.9	75.7
u234	5.50E+01	950.0	0.9	75.8
pd103	6.91E+01	950.0	0.9	75.7
th232	7.27E+01	950.0	0.9	75.7
cd113m	8.69E+01	950.0	0.9	75.7
sr90	3.64E+02	34.1	52.4	49.4
u236	9.99E+01	950.0	0.9	75.7
v49	1.07E+02	950.0	1.2	78.1
pu239	1.14E+02	950.0	2.3	79.0
w185	1.07E+02	950.0	0.9	75.7
pu236	1.44E+02	950.0	3.4	85.6
cf252	1.34E+02	950.0	0.9	75.7

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
cm242	4.05E+02	950.0	27.5	116.7
u238	1.86E+02	950.0	0.9	75.7
cl36	3.35E+02	950.0	8.5	140.8
cm244	8.69E+02	797.4	59.4	157.5
pu240	2.60E+02	950.0	1.3	76.8
ca41	4.10E+02	950.0	0.9	75.7
pu238	1.62E+03	950.0	45.3	146.1
sm145	5.73E+02	950.0	0.9	75.7
pu242	6.96E+02	950.0	0.9	75.7
pm147	7.00E+02	950.0	0.9	75.7
er169	1.53E+03	950.0	0.9	75.7
fe55	1.63E+03	950.0	0.9	75.7
pu241	3.67E+03	950.0	0.9	75.7
bi210	1.96E+04	950.0	0.9	75.7
bk249	5.28E+04	950.0	0.9	75.7
pr143	2.15E+05	526.8	72.8	190.2
tc97	5.81E+05	950.0	0.9	75.7
ca45	5.83E+05	950.0	0.9	75.7
ge71	5.83E+05	950.0	0.9	75.7
nb93m	5.83E+05	950.0	0.9	75.7
mo93	5.83E+05	950.0	0.9	75.7
tc97m	5.83E+05	950.0	0.9	75.7
cd109	5.83E+05	950.0	0.9	75.7
sn113m	5.83E+05	950.0	0.9	75.7
sn119m	5.83E+05	950.0	0.9	75.7
sn121m	5.83E+05	950.0	0.9	75.7
te123	5.83E+05	950.0	0.9	75.7
i125	5.83E+05	950.0	0.9	75.7
i129	5.83E+05	950.0	0.9	75.7
cs131	5.83E+05	950.0	0.9	75.7
pm145	5.83E+05	950.0	0.9	75.7
sm151	5.83E+05	950.0	0.9	75.7
tb157	5.83E+05	950.0	0.9	75.7
dy159	5.83E+05	950.0	0.9	75.7
tm170	5.83E+05	950.0	0.9	75.7
tm171	5.83E+05	950.0	0.9	75.7
os194	5.83E+05	950.0	0.9	75.7
pt193	5.83E+05	950.0	0.9	75.7
tl204	5.83E+05	950.0	0.9	75.7
pb205	5.83E+05	950.0	0.9	75.7
pb210	5.83E+05	950.0	0.9	75.7
ra225	5.83E+05	950.0	0.9	75.7
ra228	5.83E+05	950.0	0.9	75.7
np235	5.83E+05	950.0	0.9	75.7
cm246	5.83E+05	950.0	0.9	75.7
cm248	5.83E+05	950.0	0.9	75.7

Table 5.4.4-6 HAC Gamma Dose Rates for the Maximum Radionuclide Loading (Cont.)

Radionuclide	Source Strength Density (Ci/g)	1 Meter from Package Surface (mrem/hr)		
X	a_X	Side	Bottom	Top
cf250	5.83E+05	950.0	0.9	75.7
se72	5.83E+05	950.0	0.9	75.7
as73	5.83E+05	950.0	0.9	75.7
te118	5.83E+05	950.0	0.9	75.7
sb119	5.83E+05	950.0	0.9	75.7
nd140	5.83E+05	950.0	0.9	75.7
yb166	5.83E+05	950.0	0.9	75.7
h3	5.83E+05	950.0	0.9	75.7
ni63	5.83E+05	950.0	0.9	75.7
sr89	5.83E+05	950.0	0.9	75.7
tc99	5.83E+05	950.0	0.9	75.7
am242	5.83E+05	950.0	0.9	75.7
c14	5.83E+05	950.0	0.9	75.7

5.5 Appendix

5.5.1 List of Gamma Radionuclides with Greater than 1 Day Half Life

Table 5.5.1-1 List of Gamma Radionuclides with Greater Than 1 Day Half Life

Nuclide	ID	Branch	Daughter	Yield
na22	110220			
na24	110240			
cl36	170360			
ar37	180370			
k40	190400			
ca41	200410			
ca45	200450			
ca47	200470			
sc46	210460			
sc47	210470			
sc48	210480			
v49	230490			
cr51	240510			
mn54	250540			
fe55	260550			
fe59	260590			
co57	270570			
co58	270580			
co60	270600			
ni59	280590			
cu64	290640			
cu67	290670			
zn65	300650			
ge71	320710			
as76	330760			
as77	330770			
se75	340750			
br82	350820			
kr79	360790			
kr81	360810			
kr85	360850			
rb86	370860			
sr85	380850			
sr90	390900	br	y90	1
y91	390910			
zr89	400890			
zr95	400950			
nb91	410910			
nb92	410920			
nb93m	410931			
nb94	410940			
nb95	410950			
nb95m	410951			
mo93	420930			
tc97	430970			
tc97m	430971			
tc98	430980			
mo99	430991	br	tc99m	0.88
ru97	440970			
ru103	441030			
cs134	551340			
cs136	551360			
ba131	561310			
ba133	561330			
ba135m	561351			
cs137	561371	br	ba137m	0.95
ba140	561400			
la137	571370			
la138	571380			
la140	571400			
ce139	581390			
ce141	581410			
ce143	581430			
ce144	581440			
pr143	591430			
pr144	591440			
nd147	601470			
pm145	611450			
pm147	611470			
pm148	611480			
pm148m	611481			
pm149	611490			
pm151	611510			
sm145	621450			
sm151	621510			
sm153	621530			
eu152	631520			
eu154	631540			
eu155	631550			
eu156	631560			
gd153	641530			
tb157	651570			
tb160	651600			
tb161	651610			
dy159	661590			
dy166	661660			
ho166	671660			
ho166m	671661			
er169	681690			
er172	681720			
tm170	691700			
tm171	691710			
tm172	691720			
yb169	701690			
yb175	701750			
lu176	711760			
lu177	711770			
lu177m	711771			
hf175	721750			
hf181	721810			
pa232	912320			
pa233	912330			
u230	922300			
u232	922320			
u233	922330			
u234	922340			
u235	922350			
u236	922360			
u237	922370			
u238	922380			
np235	932350			
np236	932360			
np237	932370			
np238	932380			
np239	932390			
pu236	942360			
pu237	942370			
pu238	942380			
pu239	942390			
pu240	942400			
pu241	942410			
pu242	942420			
pu246	942460			
am240	952400			
am241	952410			
am242m	952421			
am243	952430			
cm241	962410			
cm242	962420			
cm243	962430			
cm244	962440			
cm245	962450			
cm246	962460			
cm247	962470			
cm248	962480			
bk249	972490			
cf249	982490			
cf250	982500			
cf251	982510			
cf252	982520			
es253	992530			
es254	992540			
be7	40070			
ga67	310670			
ge69	320690			
as71	330710			
zn72	300720			
as72	330720			
se72	340720			
as73	330730			

Table 5.5.1-1 (continued)

Nuclide	ID	Branch	Daughter	Yield
rh102	451020			
rh105	451050			
ru106	451060	br	rh106	1
pd103	461030			
ag108m	471081			
ag110	471100			
ag110m	471101			
ag111	471110			
cd109	481090			
cd113m	481131			
cd115	481150			
cd115m	481151			
in113m	491131			
in114m	491141			
sn113	501130			
sn113m	501131			
sn117m	501171			
sn119m	501191			
sn121m	501211			
sn123	501230			
sn125	501250			
sb122	511220			
sb124	511240			
sb125	511250			
sb126	511260			
te121	521210			
te121m	521211			
te123	521230			
te123m	521231			
te125m	521251			
te127m	521271			
te129m	521291			
te131m	521311			
i125	531250			
i126	531260			
i129	531290			
i131	531310			
xe127	541270			
xe129m	541291			
xe131m	541311			
xe133	541330			
xe133m	541331			
cs131	551310			
cs132	551320			

Nuclide	ID	Branch	Daughter	Yield
hf182	721820			
ta182	731820			
ta183	731830			
w181	741810			
w185	741850			
w188	741880			
re186	751860			
re189	751890			
os185	761850			
os191	761910			
os193	761930			
os194	761940			
ir192	771920			
ir194m	771941			
pt191	781910			
pt193	781930			
pt193m	781931			
pt195m	781951			
au198	791980			
au199	791990			
hg203	802030			
tl204	812040			
pb205	822050			
bi208	832080			
bi210	832100			
bi210m	832101			
po210	842100			
pb210	822100			
rn222	862220			
ra223	882230			
ra224	882240			
ra225	882250			
ra226	882260			
ra228	882280			
ac225	892250			
ac227	892270			
th227	902270			
th228	902280			
th229	902290			
th230	902300			
th231	902310			
th232	902320			
th234	902340			
pa231	912310			

Nuclide	ID	Branch	Daughter	Yield
as74	330740			
br77	350770			
rb83	370830			
sr83	380830			
rb84	370840			
y87	390870			
y88	390880			
zr88	400880			
tc95m	430951			
tc96	430960			
rh99	450990			
rh101	451010			
rh101m	451011			
rh102m	451021			
ag105	471050			
ag106m	471061			
te118	521180			
sb119	511190			
sb120m	511201			
i124	531240			
sn126	501260			
sb127	511270			
cs129	551290			
te132	521320			
nd140	601400			
pm143	611430			
cs144	551440			
pm144	611440			
pm146	611460			
gd147	641470			
eu149	631490			
gd149	641490			
tb153	651530			
tb155	651550			
tb156	651560			
tb158	651580			
tm165	691650			
yb166	701660			
tm167	691670			
tm168	691680			
lu169	711690			
lu171	711710			
lu172	711720			
hf172	721720			

5.5.2 Gamma Radionuclide Responses

Table 5.5.2-1 NCT Gamma Dose Rate Responses (mrem/hr/Ci)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
na24	4.24E+00	3.01E+00	2.16E+00	6.11E-01	1.51E-01
bi208	3.81E+00	2.73E+00	1.98E+00	5.50E-01	1.36E-01
cs144	2.69E+00	1.95E+00	1.45E+00	3.92E-01	9.64E-02
y88	1.43E+00	9.45E-01	6.21E-01	2.03E-01	4.99E-02
la140	8.89E-01	5.82E-01	3.96E-01	1.27E-01	3.11E-02
sb124	6.64E-01	4.32E-01	2.96E-01	9.43E-02	2.29E-02
eu156	6.34E-01	4.34E-01	2.97E-01	9.15E-02	2.22E-02
sc48	5.39E-01	3.54E-01	2.51E-01	7.74E-02	1.88E-02
la138	3.76E-01	2.40E-01	1.66E-01	5.34E-02	1.30E-02
tb156	3.56E-01	2.32E-01	1.61E-01	5.04E-02	1.23E-02
ag106m	3.28E-01	2.11E-01	1.51E-01	4.65E-02	1.14E-02
lu169	3.18E-01	2.08E-01	1.44E-01	4.54E-02	1.10E-02
na22	2.76E-01	1.78E-01	1.28E-01	3.84E-02	9.44E-03
sb120m	2.63E-01	1.73E-01	1.32E-01	3.75E-02	9.17E-03
i124	2.63E-01	1.73E-01	1.20E-01	3.73E-02	9.05E-03
br82	2.47E-01	1.58E-01	1.16E-01	3.48E-02	8.48E-03
lu172	2.16E-01	1.44E-01	1.07E-01	3.09E-02	7.59E-03
ta182	2.11E-01	1.37E-01	9.87E-02	2.98E-02	7.26E-03
ca47	2.04E-01	1.32E-01	9.46E-02	2.86E-02	7.02E-03
sc46	1.88E-01	1.24E-01	9.61E-02	2.70E-02	6.57E-03
te131m	1.82E-01	1.22E-01	8.86E-02	2.60E-02	6.31E-03
eu152	1.74E-01	1.12E-01	8.06E-02	2.47E-02	6.03E-03
as72	1.69E-01	1.18E-01	8.96E-02	2.43E-02	5.97E-03
tm172	1.56E-01	1.00E-01	6.79E-02	2.22E-02	5.38E-03
eu154	1.52E-01	9.87E-02	7.29E-02	2.13E-02	5.23E-03
pm148	1.33E-01	8.48E-02	5.94E-02	1.88E-02	4.60E-03
cs136	1.32E-01	8.93E-02	7.23E-02	1.89E-02	4.69E-03
ge69	1.16E-01	7.55E-02	5.44E-02	1.65E-02	4.00E-03
tb160	9.28E-02	6.15E-02	4.79E-02	1.33E-02	3.23E-03
rh102m	8.02E-02	5.06E-02	4.27E-02	1.10E-02	2.70E-03
sn125	7.86E-02	5.44E-02	3.87E-02	1.14E-02	2.77E-03
gd147	7.59E-02	4.93E-02	3.82E-02	1.07E-02	2.61E-03
sr83	6.53E-02	4.24E-02	3.09E-02	9.20E-03	2.24E-03
tc96	6.48E-02	4.41E-02	4.52E-02	9.27E-03	2.30E-03
k40	6.02E-02	3.84E-02	2.64E-02	8.55E-03	2.09E-03
co60[1]	5.60E-02	3.38E-02	2.65E-02	8.26E-03	1.01E-03

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
as76	5.15E-02	3.42E-02	2.42E-02	7.28E-03	1.77E-03
nb92	4.23E-02	2.91E-02	2.71E-02	6.06E-03	1.48E-03
np238	4.09E-02	2.84E-02	2.39E-02	5.92E-03	1.47E-03
am240	3.44E-02	2.45E-02	2.29E-02	5.05E-03	1.24E-03
tb158	3.30E-02	2.29E-02	2.03E-02	4.79E-03	1.17E-03
sb126	2.94E-02	1.49E-02	2.00E-02	3.37E-03	8.33E-04
ag110m[1]	2.90E-02	1.74E-02	1.38E-02	4.27E-03	5.24E-04
ho166m	2.79E-02	1.78E-02	1.99E-02	3.79E-03	9.43E-04
pa232	2.37E-02	1.68E-02	1.64E-02	3.47E-03	8.54E-04
pm148m	3.36E-02	1.99E-02	2.10E-02	4.31E-03	1.07E-03
nb94	2.32E-02	1.58E-02	2.04E-02	3.23E-03	8.18E-04
rb84	2.24E-02	1.53E-02	1.46E-02	3.22E-03	8.00E-04
tm168	2.21E-02	1.48E-02	1.60E-02	3.11E-03	7.73E-04
pr144	2.12E-02	1.47E-02	1.00E-02	3.06E-03	7.43E-04
fe59[1]	1.97E-02	1.19E-02	9.70E-03	2.91E-03	3.57E-04
rh99	1.92E-02	1.19E-02	8.93E-03	2.64E-03	6.42E-04
tm165	1.80E-02	1.14E-02	9.10E-03	2.52E-03	6.11E-04
zr89	1.29E-02	7.86E-03	5.62E-03	1.76E-03	4.33E-04
rh102	1.24E-02	7.53E-03	5.93E-03	1.68E-03	4.07E-04
as71	1.16E-02	6.76E-03	5.99E-03	1.51E-03	3.70E-04
tc98	1.10E-02	4.62E-03	9.49E-03	1.05E-03	2.69E-04
ag108m	1.05E-02	4.21E-03	8.88E-03	9.77E-04	2.49E-04
ru106	9.55E-03	6.08E-03	4.73E-03	1.31E-03	3.21E-04
tc95m	9.44E-03	6.12E-03	7.01E-03	1.30E-03	3.24E-04
ir194m	1.06E-02	3.32E-03	6.86E-03	9.18E-04	2.23E-04
cs132	8.10E-03	3.69E-03	4.78E-03	8.84E-04	2.15E-04
rb86	7.93E-03	5.43E-03	4.39E-03	1.14E-03	2.85E-04
pm144	7.84E-03	1.79E-03	6.00E-03	5.43E-04	1.34E-04
nb95	7.33E-03	3.81E-03	6.64E-03	7.98E-04	2.07E-04
zr95	7.25E-03	3.76E-03	6.57E-03	7.88E-04	2.05E-04
lu171	6.84E-03	3.80E-03	5.52E-03	8.08E-04	2.05E-04
ho166	6.68E-03	4.30E-03	2.86E-03	9.54E-04	2.31E-04
zn65[1]	5.98E-03	3.65E-03	3.27E-03	8.84E-04	1.09E-04
sb127	5.38E-03	2.44E-03	3.63E-03	5.73E-04	1.41E-04
tb153	5.40E-03	3.35E-03	3.17E-03	7.30E-04	1.78E-04
ag105	5.01E-03	2.79E-03	2.97E-03	6.22E-04	1.55E-04
te121m	4.92E-03	2.89E-03	2.37E-03	6.56E-04	1.59E-04
sb122	4.82E-03	2.40E-03	2.49E-03	5.71E-04	1.38E-04

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
pm146	4.61E-03	2.17E-03	4.01E-03	4.75E-04	1.22E-04
kr79	3.80E-03	2.10E-03	1.97E-03	4.84E-04	1.17E-04
i126	3.75E-03	1.68E-03	2.29E-03	4.05E-04	9.91E-05
gd149	3.71E-03	1.87E-03	2.63E-03	4.24E-04	1.05E-04
cd115m	3.49E-03	2.32E-03	1.76E-03	4.96E-04	1.21E-04
as74	3.20E-03	9.61E-04	1.84E-03	2.84E-04	6.68E-05
pm143	2.83E-03	1.47E-03	2.56E-03	3.08E-04	7.99E-05
cu64	2.54E-03	1.30E-03	1.22E-03	3.12E-04	7.49E-05
ba131	2.47E-03	1.19E-03	1.40E-03	2.84E-04	6.94E-05
cs134[1]	2.25E-03	1.34E-03	1.61E-03	3.43E-04	4.36E-05
os185	2.15E-03	1.55E-03	1.86E-03	3.14E-04	7.92E-05
co58[1]	2.01E-03	1.18E-03	1.35E-03	2.97E-04	3.83E-05
ce143	1.95E-03	9.61E-04	1.25E-03	2.24E-04	5.49E-05
sb125	1.62E-03	3.00E-04	1.18E-03	1.05E-04	2.54E-05
pm151	1.62E-03	6.63E-04	1.20E-03	1.62E-04	4.00E-05
sr85	1.61E-03	9.07E-05	1.04E-03	8.62E-05	1.89E-05
te121	1.60E-03	8.81E-05	1.03E-03	8.52E-05	1.86E-05
br77	2.06E-03	9.35E-04	1.33E-03	2.26E-04	5.55E-05
rb83	1.53E-03	1.16E-04	1.01E-03	8.54E-05	1.90E-05
mn54[1]	1.05E-03	5.09E-04	9.71E-04	1.25E-04	1.65E-05
cm241	1.04E-03	2.41E-05	5.56E-04	5.29E-05	1.13E-05
lu176	1.02E-03	4.84E-06	5.22E-04	5.03E-05	1.05E-05
se75	1.00E-03	4.83E-06	5.14E-04	4.95E-05	1.03E-05
tc99m	5.12E-04	2.42E-06	2.62E-04	2.52E-05	5.27E-06
y87	9.93E-04	5.00E-06	5.09E-04	4.89E-05	1.02E-05
i131	9.19E-04	1.33E-04	5.96E-04	5.84E-05	1.36E-05
rh101	8.83E-04	4.18E-06	4.52E-04	4.35E-05	9.09E-06
mo99	2.41E-03	9.25E-04	1.83E-03	2.29E-04	5.70E-05
hf181	8.50E-04	6.10E-06	4.37E-04	4.20E-05	8.81E-06
y91	8.21E-04	5.33E-04	3.79E-04	1.15E-04	2.82E-05
ru103	7.53E-04	5.15E-05	4.44E-04	4.12E-05	9.16E-06
au198	7.21E-04	1.09E-04	3.83E-04	4.98E-05	1.13E-05
xe127	6.63E-04	3.25E-06	3.39E-04	3.26E-05	6.83E-06
bi210m	6.05E-04	3.45E-05	3.47E-04	3.25E-05	7.15E-06
ru97	5.93E-04	1.67E-05	3.14E-04	3.09E-05	6.59E-06
sn123	5.85E-04	4.01E-04	3.24E-04	8.39E-05	2.11E-05
yb169	5.81E-04	2.79E-06	2.97E-04	2.86E-05	5.98E-06
co57	5.78E-04	4.02E-06	2.97E-04	2.86E-05	5.99E-06

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
ta183	5.61E-04	2.66E-06	2.87E-04	2.76E-05	5.78E-06
np239	5.60E-04	2.65E-06	2.87E-04	2.76E-05	5.77E-06
ba133	5.60E-04	2.65E-06	2.87E-04	2.76E-05	5.77E-06
zr88	5.58E-04	2.64E-06	2.86E-04	2.75E-05	5.75E-06
zn72	5.55E-04	2.63E-06	2.84E-04	2.73E-05	5.71E-06
rh101m	5.41E-04	6.06E-06	2.86E-04	2.70E-05	5.67E-06
te132	5.28E-04	2.50E-06	2.70E-04	2.60E-05	5.44E-06
cf249	5.25E-04	2.91E-06	2.69E-04	2.59E-05	5.42E-06
cs129	5.24E-04	9.56E-05	2.95E-04	3.84E-05	8.74E-06
hf182	5.15E-04	2.44E-06	2.64E-04	2.54E-05	5.31E-06
sn117m	5.08E-04	2.41E-06	2.60E-04	2.50E-05	5.23E-06
cd115	5.08E-04	2.53E-05	3.19E-04	2.69E-05	5.85E-06
hf175	4.98E-04	2.36E-06	2.55E-04	2.45E-05	5.13E-06
u235	4.93E-04	2.37E-06	2.52E-04	2.43E-05	5.08E-06
ba140	4.86E-04	2.24E-05	3.02E-04	2.56E-05	5.55E-06
pt191	4.85E-04	3.11E-05	2.95E-04	2.65E-05	5.84E-06
te123m	4.82E-04	2.29E-06	2.47E-04	2.38E-05	4.97E-06
ag110	4.79E-04	2.45E-04	2.72E-04	5.61E-05	1.37E-05
in114m	4.73E-04	1.68E-04	3.76E-04	4.24E-05	1.06E-05
hg203	4.68E-04	2.22E-06	2.39E-04	2.30E-05	4.81E-06
cm247	4.67E-04	2.21E-06	2.39E-04	2.30E-05	4.80E-06
cf251	4.61E-04	2.18E-06	2.36E-04	2.27E-05	4.75E-06
ce139	4.59E-04	2.17E-06	2.35E-04	2.26E-05	4.72E-06
pu246	4.51E-04	2.14E-06	2.31E-04	2.22E-05	4.64E-06
sc47	3.90E-04	1.85E-06	2.00E-04	1.92E-05	4.02E-06
in113m	3.69E-04	1.75E-06	1.89E-04	1.81E-05	3.79E-06
u237	3.66E-04	1.73E-06	1.87E-04	1.80E-05	3.77E-06
cm243	3.62E-04	1.71E-06	1.85E-04	1.78E-05	3.73E-06
pa233	3.55E-04	1.68E-06	1.82E-04	1.75E-05	3.66E-06
ar37	3.41E-04	3.44E-05	2.13E-04	2.00E-05	4.54E-06
tb155	3.33E-04	2.13E-06	1.71E-04	1.65E-05	3.45E-06
er172	3.10E-04	2.32E-06	1.60E-04	1.54E-05	3.22E-06
lu177m	3.07E-04	1.45E-06	1.57E-04	1.51E-05	3.16E-06
cm245	3.04E-04	1.44E-06	1.56E-04	1.50E-05	3.13E-06
np236	2.95E-04	1.40E-06	1.51E-04	1.45E-05	3.04E-06
ga67	2.87E-04	2.16E-05	1.57E-04	1.69E-05	3.71E-06
cu67	2.86E-04	1.36E-06	1.46E-04	1.41E-05	2.95E-06
nd147	2.81E-04	1.90E-05	1.81E-04	1.53E-05	3.38E-06

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
au199	2.80E-04	1.32E-06	1.43E-04	1.38E-05	2.88E-06
ce141	2.77E-04	1.31E-06	1.42E-04	1.36E-05	2.85E-06
tm167	2.67E-04	2.58E-06	1.40E-04	1.32E-05	2.78E-06
cs137[1]	2.58E-04	2.58E-05	1.80E-04	1.45E-05	1.76E-06
te129m	2.45E-04	1.06E-04	1.84E-04	2.47E-05	6.18E-06
th227	2.05E-04	2.99E-06	1.06E-04	1.04E-05	2.19E-06
ra223	2.01E-04	1.79E-06	1.04E-04	9.98E-06	2.10E-06
pu237	1.83E-04	8.65E-07	9.35E-05	9.00E-06	1.88E-06
sm153	1.75E-04	1.14E-06	8.99E-05	8.63E-06	1.81E-06
sn126	1.74E-04	8.23E-07	8.89E-05	8.56E-06	1.79E-06
os191	1.66E-04	7.89E-07	8.52E-05	8.20E-06	1.71E-06
nb95m	1.53E-04	1.40E-06	7.91E-05	7.63E-06	1.60E-06
rh105	1.40E-04	6.64E-07	7.17E-05	6.90E-06	1.44E-06
re189	1.33E-04	1.54E-06	7.05E-05	6.62E-06	1.39E-06
eu155	1.26E-04	5.96E-07	6.43E-05	6.19E-06	1.29E-06
gd153	1.23E-04	5.84E-07	6.31E-05	6.07E-06	1.27E-06
os193	1.23E-04	6.19E-06	6.92E-05	6.71E-06	1.45E-06
th229	1.19E-04	5.64E-07	6.09E-05	5.86E-06	1.23E-06
lu177	1.03E-04	4.86E-07	5.25E-05	5.05E-06	1.06E-06
hf172	9.56E-05	4.53E-07	4.89E-05	4.71E-06	9.85E-07
ba135m	8.95E-05	4.24E-07	4.58E-05	4.41E-06	9.22E-07
yb175	6.78E-05	3.21E-07	3.47E-05	3.34E-06	6.98E-07
eu149	6.68E-05	1.19E-06	3.65E-05	3.36E-06	7.12E-07
ce144	6.37E-05	3.02E-07	3.26E-05	3.14E-06	6.55E-07
be7	5.94E-05	2.81E-07	3.04E-05	2.92E-06	6.11E-07
cr51	5.79E-05	2.74E-07	2.96E-05	2.85E-06	5.96E-07
xe133m	5.74E-05	2.72E-07	2.94E-05	2.83E-06	5.91E-07
re186	5.64E-05	1.47E-06	2.99E-05	2.91E-06	6.22E-07
pm149	5.62E-05	2.70E-05	4.16E-05	6.43E-06	1.57E-06
pa231	5.47E-05	2.67E-07	2.80E-05	2.70E-06	5.64E-07
ir192	4.88E-05	4.30E-07	2.51E-05	2.43E-06	5.09E-07
ag111	4.81E-05	1.58E-06	2.55E-05	2.54E-06	5.44E-07
xe129m	2.63E-05	1.25E-07	1.35E-05	1.30E-06	2.71E-07
ra224	2.30E-05	1.51E-07	1.18E-05	1.14E-06	2.38E-07
ac225	2.28E-05	1.24E-07	1.17E-05	1.12E-06	2.35E-07
kr81	2.24E-05	1.06E-07	1.15E-05	1.10E-06	2.30E-07
ra226	2.01E-05	9.93E-08	1.03E-05	9.92E-07	2.07E-07
np237	1.95E-05	9.26E-08	1.00E-05	9.63E-07	2.01E-07

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
as77	1.88E-05	4.38E-07	1.05E-05	9.53E-07	2.03E-07
pt195m	1.74E-05	8.25E-08	8.91E-06	8.58E-07	1.79E-07
xe131m	1.13E-05	5.33E-08	5.76E-06	5.54E-07	1.16E-07
sn113	1.05E-05	5.74E-08	5.39E-06	5.18E-07	1.08E-07
th231	7.14E-06	3.38E-08	3.65E-06	3.51E-07	7.35E-08
kr85	7.04E-06	3.90E-07	4.54E-06	3.76E-07	8.21E-08
dy166	6.73E-06	3.19E-08	3.45E-06	3.32E-07	6.93E-08
nb91	5.32E-06	2.95E-07	3.43E-06	2.84E-07	6.21E-08
ni59	5.15E-06	2.86E-06	3.87E-06	6.27E-07	1.56E-07
am243	4.11E-06	3.15E-08	2.12E-06	2.04E-07	4.27E-08
w188	3.66E-06	1.73E-08	1.87E-06	1.80E-07	3.77E-08
th228	2.98E-06	1.70E-08	1.53E-06	1.47E-07	3.08E-08
tb161	2.79E-06	4.99E-08	1.53E-06	1.40E-07	2.97E-08
es254	2.56E-06	1.21E-08	1.31E-06	1.26E-07	2.63E-08
u230	1.88E-06	9.22E-09	9.62E-07	9.26E-08	1.94E-08
te125m	1.62E-06	7.67E-09	8.28E-07	7.97E-08	1.67E-08
th234	1.62E-06	7.66E-09	8.28E-07	7.97E-08	1.67E-08
la137	1.33E-06	2.74E-07	9.99E-07	8.85E-08	2.16E-08
rn222	1.23E-06	6.83E-08	7.96E-07	6.58E-08	1.44E-08
am242m	9.57E-07	4.53E-09	4.90E-07	4.71E-08	9.85E-09
w181	6.67E-07	3.16E-09	3.41E-07	3.29E-08	6.87E-09
pt193m	6.44E-07	3.05E-09	3.30E-07	3.17E-08	6.63E-09
es253	6.40E-07	2.88E-08	3.33E-07	3.50E-08	7.52E-09
te127m	5.89E-07	1.09E-07	4.32E-07	3.81E-08	9.22E-09
u232	4.51E-07	2.46E-09	2.31E-07	2.22E-08	4.65E-09
u233	4.50E-07	1.66E-08	2.30E-07	2.42E-08	5.16E-09
xe133	4.21E-07	1.99E-09	2.15E-07	2.07E-08	4.33E-09
th230	4.03E-07	1.92E-09	2.06E-07	1.99E-08	4.15E-09
ac227	2.38E-07	1.13E-09	1.22E-07	1.17E-08	2.45E-09
am241	2.14E-07	1.52E-08	1.22E-07	1.21E-08	2.68E-09
u234	2.08E-07	1.02E-09	1.07E-07	1.03E-08	2.14E-09
po210	1.69E-07	1.28E-07	1.46E-07	2.59E-08	6.50E-09
pd103	1.66E-07	7.85E-10	8.48E-08	8.16E-09	1.71E-09
th232	1.57E-07	7.46E-10	8.05E-08	7.75E-09	1.62E-09
cd113m	1.32E-07	6.24E-10	6.74E-08	6.49E-09	1.36E-09
u236	1.15E-07	5.43E-10	5.87E-08	5.65E-09	1.18E-09
v49	1.09E-07	8.22E-10	5.66E-08	5.39E-09	1.13E-09
w185	1.07E-07	5.06E-10	5.46E-08	5.26E-09	1.10E-09

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
pu239	1.03E-07	2.08E-09	5.42E-08	5.26E-09	1.12E-09
pu236	8.60E-08	2.57E-09	4.69E-08	4.42E-09	9.48E-10
cf252	8.54E-08	4.04E-10	4.37E-08	4.20E-09	8.79E-10
u238	6.15E-08	2.92E-10	3.15E-08	3.03E-09	6.34E-10
cl36	5.51E-08	3.06E-09	3.56E-08	2.94E-09	6.43E-10
pu240	4.44E-08	4.12E-10	2.29E-08	2.21E-09	4.64E-10
cm242	4.25E-08	9.80E-09	2.48E-08	3.37E-09	7.87E-10
sr90	3.91E-08	2.73E-08	1.86E-08	5.67E-09	1.38E-09
ca41	2.79E-08	1.32E-10	1.43E-08	1.37E-09	2.87E-10
cm244	2.22E-08	9.60E-09	1.61E-08	2.38E-09	5.80E-10
sm145	2.00E-08	9.46E-11	1.02E-08	9.84E-10	2.06E-10
pu242	1.64E-08	7.79E-11	8.41E-09	8.10E-10	1.69E-10
pm147	1.64E-08	7.75E-11	8.37E-09	8.06E-10	1.68E-10
pu238	1.21E-08	3.95E-09	7.93E-09	1.09E-09	2.65E-10
er169	7.46E-09	3.54E-11	3.82E-09	3.68E-10	7.68E-11
fe55	7.02E-09	3.33E-11	3.59E-09	3.46E-10	7.23E-11
pu241	3.12E-09	1.48E-11	1.60E-09	1.54E-10	3.21E-11
bi210	5.83E-10	2.76E-12	2.99E-10	2.87E-11	6.01E-12
bk249	2.17E-10	1.03E-12	1.11E-10	1.07E-11	2.23E-12
pr143	8.82E-11	4.58E-11	7.99E-11	9.59E-12	2.49E-12
tc97	1.97E-11	9.34E-14	1.01E-11	9.71E-13	2.03E-13
ca45	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
ge71	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
nb93m	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
mo93	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
tc97m	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
cd109	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sn113m	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sn119m	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sn121m	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
te123	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
i125	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
i129	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
cs131	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
pm145	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sm151	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
tb157	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
dy159	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13

Table 5.5.2-1 (Continued)

Radionuclide	NCT Surface 71.47(b)(1) or (2)			NCT 2 Meter 71.47(b)(3)	Normally occupied space 71.47(b)(4)
	Side	Bottom	Top		
tm170	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
tm171	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
os194	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
pt193	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
tl204	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
pb205	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
pb210	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
ra225	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
ra228	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
np235	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
cm246	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
cm248	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
cf250	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
se72	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
as73	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
te118	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sb119	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
nd140	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
yb166	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
h3	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
ni63	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
sr89	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
tc99	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
am242	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13
c14	1.96E-11	9.30E-14	1.00E-11	9.67E-13	2.02E-13

Note 1: Marked nuclides are analyzed individually.

Table 5.5.2-2 HAC Gamma Dose Rate Responses (mrem/hr/Ci)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
na24	2.23E+00	3.47E+00	3.41E+00
bi208	1.93E+00	3.11E+00	3.07E+00
cs144	1.43E+00	2.20E+00	2.27E+00
y88	8.44E-01	1.17E+00	1.03E+00
la140	5.64E-01	7.20E-01	6.62E-01
sb124	4.20E-01	5.41E-01	4.79E-01
eu156	3.77E-01	5.17E-01	4.86E-01
sc48	4.91E-01	4.79E-01	4.80E-01
la138	2.71E-01	3.20E-01	2.89E-01
tb156	2.81E-01	3.02E-01	2.83E-01
ag106m	3.09E-01	2.75E-01	2.73E-01
lu169	2.32E-01	2.68E-01	2.50E-01
na22	2.53E-01	2.42E-01	2.32E-01
sb120m	3.02E-01	2.40E-01	2.56E-01
i124	1.79E-01	2.12E-01	1.96E-01
br82	2.61E-01	2.12E-01	2.16E-01
lu172	2.25E-01	1.93E-01	1.97E-01
ta182	1.94E-01	1.86E-01	1.84E-01
ca47	1.69E-01	1.81E-01	1.70E-01
sc46	2.34E-01	1.71E-01	1.91E-01
te131m	1.68E-01	1.53E-01	1.56E-01
eu152	1.58E-01	1.52E-01	1.47E-01
as72	1.64E-01	1.40E-01	1.52E-01
tm172	1.06E-01	1.30E-01	1.17E-01
eu154	1.53E-01	1.35E-01	1.35E-01
pm148	1.01E-01	1.13E-01	1.04E-01
cs136	1.86E-01	1.26E-01	1.41E-01
ge69	1.13E-01	9.91E-02	1.01E-01
tb160	1.20E-01	8.54E-02	9.54E-02
rh102m	1.41E-01	7.07E-02	8.57E-02
sn125	5.79E-02	6.61E-02	6.56E-02
gd147	1.05E-01	6.65E-02	7.37E-02
sr83	6.71E-02	5.33E-02	5.44E-02
tc96	1.81E-01	6.47E-02	9.92E-02
k40	4.14E-02	5.12E-02	4.56E-02
co60[1]	6.08E-02	8.49E-02	7.11E-02

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
as76	4.18E-02	4.21E-02	4.10E-02
nb92	1.02E-01	4.31E-02	6.02E-02
np238	6.39E-02	4.10E-02	4.85E-02
am240	8.10E-02	3.64E-02	5.08E-02
tb158	6.46E-02	3.35E-02	4.39E-02
sb126	1.32E-01	2.21E-02	4.51E-02
ag110m[1]	3.82E-02	4.20E-02	3.62E-02
ho166m	9.97E-02	2.63E-02	4.41E-02
pa232	6.34E-02	2.50E-02	3.65E-02
pm148m	1.04E-01	2.90E-02	4.49E-02
nb94	1.03E-01	2.46E-02	4.76E-02
rb84	5.68E-02	2.14E-02	3.06E-02
tm168	7.58E-02	2.19E-02	3.56E-02
pr144	1.16E-02	1.70E-02	1.60E-02
fe59[1]	2.51E-02	3.07E-02	2.71E-02
rh99	2.80E-02	1.53E-02	1.63E-02
tm165	3.13E-02	1.56E-02	1.80E-02
zr89	1.48E-02	9.89E-03	9.80E-03
rh102	2.19E-02	9.97E-03	1.15E-02
as71	3.09E-02	9.34E-03	1.20E-02
tc98	7.31E-02	7.49E-03	2.30E-02
ag108m	7.54E-02	6.82E-03	2.16E-02
ru106	1.33E-02	7.62E-03	8.54E-03
tc95m	3.84E-02	9.16E-03	1.57E-02
ir194m	8.27E-02	5.04E-03	1.63E-02
cs132	3.35E-02	5.14E-03	1.05E-02
rb86	1.05E-02	7.74E-03	8.49E-03
pm144	6.58E-02	3.02E-03	1.48E-02
nb95	4.42E-02	6.11E-03	1.60E-02
zr95	4.37E-02	6.04E-03	1.58E-02
lu171	3.32E-02	5.86E-03	1.29E-02
ho166	4.45E-03	5.59E-03	5.07E-03
zn65[1]	9.75E-03	9.59E-03	9.52E-03
sb127	2.83E-02	3.62E-03	8.34E-03
tb153	1.69E-02	4.80E-03	6.80E-03
ag105	2.04E-02	4.03E-03	6.31E-03
te121m	1.29E-02	3.95E-03	4.81E-03
sb122	1.67E-02	3.30E-03	5.18E-03

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
pm146	3.23E-02	3.49E-03	9.73E-03
kr79	1.16E-02	2.89E-03	4.15E-03
i126	1.83E-02	2.38E-03	5.05E-03
gd149	2.34E-02	2.86E-03	6.23E-03
cd115m	3.85E-03	3.22E-03	3.37E-03
as74	2.24E-02	1.29E-03	4.22E-03
pm143	1.71E-02	2.36E-03	6.16E-03
cu64	7.86E-03	1.74E-03	2.53E-03
ba131	1.58E-02	1.72E-03	3.12E-03
cs134[1]	9.51E-03	3.76E-03	5.00E-03
os185	8.83E-03	2.38E-03	4.31E-03
co58[1]	6.81E-03	3.13E-03	4.01E-03
ce143	1.08E-02	1.40E-03	2.86E-03
sb125	1.60E-02	5.12E-04	2.95E-03
pm151	1.39E-02	1.04E-03	2.93E-03
sr85	1.80E-02	1.63E-04	2.67E-03
te121	1.79E-02	1.59E-04	2.65E-03
br77	1.28E-02	1.38E-03	3.03E-03
rb83	1.68E-02	2.02E-04	2.57E-03
mn54[1]	6.38E-03	1.53E-03	3.11E-03
cm241	1.78E-02	4.96E-05	1.54E-03
lu176	1.84E-02	1.76E-05	1.47E-03
se75	1.81E-02	1.75E-05	1.45E-03
tc99m	9.23E-03	8.84E-06	7.36E-04
y87	1.79E-02	1.76E-05	1.43E-03
i131	1.21E-02	2.24E-04	1.55E-03
rh101	1.59E-02	1.52E-05	1.27E-03
mo99	2.13E-02	1.46E-03	4.49E-03
hf181	1.52E-02	1.81E-05	1.23E-03
y91	6.64E-04	7.26E-04	6.81E-04
ru103	1.13E-02	9.23E-05	1.19E-03
au198	1.03E-02	1.63E-04	9.99E-04
xe127	1.20E-02	1.16E-05	9.53E-04
bi210m	9.41E-03	6.28E-05	9.37E-04
ru97	1.03E-02	3.18E-05	8.71E-04
sn123	7.75E-04	5.71E-04	6.25E-04
yb169	1.05E-02	1.01E-05	8.36E-04
co57	1.04E-02	1.21E-05	8.34E-04

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
ta183	1.01E-02	9.69E-06	8.07E-04
np239	1.01E-02	9.68E-06	8.06E-04
ba133	1.01E-02	9.68E-06	8.06E-04
zr88	1.01E-02	9.64E-06	8.03E-04
zn72	1.00E-02	9.58E-06	7.98E-04
rh101m	9.28E-03	1.51E-05	7.94E-04
te132	9.53E-03	9.12E-06	7.60E-04
cf249	9.46E-03	9.73E-06	7.56E-04
cs129	6.96E-03	1.46E-04	7.68E-04
hf182	9.30E-03	8.90E-06	7.41E-04
sn117m	9.17E-03	8.78E-06	7.31E-04
cd115	6.07E-03	4.62E-05	8.28E-04
hf175	9.00E-03	8.61E-06	7.17E-04
u235	8.90E-03	8.57E-06	7.09E-04
ba140	6.03E-03	4.12E-05	7.87E-04
pt191	6.43E-03	5.50E-05	7.76E-04
te123m	8.71E-03	8.33E-06	6.94E-04
ag110	1.58E-03	3.22E-04	5.58E-04
in114m	4.22E-03	2.72E-04	9.30E-04
hg203	8.44E-03	8.08E-06	6.73E-04
cm247	8.42E-03	8.06E-06	6.71E-04
cf251	8.32E-03	7.96E-06	6.63E-04
ce139	8.28E-03	7.92E-06	6.60E-04
pu246	8.14E-03	7.79E-06	6.49E-04
sc47	7.04E-03	6.74E-06	5.61E-04
in113m	6.65E-03	6.37E-06	5.30E-04
u237	6.61E-03	6.32E-06	5.26E-04
cm243	6.53E-03	6.25E-06	5.20E-04
pa233	6.41E-03	6.13E-06	5.11E-04
ar37	4.60E-03	5.91E-05	5.58E-04
tb155	5.97E-03	6.66E-06	4.81E-04
er172	5.55E-03	6.71E-06	4.48E-04
lu177m	5.53E-03	5.30E-06	4.41E-04
cm245	5.49E-03	5.26E-06	4.38E-04
np236	5.32E-03	5.09E-06	4.24E-04
ga67	4.79E-03	3.59E-05	4.30E-04
cu67	5.16E-03	4.94E-06	4.11E-04
nd147	3.24E-03	3.40E-05	4.66E-04

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
au199	5.05E-03	4.83E-06	4.02E-04
ce141	4.99E-03	4.78E-06	3.98E-04
tm167	4.63E-03	6.76E-06	3.89E-04
cs137[1]	2.60E-03	8.58E-05	5.87E-04
te129m	1.41E-03	1.63E-04	4.29E-04
th227	3.66E-03	6.58E-06	2.97E-04
ra223	3.58E-03	4.84E-06	2.91E-04
pu237	3.30E-03	3.16E-06	2.63E-04
sm153	3.13E-03	3.53E-06	2.52E-04
sn126	3.14E-03	3.00E-06	2.50E-04
os191	3.00E-03	2.88E-06	2.39E-04
nb95m	2.75E-03	3.71E-06	2.22E-04
rh105	2.53E-03	2.42E-06	2.02E-04
re189	2.27E-03	3.79E-06	1.95E-04
eu155	2.27E-03	2.17E-06	1.81E-04
gd153	2.22E-03	2.13E-06	1.77E-04
os193	1.91E-03	1.09E-05	1.87E-04
th229	2.15E-03	2.06E-06	1.71E-04
lu177	1.85E-03	1.77E-06	1.48E-04
hf172	1.73E-03	1.65E-06	1.38E-04
ba135m	1.62E-03	1.55E-06	1.29E-04
yb175	1.22E-03	1.17E-06	9.75E-05
eu149	1.08E-03	2.59E-06	1.00E-04
ce144	1.15E-03	1.10E-06	9.16E-05
be7	1.07E-03	1.03E-06	8.54E-05
cr51	1.04E-03	9.99E-07	8.32E-05
xe133m	1.04E-03	9.92E-07	8.26E-05
re186	9.85E-04	2.89E-06	8.30E-05
pm149	4.85E-04	4.16E-05	1.01E-04
pa231	9.87E-04	9.58E-07	7.87E-05
ir192	8.75E-04	1.16E-06	7.04E-05
ag111	8.35E-04	2.92E-06	7.06E-05
xe129m	4.76E-04	4.55E-07	3.79E-05
ra224	4.14E-04	4.67E-07	3.32E-05
ac225	4.09E-04	4.20E-07	3.28E-05
kr81	4.04E-04	3.87E-07	3.22E-05
ra226	3.63E-04	3.54E-07	2.90E-05
np237	3.53E-04	3.38E-07	2.81E-05

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
as77	2.90E-04	8.95E-07	2.85E-05
pt195m	3.14E-04	3.01E-07	2.51E-05
xe131m	2.03E-04	1.94E-07	1.62E-05
sn113	1.89E-04	1.94E-07	1.51E-05
th231	1.29E-04	1.23E-07	1.03E-05
kr85	7.87E-05	7.05E-07	1.17E-05
dy166	1.22E-04	1.16E-07	9.69E-06
nb91	5.95E-05	5.33E-07	8.82E-06
ni59	2.69E-05	4.36E-06	9.01E-06
am243	7.36E-05	9.09E-08	5.94E-06
w188	6.60E-05	6.32E-08	5.26E-06
th228	5.37E-05	5.58E-08	4.28E-06
tb161	4.52E-05	1.08E-07	4.18E-06
es254	4.61E-05	4.42E-08	3.68E-06
u230	3.39E-05	3.30E-08	2.70E-06
te125m	2.92E-05	2.80E-08	2.33E-06
th234	2.92E-05	2.79E-08	2.33E-06
la137	1.19E-05	4.67E-07	2.48E-06
rn222	1.38E-05	1.23E-07	2.04E-06
am242m	1.73E-05	1.65E-08	1.38E-06
w181	1.20E-05	1.15E-08	9.60E-07
pt193m	1.16E-05	1.11E-08	9.26E-07
es253	1.09E-05	4.85E-08	9.19E-07
te127m	5.54E-06	1.87E-07	1.08E-06
u232	8.12E-06	8.29E-09	6.49E-07
u233	7.75E-06	2.75E-08	6.37E-07
xe133	7.60E-06	7.27E-09	6.05E-07
th230	7.27E-06	6.98E-09	5.80E-07
ac227	4.29E-06	4.11E-09	3.42E-07
am241	3.43E-06	2.63E-08	3.30E-07
u234	3.75E-06	3.66E-09	3.00E-07
po210	6.48E-07	1.96E-07	3.38E-07
pd103	2.99E-06	2.86E-09	2.38E-07
th232	2.84E-06	2.72E-09	2.26E-07
cd113m	2.38E-06	2.28E-09	1.90E-07
u236	2.07E-06	1.98E-09	1.65E-07
v49	1.92E-06	2.38E-09	1.58E-07
w185	1.93E-06	1.84E-09	1.54E-07

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
pu239	1.81E-06	4.31E-09	1.51E-07
pu236	1.43E-06	5.06E-09	1.29E-07
cf252	1.54E-06	1.47E-09	1.23E-07
u238	1.11E-06	1.06E-09	8.85E-08
cl36	6.17E-07	5.52E-09	9.15E-08
pu240	7.94E-07	1.09E-09	6.42E-08
cm242	5.11E-07	1.48E-08	6.27E-08
sr90	2.04E-08	3.13E-08	2.95E-08
ca41	5.04E-07	4.82E-10	4.02E-08
cm244	2.00E-07	1.49E-08	3.94E-08
sm145	3.60E-07	3.45E-10	2.87E-08
pu242	2.97E-07	2.84E-10	2.36E-08
pm147	2.95E-07	2.83E-10	2.35E-08
pu238	1.28E-07	6.08E-09	1.96E-08
er169	1.35E-07	1.29E-10	1.07E-08
fe55	1.27E-07	1.21E-10	1.01E-08
pu241	5.63E-08	5.39E-11	4.49E-09
bi210	1.05E-08	1.01E-11	8.39E-10
bk249	3.92E-09	3.75E-12	3.12E-10
pr143	5.32E-10	7.35E-11	1.92E-10
tc97	3.56E-10	3.40E-13	2.83E-11
ca45	3.54E-10	3.39E-13	2.82E-11
ge71	3.54E-10	3.39E-13	2.82E-11
nb93m	3.54E-10	3.39E-13	2.82E-11
mo93	3.54E-10	3.39E-13	2.82E-11
tc97m	3.54E-10	3.39E-13	2.82E-11
cd109	3.54E-10	3.39E-13	2.82E-11
sn113m	3.54E-10	3.39E-13	2.82E-11
sn119m	3.54E-10	3.39E-13	2.82E-11
sn121m	3.54E-10	3.39E-13	2.82E-11
te123	3.54E-10	3.39E-13	2.82E-11
i125	3.54E-10	3.39E-13	2.82E-11
i129	3.54E-10	3.39E-13	2.82E-11
cs131	3.54E-10	3.39E-13	2.82E-11
pm145	3.54E-10	3.39E-13	2.82E-11
sm151	3.54E-10	3.39E-13	2.82E-11
tb157	3.54E-10	3.39E-13	2.82E-11
dy159	3.54E-10	3.39E-13	2.82E-11

Table 5.5.2-2 (Continued)

Radionuclide	HAC 1 Meter 71.51(a)(2)		
	Side	Bottom	Top
tm170	3.54E-10	3.39E-13	2.82E-11
tm171	3.54E-10	3.39E-13	2.82E-11
os194	3.54E-10	3.39E-13	2.82E-11
pt193	3.54E-10	3.39E-13	2.82E-11
tl204	3.54E-10	3.39E-13	2.82E-11
pb205	3.54E-10	3.39E-13	2.82E-11
pb210	3.54E-10	3.39E-13	2.82E-11
ra225	3.54E-10	3.39E-13	2.82E-11
ra228	3.54E-10	3.39E-13	2.82E-11
np235	3.54E-10	3.39E-13	2.82E-11
cm246	3.54E-10	3.39E-13	2.82E-11
cm248	3.54E-10	3.39E-13	2.82E-11
cf250	3.54E-10	3.39E-13	2.82E-11
se72	3.54E-10	3.39E-13	2.82E-11
as73	3.54E-10	3.39E-13	2.82E-11
te118	3.54E-10	3.39E-13	2.82E-11
sb119	3.54E-10	3.39E-13	2.82E-11
nd140	3.54E-10	3.39E-13	2.82E-11
yb166	3.54E-10	3.39E-13	2.82E-11
h3	3.54E-10	3.39E-13	2.82E-11
ni63	3.54E-10	3.39E-13	2.82E-11
sr89	3.54E-10	3.39E-13	2.82E-11
tc99	3.54E-10	3.39E-13	2.82E-11
am242	3.54E-10	3.39E-13	2.82E-11
c14	3.54E-10	3.39E-13	2.82E-11

Note 1: Marked nuclides are analyzed individually.

5.5.3 Radionuclide Maximum Ci/g Loading Limits

Table 5.5.3-1 Radionuclide Maximum Ci/g Loading Limits based on Gamma Response

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
ac225	5.06E-01	HAC
ac227	4.82E+01	HAC
ag105	3.32E-03	NCT
ag106m	4.45E-05	NCT
ag108m	2.12E-03	NCT
ag110	3.68E-02	NCT
ag110m[1]	4.84E-04	NCT
ag111	2.47E-01	HAC
am240	4.09E-04	NCT
am241	6.02E+01	HAC
am242	5.83E+05	HAC
am242m	1.20E+01	HAC
am243	2.81E+00	HAC
ar37	4.49E-02	HAC
as71	1.37E-03	NCT
as72	8.49E-05	NCT
as73	5.83E+05	HAC
as74	7.27E-03	NCT
as76	2.84E-04	NCT
as77	7.12E-01	HAC
au198	2.01E-02	HAC
au199	4.09E-02	HAC
ba131	7.28E-03	NCT
ba133	2.04E-02	HAC
ba135m	1.28E-01	HAC
ba140	3.43E-02	HAC
be7	1.93E-01	HAC
bi208	3.76E-06	NCT
bi210	1.96E+04	HAC
bi210m	2.20E-02	HAC
bk249	5.28E+04	HAC
br77	9.13E-03	NCT
br82	5.93E-05	NCT
c14	5.83E+05	HAC
ca41	4.10E+02	HAC
ca45	5.83E+05	HAC

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
h3	5.83E+05	HAC
be7	1.93E-01	HAC
c14	5.83E+05	HAC
na22	5.38E-05	NCT
na24	3.38E-06	NCT
cl36	3.35E+02	HAC
ar37	4.49E-02	HAC
k40	2.42E-04	NCT
ca41	4.10E+02	HAC
ca45	5.83E+05	HAC
sc46	7.66E-05	NCT
ca47	7.23E-05	NCT
sc47	2.93E-02	HAC
sc48	2.67E-05	NCT
v49	1.07E+02	HAC
cr51	1.98E-01	HAC
mn54[1]	1.65E-02	NCT
fe55	1.63E+03	HAC
co57	1.99E-02	HAC
co58[1]	6.96E-03	NCT
fe59[1]	7.11E-04	NCT
ni59	3.30E+00	NCT
co60[1]	2.50E-04	NCT
ni63	5.83E+05	HAC
cu64	6.61E-03	NCT
zn65[1]	2.34E-03	NCT
cu67	4.00E-02	HAC
ga67	4.31E-02	HAC
ge69	1.25E-04	NCT
as71	1.37E-03	NCT
ge71	5.83E+05	HAC
as72	8.49E-05	NCT
se72	5.83E+05	HAC
zn72	2.06E-02	HAC
as73	5.83E+05	HAC
as74	7.27E-03	NCT

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
ca47	7.23E-05	NCT
cd109	5.83E+05	HAC
cd113m	8.69E+01	HAC
cd115	3.40E-02	HAC
cd115m	4.17E-03	NCT
ce139	2.50E-02	HAC
ce141	4.14E-02	HAC
ce143	9.23E-03	NCT
ce144	1.80E-01	HAC
cf249	2.18E-02	HAC
cf250	5.83E+05	HAC
cf251	2.48E-02	HAC
cf252	1.34E+02	HAC
cl36	3.35E+02	HAC
cm241	1.16E-02	HAC
cm242	4.05E+02	HAC
cm243	3.16E-02	HAC
cm244	8.69E+02	NCT
cm245	3.76E-02	HAC
cm246	5.83E+05	HAC
cm247	2.45E-02	HAC
cm248	5.83E+05	HAC
co57	1.99E-02	HAC
co58[1]	6.96E-03	NCT
co60[1]	2.50E-04	NCT
cr51	1.98E-01	HAC
cs129	2.97E-02	HAC
cs131	5.83E+05	HAC
cs132	2.34E-03	NCT
cs134[1]	6.03E-03	NCT
cs136	1.09E-04	NCT
cs137[1]	7.95E-02	HAC
cs144	5.27E-06	NCT
cu64	6.61E-03	NCT
cu67	4.00E-02	HAC
dy159	5.83E+05	HAC
dy166	1.70E+00	HAC
er169	1.53E+03	HAC

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
se75	1.14E-02	HAC
as76	2.84E-04	NCT
as77	7.12E-01	HAC
br77	9.13E-03	NCT
kr79	4.27E-03	NCT
kr81	5.11E-01	HAC
br82	5.93E-05	NCT
rb83	1.23E-02	HAC
sr83	2.25E-04	NCT
rb84	6.41E-04	NCT
kr85	2.62E+00	HAC
sr85	1.15E-02	HAC
rb86	1.82E-03	NCT
y87	1.16E-02	HAC
y88	1.02E-05	NCT
zr88	2.05E-02	HAC
sr89	5.83E+05	HAC
zr89	1.18E-03	NCT
sr90	3.64E+02	NCT
nb91	3.47E+00	HAC
y91	1.80E-02	NCT
nb92	3.41E-04	NCT
mo93	5.83E+05	HAC
nb93m	5.83E+05	HAC
nb94	6.40E-04	NCT
nb95	2.59E-03	NCT
zr95	2.62E-03	NCT
nb95m	7.52E-02	HAC
tc95m	1.59E-03	NCT
tc96	2.23E-04	NCT
ru97	2.01E-02	HAC
tc97	5.81E+05	HAC
tc97m	5.83E+05	HAC
tc98	1.97E-03	NCT
mo99	9.03E-03	NCT
rh99	7.83E-04	NCT
tc99	5.83E+05	HAC
tc99m	2.24E-02	HAC

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
er172	3.72E-02	HAC
es253	1.90E+01	HAC
es254	4.48E+00	HAC
eu149	1.91E-01	HAC
eu152	8.35E-05	NCT
eu154	9.69E-05	NCT
eu155	9.11E-02	HAC
eu156	2.26E-05	NCT
fe55	1.63E+03	HAC
fe59[1]	7.11E-04	NCT
ga67	4.31E-02	HAC
gd147	1.93E-04	NCT
gd149	4.88E-03	NCT
gd153	9.29E-02	HAC
ge69	1.25E-04	NCT
ge71	5.83E+05	HAC
h3	5.83E+05	HAC
hf172	1.20E-01	HAC
hf175	2.30E-02	HAC
hf181	1.36E-02	HAC
hf182	2.22E-02	HAC
hg203	2.45E-02	HAC
ho166	2.17E-03	NCT
ho166m	5.45E-04	NCT
i124	5.54E-05	NCT
i125	5.83E+05	HAC
i126	5.10E-03	NCT
i129	5.83E+05	HAC
i131	1.71E-02	HAC
in113m	3.11E-02	HAC
in114m	4.87E-02	NCT
ir192	2.36E-01	HAC
ir194m	2.25E-03	NCT
k40	2.42E-04	NCT
kr79	4.27E-03	NCT
kr81	5.11E-01	HAC
kr85	2.62E+00	HAC
la137	1.73E+01	HAC

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
rh101	1.30E-02	HAC
rh101m	2.23E-02	HAC
rh102	1.23E-03	NCT
rh102m	1.88E-04	NCT
pd103	6.91E+01	HAC
ru103	1.83E-02	HAC
ag105	3.32E-03	NCT
rh105	8.17E-02	HAC
ru106	1.57E-03	NCT
ag106m	4.45E-05	NCT
ag108m	2.12E-03	NCT
cd109	5.83E+05	HAC
ag110	3.68E-02	NCT
ag110m[1]	4.84E-04	NCT
ag111	2.47E-01	HAC
sn113	1.09E+00	HAC
cd113m	8.69E+01	HAC
in113m	3.11E-02	HAC
sn113m	5.83E+05	HAC
in114m	4.87E-02	NCT
cd115	3.40E-02	HAC
cd115m	4.17E-03	NCT
sn117m	2.25E-02	HAC
te118	5.83E+05	HAC
sb119	5.83E+05	HAC
sn119m	5.83E+05	HAC
sb120m	5.51E-05	NCT
te121	1.15E-02	HAC
sn121m	5.83E+05	HAC
te121m	3.15E-03	NCT
sb122	3.62E-03	NCT
sn123	2.46E-02	NCT
te123	5.83E+05	HAC
te123m	2.37E-02	HAC
i124	5.54E-05	NCT
sb124	2.19E-05	NCT
i125	5.83E+05	HAC
sb125	1.29E-02	HAC

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
la138	3.87E-05	NCT
la140	1.63E-05	NCT
lu169	4.55E-05	NCT
lu171	2.56E-03	NCT
lu172	6.68E-05	NCT
lu176	1.12E-02	HAC
lu177	1.12E-01	HAC
lu177m	3.73E-02	HAC
mn54[1]	1.65E-02	NCT
mo93	5.83E+05	HAC
mo99	9.03E-03	NCT
na22	5.38E-05	NCT
na24	3.38E-06	NCT
nb91	3.47E+00	HAC
nb92	3.41E-04	NCT
nb93m	5.83E+05	HAC
nb94	6.40E-04	NCT
nb95	2.59E-03	NCT
nb95m	7.52E-02	HAC
nd140	5.83E+05	HAC
nd147	6.37E-02	HAC
ni59	3.30E+00	NCT
ni63	5.83E+05	HAC
np235	5.83E+05	HAC
np236	3.88E-02	HAC
np237	5.86E-01	HAC
np238	3.49E-04	NCT
np239	2.04E-02	HAC
os185	6.57E-03	NCT
os191	6.88E-02	HAC
os193	1.08E-01	HAC
os194	5.83E+05	HAC
pa231	2.09E-01	HAC
pa232	5.96E-04	NCT
pa233	3.22E-02	HAC
pb205	5.83E+05	HAC
pb210	5.83E+05	HAC
pd103	6.91E+01	HAC

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
sn125	1.82E-04	NCT
te125m	7.07E+00	HAC
i126	5.10E-03	NCT
sb126	6.14E-04	NCT
sn126	6.59E-02	HAC
sb127	3.61E-03	NCT
xe127	1.73E-02	HAC
te127m	3.73E+01	HAC
cs129	2.97E-02	HAC
i129	5.83E+05	HAC
te129m	8.36E-02	NCT
xe129m	4.35E-01	HAC
ba131	7.28E-03	NCT
cs131	5.83E+05	HAC
i131	1.71E-02	HAC
te131m	7.96E-05	NCT
xe131m	1.02E+00	HAC
cs132	2.34E-03	NCT
te132	2.17E-02	HAC
ba133	2.04E-02	HAC
xe133	2.72E+01	HAC
xe133m	1.99E-01	HAC
cs134[1]	6.03E-03	NCT
ba135m	1.28E-01	HAC
cs136	1.09E-04	NCT
cs137[1]	7.95E-02	HAC
la137	1.73E+01	HAC
la138	3.87E-05	NCT
ce139	2.50E-02	HAC
ba140	3.43E-02	HAC
la140	1.63E-05	NCT
nd140	5.83E+05	HAC
ce141	4.14E-02	HAC
ce143	9.23E-03	NCT
pm143	6.71E-03	NCT
pr143	2.15E+05	NCT
ce144	1.80E-01	HAC
cs144	5.27E-06	NCT

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric			Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition	Radionuclide	Max. Ci/g	Condition
pm143	6.71E-03	NCT	pm144	3.14E-03	HAC
pm144	3.14E-03	HAC	pr144	6.75E-04	NCT
pm145	5.83E+05	HAC	pm145	5.83E+05	HAC
pm146	4.35E-03	NCT	sm145	5.73E+02	HAC
pm147	7.00E+02	HAC	pm146	4.35E-03	NCT
pm148	1.10E-04	NCT	gd147	1.93E-04	NCT
pm148m	4.79E-04	NCT	nd147	6.37E-02	HAC
pm149	3.21E-01	NCT	pm147	7.00E+02	HAC
pm151	1.27E-02	NCT	pm148	1.10E-04	NCT
po210	7.99E+01	NCT	pm148m	4.79E-04	NCT
pr143	2.15E+05	NCT	eu149	1.91E-01	HAC
pr144	6.75E-04	NCT	gd149	4.88E-03	NCT
pt191	3.21E-02	HAC	pm149	3.21E-01	NCT
pt193	5.83E+05	HAC	pm151	1.27E-02	NCT
pt193m	1.78E+01	HAC	sm151	5.83E+05	HAC
pt195m	6.57E-01	HAC	eu152	8.35E-05	NCT
pu236	1.44E+02	HAC	gd153	9.29E-02	HAC
pu237	6.27E-02	HAC	sm153	6.61E-02	HAC
pu238	1.62E+03	HAC	tb153	2.83E-03	NCT
pu239	1.14E+02	HAC	eu154	9.69E-05	NCT
pu240	2.60E+02	HAC	eu155	9.11E-02	HAC
pu241	3.67E+03	HAC	tb155	3.46E-02	HAC
pu242	6.96E+02	HAC	eu156	2.26E-05	NCT
pu246	2.54E-02	HAC	tb156	4.10E-05	NCT
ra223	5.77E-02	HAC	tb157	5.83E+05	HAC
ra224	4.99E-01	HAC	tb158	4.32E-04	NCT
ra225	5.83E+05	HAC	dy159	5.83E+05	HAC
ra226	5.69E-01	HAC	tb160	1.56E-04	NCT
ra228	5.83E+05	HAC	tb161	4.57E+00	HAC
rb83	1.23E-02	HAC	tm165	8.21E-04	NCT
rb84	6.41E-04	NCT	dy166	1.70E+00	HAC
rb86	1.82E-03	NCT	ho166	2.17E-03	NCT
re186	2.10E-01	HAC	yb166	5.83E+05	HAC
re189	9.10E-02	HAC	ho166m	5.45E-04	NCT
rh101	1.30E-02	HAC	tm167	4.47E-02	HAC
rh101m	2.23E-02	HAC	tm168	6.65E-04	NCT
rh102	1.23E-03	NCT	er169	1.53E+03	HAC
rh102m	1.88E-04	NCT	lu169	4.55E-05	NCT

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
rh105	8.17E-02	HAC
rh99	7.83E-04	NCT
rn222	1.50E+01	HAC
ru103	1.83E-02	HAC
ru106	1.57E-03	NCT
ru97	2.01E-02	HAC
sb119	5.83E+05	HAC
sb120m	5.51E-05	NCT
sb122	3.62E-03	NCT
sb124	2.19E-05	NCT
sb125	1.29E-02	HAC
sb126	6.14E-04	NCT
sb127	3.61E-03	NCT
sc46	7.66E-05	NCT
sc47	2.93E-02	HAC
sc48	2.67E-05	NCT
se72	5.83E+05	HAC
se75	1.14E-02	HAC
sm145	5.73E+02	HAC
sm151	5.83E+05	HAC
sm153	6.61E-02	HAC
sn113	1.09E+00	HAC
sn113m	5.83E+05	HAC
sn117m	2.25E-02	HAC
sn119m	5.83E+05	HAC
sn121m	5.83E+05	HAC
sn123	2.46E-02	NCT
sn125	1.82E-04	NCT
sn126	6.59E-02	HAC
sr83	2.25E-04	NCT
sr85	1.15E-02	HAC
sr89	5.83E+05	HAC
sr90	3.64E+02	NCT
ta182	6.93E-05	NCT
ta183	2.04E-02	HAC
tb153	2.83E-03	NCT
tb155	3.46E-02	HAC
tb156	4.10E-05	NCT

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
yb169	1.97E-02	HAC
tm170	5.83E+05	HAC
lu171	2.56E-03	NCT
tm171	5.83E+05	HAC
er172	3.72E-02	HAC
hf172	1.20E-01	HAC
lu172	6.68E-05	NCT
tm172	9.32E-05	NCT
hf175	2.30E-02	HAC
yb175	1.69E-01	HAC
lu176	1.12E-02	HAC
lu177	1.12E-01	HAC
lu177m	3.73E-02	HAC
hf181	1.36E-02	HAC
w181	1.72E+01	HAC
hf182	2.22E-02	HAC
ta182	6.93E-05	NCT
ta183	2.04E-02	HAC
os185	6.57E-03	NCT
w185	1.07E+02	HAC
re186	2.10E-01	HAC
w188	3.13E+00	HAC
re189	9.10E-02	HAC
os191	6.88E-02	HAC
pt191	3.21E-02	HAC
ir192	2.36E-01	HAC
os193	1.08E-01	HAC
pt193	5.83E+05	HAC
pt193m	1.78E+01	HAC
os194	5.83E+05	HAC
ir194m	2.25E-03	NCT
pt195m	6.57E-01	HAC
au198	2.01E-02	HAC
au199	4.09E-02	HAC
hg203	2.45E-02	HAC
tl204	5.83E+05	HAC
pb205	5.83E+05	HAC
bi208	3.76E-06	NCT

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
tb157	5.83E+05	HAC
tb158	4.32E-04	NCT
tb160	1.56E-04	NCT
tb161	4.57E+00	HAC
tc95m	1.59E-03	NCT
tc96	2.23E-04	NCT
tc97	5.81E+05	HAC
tc97m	5.83E+05	HAC
tc98	1.97E-03	NCT
tc99	5.83E+05	HAC
tc99m	2.24E-02	HAC
te118	5.83E+05	HAC
te121	1.15E-02	HAC
te121m	3.15E-03	NCT
te123	5.83E+05	HAC
te123m	2.37E-02	HAC
te125m	7.07E+00	HAC
te127m	3.73E+01	HAC
te129m	8.36E-02	NCT
te131m	7.96E-05	NCT
te132	2.17E-02	HAC
th227	5.64E-02	HAC
th228	3.85E+00	HAC
th229	9.61E-02	HAC
th230	2.84E+01	HAC
th231	1.60E+00	HAC
th232	7.27E+01	HAC
th234	7.08E+00	HAC
tl204	5.83E+05	HAC
tm165	8.21E-04	NCT
tm167	4.47E-02	HAC
tm168	6.65E-04	NCT
tm170	5.83E+05	HAC
tm171	5.83E+05	HAC
tm172	9.32E-05	NCT
u230	6.10E+00	HAC
u232	2.54E+01	HAC
u233	2.67E+01	HAC

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
bi210	1.96E+04	HAC
pb210	5.83E+05	HAC
po210	7.99E+01	NCT
bi210m	2.20E-02	HAC
rn222	1.50E+01	HAC
ra223	5.77E-02	HAC
ra224	4.99E-01	HAC
ac225	5.06E-01	HAC
ra225	5.83E+05	HAC
ra226	5.69E-01	HAC
ac227	4.82E+01	HAC
th227	5.64E-02	HAC
ra228	5.83E+05	HAC
th228	3.85E+00	HAC
th229	9.61E-02	HAC
th230	2.84E+01	HAC
u230	6.10E+00	HAC
pa231	2.09E-01	HAC
th231	1.60E+00	HAC
pa232	5.96E-04	NCT
th232	7.27E+01	HAC
u232	2.54E+01	HAC
pa233	3.22E-02	HAC
u233	2.67E+01	HAC
th234	7.08E+00	HAC
u234	5.50E+01	HAC
np235	5.83E+05	HAC
u235	2.32E-02	HAC
np236	3.88E-02	HAC
pu236	1.44E+02	HAC
u236	9.99E+01	HAC
np237	5.86E-01	HAC
pu237	6.27E-02	HAC
u237	3.13E-02	HAC
np238	3.49E-04	NCT
pu238	1.62E+03	HAC
u238	1.86E+02	HAC
np239	2.04E-02	HAC

Table 5.5.3-1 (Continued)

Ordered by Alphanumeric		
Radionuclide	Max. Ci/g	Condition
u234	5.50E+01	HAC
u235	2.32E-02	HAC
u236	9.99E+01	HAC
u237	3.13E-02	HAC
u238	1.86E+02	HAC
v49	1.07E+02	HAC
w181	1.72E+01	HAC
w185	1.07E+02	HAC
w188	3.13E+00	HAC
xe127	1.73E-02	HAC
xe129m	4.35E-01	HAC
xe131m	1.02E+00	HAC
xe133	2.72E+01	HAC
xe133m	1.99E-01	HAC
y87	1.16E-02	HAC
y88	1.02E-05	NCT
y91	1.80E-02	NCT
yb166	5.83E+05	HAC
yb169	1.97E-02	HAC
yb175	1.69E-01	HAC
zn65[1]	2.34E-03	NCT
zn72	2.06E-02	HAC
zr88	2.05E-02	HAC
zr89	1.18E-03	NCT
zr95	2.62E-03	NCT

Ordered by Atomic Number		
Radionuclide	Max. Ci/g	Condition
pu239	1.14E+02	HAC
am240	4.09E-04	NCT
pu240	2.60E+02	HAC
am241	6.02E+01	HAC
cm241	1.16E-02	HAC
pu241	3.67E+03	HAC
am242	5.83E+05	HAC
cm242	4.05E+02	HAC
pu242	6.96E+02	HAC
am242m	1.20E+01	HAC
am243	2.81E+00	HAC
cm243	3.16E-02	HAC
cm244	8.69E+02	NCT
cm245	3.76E-02	HAC
cm246	5.83E+05	HAC
pu246	2.54E-02	HAC
cm247	2.45E-02	HAC
cm248	5.83E+05	HAC
bk249	5.28E+04	HAC
cf249	2.18E-02	HAC
cf250	5.83E+05	HAC
cf251	2.48E-02	HAC
cf252	1.34E+02	HAC
es253	1.90E+01	HAC
es254	4.48E+00	HAC

Note 1: Marked nuclides are analyzed individually.

5.5.4 Process Description for Calculating Maximum Allowed Source Strength Density

Generic Energy Line Method:

1. MCNP Calculated Dose Rate for Each Tally Location

MCNP6 Generic Energy Line Method Output Files			
Low energy (0.5-6.0 MeV)	**Mid energy (0.7-1.0 MeV)**	**High energy (1.1-6.0 MeV)**	**Additional energy (7.0-8.0 MeV)**
rpbnGenericlo	rpbnGenericmo	rpbnGenericho	rpbnGeneric78o
rptnGenericlo	rptnGenericmo	rptnGenericho	rptnGeneric78o
rpsnGenericlo	rpsnGenericmo	rpsnGenericho	rpsnGeneric78o
rpbaGenericlo	rpbaGenericmo	rpbaGenericho	rpbaGeneric78o
rptaGenericlo	rptaGenericmo	rptaGenericho	rptaGeneric78o
rpsaGenericlo	rpsaGenericmo	rpsaGenericho	rpsaGeneric78o

2. Compile Results

Compile all MCNP6 output Tally results into Excel sheet *Tally_Results.xlsx* and determine maximum dose rate calculated for each energy line at each dose rate location.

3. Generate Nuclide Energy Grouping

Compile all nuclide photon energy lines from Origen-S data library *origen.rev02.mpdkxgam* and generate energy grouping based on generic energy lines in excel sheet *nuclide_energy_groups.xlsx*. (As shown for Fe-59 in Figure 5.4.1-1)

4. Calculate Nuclide Dose Rates and Specific Activity Limits

Take nuclide energy groups from *nuclide_energy_groups.xlsx* and calculated energy line dose rates from *Tally_Results.xlsx* to calculate nuclide-specific dose rates and specific activity limits in Excel sheet *DoseRateCalc.xlsx*. (Results shown in Table 5.5.2-1, Table 5.5.2-2, and Table 5.5.3-1)

Individual Nuclides:

1. MCNP Calculated Dose Rate for Each Nuclide Location

MCNP6 Individual Nuclide Output Files			
Co-60	**Ba-137m**	**Zn-65**	**Fe-59**
rpbnCo60o	rpbnBa137mo	rpbnZn65o	rpbnFe59o
rptnCo60o	rptnBa137mo	rptnZn65o	rptnFe59o
rpsnCo60o	rpsnBa137mo	rpsnZn65o	rpsnFe59o
rpbaCo60o	rpbaBa137mo	rpbaZn65o	rpbaFe59o
rptaCo60o	rptaBa137mo	rptaZn65o	rptaFe59o
rpsaCo60o	rpsaBa137mo	rpsaZn65o	rpsaFe59o
Co-58	**Ag-110m**	**Mn-54**	**Cs-134**
rpbnCo58o	rpbnAg110mo	rpbnMn54o	rpbnCs134o
rptnCo58o	rptnAg110mo	rptnMn54o	rptnCs134o
rpsnCo58o	rpsnAg110mo	rpsnMn54o	rpsnCs134o
rpbaCo58o	rpbaAg110mo	rpbaMn54o	rpbaCs134o
rptaCo58o	rptaAg110mo	rptaMn54o	rptaCs134o
rpsaCo58o	rpsaAg110mo	rpsaMn54o	rpsaCs134o

2. Compile Results

Compile all MCNP6 output Tally results and calculates dose rates and specific activity limits for each nuclide individually in Excel sheets: *Co60.xlsx*, *Co58.xlsx*, *Cs137.xlsx*, *Ag110m.xlsx*, *Zn65.xlsx*, *Mn54.xlsx*, *Fe59.xlsx*, and *Cs134.xlsx*.

5.6 References

1. Robatel Technologies, LLC, Quality Assurance Program for Packaging and Transportation of Radioactive Material, 10 CFR 71 Subpart H, Dated January 31, 2012 and NRC Approved on March 21, 2012.
2. U.S. Nuclear Regulatory Commission, 10 CFR Part 71--PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL, dated March 7, 2012 and the following specific Sections:

71.31(a)(1)	71.31(a)(2)	71.33	71.35(a)
71.31.(c)	71.71	71.43(f)	71.51(a)(1)
71.47(a)	71.47(b)	71.47	71.31
71.51(a)(2)	71.73		

3. LA-UR-13-22934, "Initial MCNP 6 Release Overview – MCNP6 version 1.0," Los Alamos National Laboratory, T. Goorley, et al., April 2013.
4. "*ORIGEN-S Data Libraries*," ORNL/TM-2005/39, Volume 3, Section M6, January 2009.
5. LA-UR-13-22934, "Initial MCNP 6 Release Overview – MCNP6 version 1.0," Los Alamos National Laboratory, T. Goorley, et al., April 20 "ORIGEN-S: SCALE System Module To Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup And Decay, And Associated Radiation Source Terms," I. C. Gauld, O. W. Herman and R. M. Westfall, ORNL/TM-2005/39, Volume 2, Section F7, January 2009."ORIGEN-S Data Libraries," ORNL/TM-2005/39, Volume 3, Section M6, January 2009.
6. RTL-001-CALC-SH-0101, Rev. 1, "Source Term Characterization for the RT-100" (PROPRIETARY)
7. RTL-001-CALC-SH-0201, Rev. 5, "Shielding Evaluation of the RT-100 Transport Cask" (PROPRIETARY)
8. CN-13039-502, "Updated Resin/Filter Shielding Evaluation of the RT-100 Transport Cask"
9. ORNL/TM-2005/39, Volume III, Section M8, "*Standard Composition Library,*" L.M. Petrie, P.B. Fox and K. Lucius, January 2009.
10. PNNL-15870, "*Compendium of Material Composition Data for Radiation Transport Modeling*," R.G. Williams III, C.J. Gesh and R.T. Pagh, April 2006.
11. Faujasite-Na Mineral Data, Retrieved August 27, 2013, Retrieved from http://webmineral.com/data/Faujasite-Na.shtml.
12. J. Conlin, et al., "Listing of Available ACE Data Tables," LA-UR-13-21822 Rev-2, Los Alamos National Laboratory, Dec 2013.
13. ANSI/ANS 6.1.1-1997, "American National Standard for Neutron and Gamma Flux-To-Dose Conversion Factors," American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL, www.ans.org.

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6. CRITICALITY EVALUATION

This Section is NOT APPLICABLE. The RT-100 is not designed to transport fissile material subject to the requirements of 10 CFR Part 71 Sections 71.55 or 71.59. Therefore, no criticality evaluation is necessary for the SAR of the RT-100.

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