Enclosure 3 to E-41950

Changed Pages, TN-RAM SAR, Revision 14
(Non-Proprietary)

Non-Proprietary

SAFETY ANALYSIS REPORT
for the
TN-RAM

E-10621

May 2015

Revision *14*

AREVA Inc.
7135 Minstrel Way, Suite 300
Columbia, Maryland 21045

groove machined in the penetration cover. Leak testing of this penetration is accomplished using a vacuum bell as described in Chapter Seven.

1.2.2 Operational Features

There are no complex operational features associated with the TN-RAM. The packaging is designed to accommodate wet or dry loading/unloading operations. Loading/unloading activities can be accomplished with the packaging either horizontal or vertical. The TN-RAM is uprighted from the horizontal transport orientation to the vertical position by lifting at two of the front trunnions and allowing the packaging to pivot about the rear trunnions while supported in the transport cradle. Both impact limiters are removed prior to this handling operation. Cask handling in the vertical position can be accomplished with either pair of opposing top trunnions, or with all four top trunnions if redundancy is required. For horizontal loading/unloading operations, the cask is left in the transport cradle. Significant design features which support wet operations include self-draining bolt holes in the cask body closure flange, two penetrations for draining/drying activities, and smooth stainless steel surfaces to minimize decontamination efforts.

The sequential steps to be followed for cask loading/unloading operations and pre-transport preparations including seal testing are provided in Chapter Seven.

1.2.3 Contents of Packaging

The TN-RAM is designed to transport a payload of 9,500 lbs of dry irradiated and contaminated, non-fuel-bearing solid materials (with only trace quantities of fissile materials present as contamination) in secondary containers.

The safety analysis of the TN-RAM takes no credit for the containment provided by secondary containers.

The quantity of radioactive material is limited to a maximum of 30,000 Ci cobalt-60 or equivalent *as described in Section 5.2.1.* The radioactive material is primarily in the form of neutron activated metals, or metal oxides in solid form. Surface contamination may also be present on the irradiated components. When a wet load procedure (i.e., in-pool) is followed for cask loading, cask cavity draining and drying is performed in order to ensure that free liquids do not remain in the package during transport.

The average specific activity of the contents is limited to 10 Ci/kg.

The decay heat load of the radioactive material is limited to a maximum of 500 watts.

The TN-RAM is designed for shipment of various types of irradiated reactor hardware. The payload will vary from shipment to shipment and will consist predominantly of the following components either individually or in combinations:

1. BWR Control Rod Blades
2. BWR Local Power Range Monitors (LPRMs)
3. BWR Fuel Channels
4. BWR Poison Curtains

mechanical properties used in the structural analyses. Temperatures are also calculated to demonstrate that specified limits for seal materials are not exceeded.

The design of the steel encased wooden impact limiters is described in Chapter One. There are no temperature limits specified for the impact limiters; however, these components are considered in the thermal analysis because of their contribution as a thermal insulator. Since the impact limiters cover the lid and bottom regions of the cask, it is assumed that all decay heat is rejected radially out of the package. Similarly, the impact limiters protect the lid and bottom regions from the external heat load applied during the hypothetical thermal accident event.

Several thermal design criteria have been established for the TN-RAM.

- Containment of radioactive material is a major design requirement for the TN-RAM. Therefore, seal temperatures must be maintained within specified limits to satisfy the required containment criteria (Chapter Four) under normal and accident conditions. *According to the material report of Parker O-Ring (Reference 3-6), a* maximum equilibrium seal temperature of *450* °F is set for the silicone O-rings under normal and accident conditions. This limit applies to all containment boundary seals used in the cask closure lid and containment penetrations.
- In accordance with 10 CFR 71.43(g) (Ref*erence* 3-1) the maximum temperature of accessible package surfaces in the shade is limited to 185 °F for exclusive use shipments.
- *The lead has a melting point of approximately 621 °F. The maximum temperature of the lead used in the cask body and lid is limited to this melting point of lead.*

Table 3-1
Summary of Results

Normal Conditions of Transport			
Packaging Components		***Maximum Temperatures (°F)***	***Temperature Limits (°F)***
Outer Surface (thermal shield)	*with insolation*	*143*	*Note (1)*
	without insolation	*109*	*185*
Outer Shell (flange region)		*144*	*Note (1)*
Lead		*148*	*621*
Inner Shell/Cavity Wall		*146*	*Note (1)*
Lid		*146*	*Note (1)*
Lid Seals		*145*	*450*
Vent Port Seals		*146*	*450*
Drain Port Seals		*144*	*450*
Average Cavity Gas Temperature (2)		*176*	*Note (1)*
Accident Conditions			
Packaging Components		***Maximum Transient Temperatures (°F)***	***Temperature Limits (°F)***
Outer Surface (thermal shield)		*1173*	*Note (1)*
Outer Shell (flange region)		*801*	*Note (1)*
Lead		*612*	*621*
Inner Shell/Cavity Wall		*470*	*Note (1)*
Cavity "Cold Wall" (Peak) (3)		*220*	*Note (1)*
Lid		*499*	*Note (1)*
Lid Seals		*397*	*450*
Vent Port Seals		*441*	*450*
Drain Port Seals		*392*	*450*
Average Cavity Gas Temperature (2)		*500*	*Note (1)*

Notes:

(1) The components without an explicit temperature limit perform their intended safety function within the operating range
(2) Cavity wall temperature + 30 °F
(3) Peak value of the minimum (coldest) temperature on the cavity wall during accident

3.3 TECHNICAL SPECIFICATION OF COMPONENTS

The only packaging component for which a thermal technical specification is necessary *is* the seals. The seals used in the packaging must be made of silicone equivalent to Parker O-ring compound S604-70. The critical parameters to demonstrate equivalency to the Parker O-ring compound S604-70 are listed in the following table:

Critical parameters	**Parker O-ring compound S604-70**
Durometer hardness	65-75
Temperature range	*-65 °F to 450 °F*
Elongation, %	160

TABLE 3-4
THERMAL ANALYSIS RESULTS FOR NORMAL CONDITIONS OF TRANSPORT

Packaging Components		***Maximum Temperatures (°F)***	***Temperature Limits (°F)***
Outer Surface	*with insolation*	*143*	*Note (1)*
	without insolation	*109*	*185*
Outer Shell (flange region)		*144*	*Note (1)*
Lead		*148*	*621*
Inner Shell/Cavity Wall		*146*	*Note (1)*
Lid		*146*	*Note (1)*
Lid Seals		*145*	*450*
Vent Port Seals		*146*	*450*
Drain Port Seals		*144*	*450*
Average Cavity Gas Temperature [(2)]		*176*	*Note (1)*

Notes:

(1) The components without an explicit temperature limit perform their intended safety function within the operating range

(2) Cavity wall temperature + 30 °F

3.4.3 Minimum Temperatures

Under the minimum temperature condition of -40 °F ambient, the resulting packaging component temperatures will approach -40 °F at equilibrium. Since the packaging materials, including containment structures, impact limiters and seals, continue to function at this temperature, the minimum temperature condition has no adverse effect on the performance of the TN-RAM.

3.4.4 Maximum Internal Pressures

There are no gases generated due to the chemical or galvanic reactions as noted in Section 2.4.4. Further, since organic materials are not allowed, there are no gases generated due to radiolysis as noted in Section 4.2.2.

The TN-RAM cask model described in Section 3.4.1 is modified to remove the solar insolation. The result from the thermal evaluation of the TN-RAM cask under NCT without solar insolation shows that the maximum temperature among all the cask components is 115 °F and is only 15 °F higher than the ambient temperature of 100 °F. This shows that the heat load of 500 watts is very low and that the maximum temperature rise in the cask components because of the internal heat load is limited to 15 °F. However, to evaluate the internal pressure, it is conservatively assumed that the average cavity gas temperature is 30 °F higher than the inner shell for all conditions. Therefore, the average cavity gas temperature for NCT is 176 °F (146 °F + 30 °F).

The maximum internal pressure is calculated assuming:

- Cavity gas is saturated with water vapor. The partial water vapor pressure is based on the minimum cavity wall ("cold wall") temperature.
- Average cavity gas temperature

  = maximum cavity wall temperature +30 °F

  = 146 + 30 °F

  = 176 °F
- Cask is closed and sealed at 70 °F and 1 atm (14.7 psi)

  Partial water vapor pressure at cavity "cold wall" temperature (146 °F)

  P_w = 3.44 psia (Ref. 3-5)

Partial air pressure at 176 °F

P_a = 14.7 x (176 + 460)/(70 + 460)

= 17.64 psia

Total cavity pressure

= $P_w + P_a$

= 3.44 + 17.64

= 21.08 psia (6.38 psig)

NOTE: The maximum normal operating pressure is conservatively assumed to be 30 psig.

3.4.5 Maximum Thermal Stresses

The maximum thermal stresses during normal conditions of transport are calculated in Section 2.6 of Chapter 2.

3.4.6 Evaluation of Package Performance

The thermal analysis for normal conditions concludes that the TN-RAM design meets all applicable requirements. The maximum temperatures calculated using conservative assumptions are relatively low. The maximum temperature of any containment structural component is 146 °F, which has an insignificant effect on the mechanical properties of the containment materials used. The maximum lead temperature (148 °F) is well below allowable values. The seal temperature during normal transport conditions is well below the *450* °F long-term limit specified for continued seal function. The maximum accessible surface temperature of 109 °F is below the specified 185 °F limit.

Table 3-7

Thermal Analysis Results for Accident Conditions

Packaging Components	***Maximum Transient Temperatures (°F)***	***Time (hr)*** [4]	***Temperature Limits (°F)***
Outer Surface (thermal shield)	*1173*	*0.5*	*Note (1)*
Outer Shell	*801*	*0.5*	*Note (1)*
Lead	*612*	*0.5*	*621*
Inner Shell/Cavity Wall	*470*	*1.1*	*Note (1)*
Cavity "Cold Wall" (Peak) [3]	*220*	---	*Note (1)*
Lid	*499*	*1.0*	*Note (1)*
Lid Seals	*397*	*1.1*	*450*
Vent Port Seals	*441*	*1.0*	*450*
Drain Port Seals	*392*	*1.6*	*450*
Average Cavity Gas Temperature [2]	*500*	---	*Note (1)*

Notes:

(1) The components without an explicit temperature limit perform their intended safety function within the operating range

(2) Cavity wall temperature + 30 °F

(3) Peak value of the minimum (coldest) temperature on the cavity wall during accident

(4) Time from start of thermal accident event

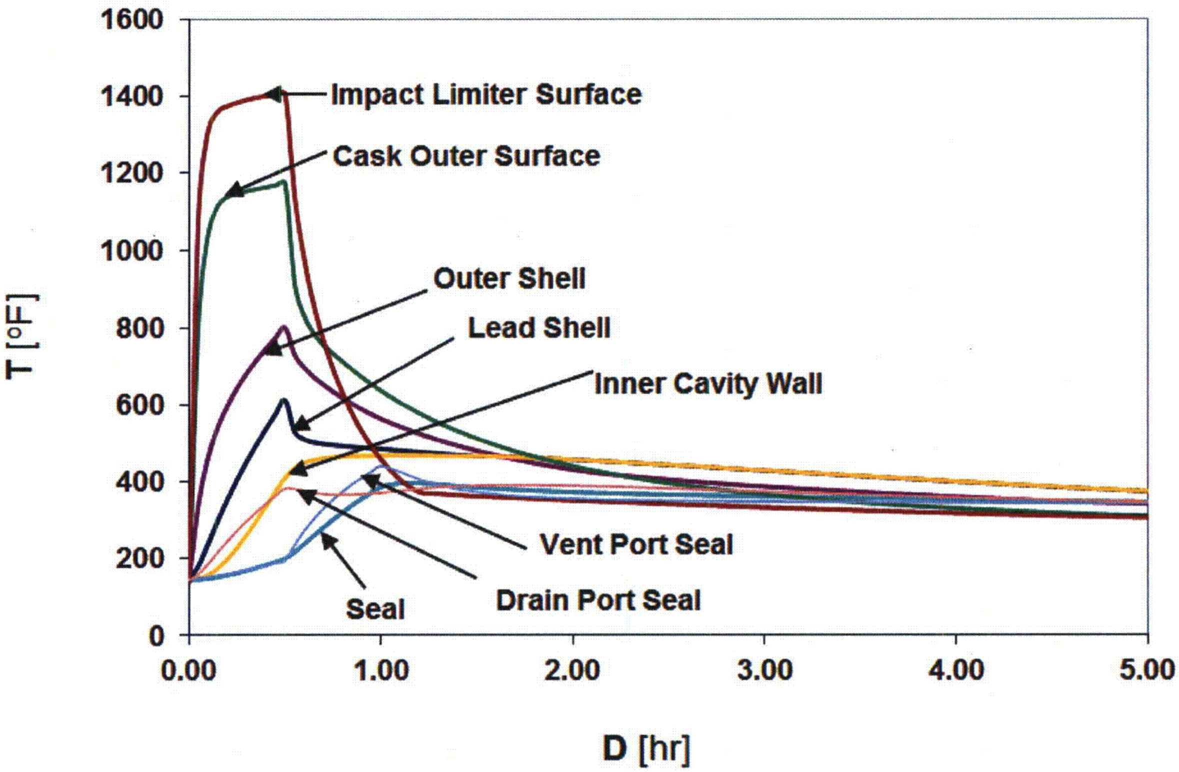


Figure 3-8
History of the Maximum Component Temperatures during Fire and Post Fire Periods

3.6 REFERENCES

3-1 U.S. Code of Federal Regulations 10 CFR *Part* 71, "Packaging and Transportation of Radioactive Material."

3-2 Kreith, F., "Principles of Heat Transfer," 3rd Edition, Harper and Row Publishers, 1973.

3-3 ANSYS Computer Code User's Manuals, Version 10.0A1.

3-4 Shappert, L. B., "Cask Designers Guide, A Guide for the Design, Fabrication and Operation of Shipping Casks for Nuclear Applications," ORNL-NSIC-68, UC-80-Reactor Technology, Oak Ridge National Laboratory, 1970.

3-5 Rohsenow et.al, "Handbook of Heat Transfer," McGraw-Hill Book Company, New York, 1973.

3-6 *Material Report of Parker Compound S0604-70, Report Number #KK1476, Parker O-Ring Division United States, Lexington, Kentucky, 1982.*

3-7 Gregory, et al., "Thermal Measurements in a Series of Long Pool Fires," SANDIA Report, SAND 85-0196, TTC-0659, 1987.

3-8 U.S. Department of Agriculture, Forest Service, "Wood Handbook: Wood as an Engineering Material."

3-9 Rohsenow, Hartnett, Cho, "Handbook of Heat Transfer," 3rd Edition, 1998.

3-10 NUHOMS®-MP197 Transport Packaging Safety Analysis Report, Rev.4, Transnuclear, Inc, CoC 9302, Docket No. 71-9302.

3-11 Mitchell S. Sweet, "Fire Performance of Wood: Test Methods and Fire Retardant Treatments," Fire Safety of Wood Products, USDA Forest Service. *Retrieved from* http://www.fpl.fs.fed.us/documnts/pdf1993/sweet93a.pdf.

CHAPTER FIVE
SHIELDING EVALUATION

TABLE OF CONTENTS

PAGE

CHAPTER FIVE SHIELDING EVALUATION *5-1*

5.1 DESCRIPTION OF SHIELDING DESIGN *5-2*

5.1.1 Design Features *5-2*
5.1.2 Summary Table of Maximum Radiation Levels *5-2*

5.2 RADIATION SOURCE *5-4*

5.2.1 Gamma Source *5-4*
5.2.2 Neutron Source *5-4*

5.3 SHIELDING MODEL *5-5*

5.3.1 Configuration of Source and Shielding *5-5*
5.3.2 Material Properties *5-6*

5.4 SHIELDING EVALUATION *5-8*

5.4.1 Methods *5-8*
5.4.2 Input and Output Data *5-8*
5.4.3 Flux-to-Dose-Rate Conversion *5-8*
5.4.4 External Radiation Levels *5-8*
5.4.4.1 NCT dose rates *5-9*
5.4.4.2 HAC dose rates *5-10*
5.4.4.3 Original lid versus optional lid *5-10*
5.4.4.4 Cavity Drain *5-10*

5.5 APPENDIX *5-11*

5.5.1 References *5-11*
5.5.2 Sample Input File *5-12*
5.5.3 Energy dependent activity limits *5-20a*

CHAPTER FIVE
THERMAL EVALUATION

LIST OF TABLES

		PAGE
Table 5-1	*Summary of NCT Maximum Dose Rates*	*5-21*
Table 5-2	*Summary of HAC Maximum Dose Rates*	*5-21*
Table 5-3	*List of Important to Shielding Dimensions*	*5-22*
Table 5-4	*Deleted*	*5-23*
Table 5-5	*Homogenized Source Geometric Description*	*5-23*
Table 5-6	*Disk Source Geometric Description*	*5-23*
Table 5-7	*Annulus Source Geometric Description*	*5-24*
Table 5-8	*Stainless Steel Material Composition*	*5-24*
Table 5-9	*Dry Air Material Composition*	*5-24*
Table 5-10	*Balsa Material Composition*	*5-24*
Table 5-11	*Gamma Flux-to-Dose-Rate Conversion Factors*	*5-25*
Table 5-12	*Summary of All NCT Configurations*	*5-26*
Table 5-13	*Deleted*	*5-27*
Table 5-14	*Response Functions and Activity Limits by Energy*	*5-27a*

CHAPTER FIVE
SHIELDING EVALUATION

The shielding evaluation for the TN-RAM package is performed to demonstrate compliance with 10 CFR 71.47 and 10 CFR 71.51 as applicable.

The TN-RAM package is designed to transport a payload of 9500 lbs. (4309 kg) of dry, irradiated and/or contaminated non-fuel bearing solid materials (with only trace quantities of fissile material as limited by 10 CFR 71.15) in secondary containers containing a maximum of *the lesser of* 30,000 Ci of *cobalt-60* or equivalent *as described in this chapter. Material in the secondary container is secured using shoring during transport to prevent movement. No powdered material is authorized for transport.* The package is shipped exclusive-use in an open transport vehicle. The cask is designed to be shipped horizontally during transportation with the lid end facing in the direction of travel. The lid end is considered the top in this evaluation. *No credit is taken for the presence of the secondary container in this chapter.*

The dose rates are computed using MCNP5 v1.40 [5-3].

5.2 RADIATION SOURCE

5.2.1 Gamma Source

The TN-RAM is evaluated to transport 30,000 Ci of *cobalt-60* or equivalent consistent with the maximum for Category II packages. More than 99% of the disintegrations result in two gammas with energy of 1.17 and 1.33 MeV. Lower energy emission is considered to have the energy of the aforementioned gammas which is conservative. The source intensity is as follows:

$$(30\ 000\ \text{Ci})\left(3.7\text{x}10^{10}\ \frac{\text{disintegrations}}{\text{Ci s}}\right)\left(2\ \frac{\gamma}{\text{disintegration}}\right) = 2.22\text{x}10^{15}\ \gamma/\text{s}.$$

If the source is not completely *cobalt-60. The following equivalence is used*:

A set of response functions were developed that allow the loading of radionuclides that are not purely cobalt-60. Energy dependent activity maxima are shown in Table 5-14. The following equation is used:

$$\sum_i \frac{S_i(E)}{\text{Activity Limit}_i(E)} < 1$$

where, S_i (E) is the group source and Activity Limit_i (E) is the limit for the energy group. Explanation of the development and basis for these limits is shown in Section 5.5.3.

The source is the same for the NCT and HAC evaluation. The evaluation methodology uses continuous energy cross sections so the energies for the gammas can be input and simulated directly. The energy distribution of the gammas is one half of the total intensity for each energy. The spatial distribution within the various source regions is isotropic in the axial direction and a power law distribution in the radial direction.

Cobalt-60 conservatively represents the source of dry, solid, non-fuel bearing hardware.

5.2.2 Neutron Source

The TN-RAM package is not licensed to transport fissile material greater than the limits prescribed in 10 CFR 71.15. No neutron generating source material beyond an inconsequential amount as a result of surface contamination is to be transported. Therefore, no neutron source is evaluated.

5.3 SHIELDING MODEL

5.3.1 Configuration of Source and Shielding

A full, three dimensional model of the TN-RAM was created in MCNP5. Major features were modeled explicitly. The same cask model was used for the NCT and HAC analysis with minor variations as required. An axial cross section view of the TN-RAM package for NCT is shown in Figure 5-1.

Key dimensions for the cask and impact limiters are shown in Table 5-3. Dimensions are taken from the drawings provided in section 1.3. The "Dimensions used" column in Table 5-3 corresponds to the sample input file in Section 5.5.2.

Nominal dimensions are used everywhere except for the lead, which is modeled at its minimum respective thickness based on location. The modeling of the lead results in an air gap between the shells, which would not exist in the as-built package. This false gap does not contribute to any lead slumping; rather, it is included to preserve the dimensions of all modeled components.

The four upper and two lower trunnions are modeled because the steel displaces lead used for shielding.

The impact limiter model was simplified. Rather than include all the steel components in the impact limiter, only the steel shell was modeled, and the impact limiter was completely filled with balsa, which has no significant impact on dose rates. However, it preserves external dimensions of the impact limiter in the model. The dimensions form the basis for some of the NCT surface dose rates and all of the 2 m dose rates.

The cavity drain is modeled because it displaces lead in the bottom. The drain sleeve outer diameter is the most critical dimension to ensure the proper amount of lead is removed.

In the HAC evaluation, the model is the same as NCT with the following differences. The combination of the tests prescribed in 10 CFR 71.73 as applicable result in no loss of steel or lead from the cask body which makes up most of the shielding provided by the package. The impact limiters are removed and replaced with air even as they are shown to remain attached under all postulated tests as described in Section 2.7.6. The cavity in the HAC model has no material inside. The cavity is filled completely with air. This allows for the most conservative results because no self-shielding is present.

Lead slump for HAC was analyzed; however, per the discussion in Section 2.7.1.1, lead slump is not expected. However, for conservatism, a one-eighth-inch gap was considered at the top of the radial lead shielding. It is not expected for lead slump to occur anywhere else due to the design of the cask.

A payload mass of *3,000* kg is considered to be the mass of the source bearing contents for the shielding evaluation. *Reductions conservatively reduce the mass, which reduces self-shielding.*

Four source bearing configurations are modeled. The first configuration is a homogenized cylinder sized to fit the interior of the *cavity. The density of the homogenized cylinder is conservatively set as 1.71* g/cm^3. The dimensions of the homogenized source are shown in Table 5-5. This source configuration considers the effects of lower density material throughout the *cavity.*

A disk source is postulated if the source bearing contents are shifted to the top or bottom. The disk is stainless steel at full density and radius to fit inside the *cavity.* The height is calculated to meet the mass target of *3,000* kg. The second configuration is a disk source placed at the bottom of the *cavity*; the third configuration is the same disk source placed at the top of the *cavity.* The disk source dimensions are shown in Table 5-6.

The final source configuration is an annulus. This source configuration moves the source bearing contents to the edges of the *cavity.* The height and outer radius of the annular source are sized to fit the *cavity.* The inner radius was calculated to meet the mass target of *3,000* kg. The center of the annulus was filled with air. The annulus is stainless steel at full density. The dimensions of the annular source are shown in Table 5-7.

The four postulated source configurations are shown in axial views in Figure 5-2 and in radial view in Figure 5-3. The radial views are slices through the approximate center of the respective source region.

For the HAC evaluation, the source was placed inside the package using the homogenized source dimensions and location. *The postulated lead slump was included in the HAC evaluation case.* An axial cross section view of the TN-RAM package for HAC is shown in Figure 5-4. The location of the lead slump is shown in Figure 5-5.

5.3.2 Material Properties

All the steel in the model is assumed to be stainless steel type 304. The elemental composition and density are shown in Table 5-8 [5-2]. The source bearing material was also assumed to be stainless steel type 304.

The elemental composition and density of dry air used in the model are shown in Table 5-9 [5-2].

5.4 SHIELDING EVALUATION

5.4.1 Methods

The software package, Monte Carlo N-Particle (MCNP5), is used to evaluate the TN-RAM *transportation* package. MCNP5 is a robust, well-supported Monte Carlo transport code from Los Alamos National Laboratory utilized to compute dose rates for shielding licenses [5-3].

A three-dimensional model is developed that captures all of the relevant design parameters of the package and contents. Dose rates are calculated by tallying the gamma fluxes using mesh tallies in the areas of interest and converting these fluxes to dose rates using flux-to-dose rate conversion factors.

Simple Russian roulette is used as a variance reduction technique for most tallies. The importance of the particles increases as the particles traverse the shielding materials. The geometry of the package and contents is modeled in a lower universe. This lower universe is filled in the top-level universe where the geometrically based importance splitting occurs.

5.4.2 Input and Output Data

A sample input file is provided in section 5.5.2. Tallies in the sample were the same for all analyzed configurations.

5.4.3 Flux-to-Dose-Rate Conversion

The ANSI/ANS 6.1.1-1977 flux-to-dose-rate conversion factors for gamma rays are used in this evaluation [5-1]. The factors are shown in Table 5-11.

5.4.4 External Radiation Levels

Dose rates are calculated using the mesh tally feature of MCNP5. Radial tallies are segmented axially between 20 and 22 cm. Axial tallies are segmented radially approximately 22 cm. There is no angular segmentation for any tally. The cask is angularly symmetric except for the trunnions and the cavity drain. Dose rates for NCT use the impact limiter surfaces as the basis for the top and bottom. The cask body is the basis for the NCT side dose rates. The width of the vehicle is not defined; therefore, the surface of the vehicle is assumed to be coincident with the radial surface of the impact limiters. The ends of the vehicle are assumed to be coincident with the top and bottom of the package. Tallies are shown in Figure 5-7. Red lines denote surface tallies used to show compliance with 10 CFR 71.47(b)(1) and 71.47(b)(2). Blue lines denote 1 m HAC tallies used to show compliance with 10 CFR 71.51(a)(2). Green lines denote 2 m NCT tallies used to shown compliance with 10 CFR 71.47(b)(3). The tally numbers correspond to the sample input file in Section 5.5.2.

Tallies used to develop the response functions for the energy dependent activities were surface tallies. The special tally treatment available in MCNP5 was used to track contributions to the tally based on the source energy weight. Only one case was required to develop response functions for all energies. The tally was a band at 2 m in the approximate center of the cask. The tally was 17 cm tall. The same tally was used for the dose rate check for the response functions.

Other than the trunnions and the cavity drain, the radial and bottom lead shielding is not displaced. The lead in the original lid contains a penetration for a vent. However, the vent plug contains more lead axially than the lid so the penetration is of no consequence during transportation. The optional lid has no penetration through the lead shielding. The optional lid contains three steel lifting plugs. These displace some lead in the optional lid. These features were modeled in the comparison described in Section 5.4.4.3.

For HAC, dose rates are taken with the surface of the cask as the basis. While the impact limiters are shown to remain attached to the cask during all postulated accidents as prescribed by 10 CFR 71.73 as applicable (Sections 2.10.2 and 2.10.3), for the purpose of the shielding evaluation, the impact limiters are removed from the HAC model and replaced with air. The HAC dose rate tallies are similar to the NCT tallies. No angular segmentation is used. Radial or axial segmentation is approximately 22 cm.

5.4.4.1 NCT dose rates

A summary of all the NCT dose rates for all source configurations evaluated is shown in Table 5-12.

For the radial 2 m dose rate, the *homogenized case* has the maximum dose rate of *9.07* mrem/h. *This* dose rate *is* below the limit of 10 mrem/h. Additionally, the relative uncertainty is *two* percent, which is approximately 0.*2* mrem/h. The dose rate plus three sigma uncertainty is still below the 10 CFR 71.47(b)(3) limit.

The 2 m top dose rate from the top of the impact limiter maximum was *1.82* mrem/h with the disk top source configuration. This is below the limit of 10 mrem/h.

The 2 m bottom dose rates from the bottom of the impact limiter maximum was *1.99* mrem/h with the disk bottom source configuration, which is below the limit of 10 mrem/h.

The maximum radial surface dose rate occurred with the *disk top* configuration and was *107* mrem/h below the 10 CFR 71.47(b)(1) limit of 200 mrem/h. The dose rate here was on the surface of the cask body *that* sliced through the trunnion.

The maximum top surface dose rate occurred with the *disk top* source and is *11.7* mrem/h, which is below the limit of 200 mrem/h.

The maximum bottom surface dose rate occurred with the disk bottom source as what *20.0* mrem/h, which is below the limit of 200 mrem/h.

The external surfaces of the package were assumed to be coincident with the external surfaces of the vehicle. These dose rates satisfy both the requirements of 10 CFR 71.47(b)(1) and 10 CFR 71.47(b)(2).

The occupied space for personnel was assumed to be 5 m from either end of the package. The maximum top dose rate was *0.24* mrem/h and *0.21* mrem/h for the bottom with *homogenized* configuration. Therefore, personnel do not have to follow the requirements of 10 CFR 20.1502.

5.4.4.2 HAC dose rates

A summary of all the HAC dose rates is shown in Table 5-*2*. All dose rates in this table are taken 1 m from the external surface of the cask. The maximum radial dose rate is *354* mrem/h, which is below the 10 CFR 71.51(a)(2) limit of 1,000 mrem/h. The maximum top HAC dose rate is *126* mrem/h, which is below the limit of 1,000 mrem/h. The maximum bottom HAC dose rate is *171* mrem/h, which is below the limit of 1,000 mrem/h.

5.4.4.3 Original lid versus optional lid

A comparison was made between the original and optional lids. The optional lid has 0.2 in. less lead than the original lid, but adds 0.375 in. of steel. Using the homogenized source configuration, both lids were modeled, and the top surface dose rates for NCT were compared. A dose rate distribution for both cases is shown in Figure 5-6. As shown in the figure, the original lid *bounds the optional lid*. Therefore, the original lid was used in the development of the NCT and HAC dose rates presented in this chapter.

5.4.4.4 Cavity Drain

The cavity drain was modeled explicitly. The cavity drain tube displaces lead directly under the cavity. Bottom dose rates are marginally higher than the top as a result. However, due to the increased distance from the cask and material of the impact limiters during NCT, the dose rates radially are bounding for all configurations. The cavity drain has no appreciable impact on the dose rates.

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

5.5.3 Energy dependent activity limits

In order to allow gamma emitting nuclides that are not cobalt-60 in the cask for transportation, energy dependent maximum activities were calculated. The purpose of these activities is to ensure that, regardless of the payload, the dose rates will not exceed the regulatory limits.

The maximum activities were determined by first generating response functions for various energies. Response functions are calculated in terms of mrem/h/γ/s. The response functions were tallied at 2 m from the extents of the package in a band around the approximate axial middle of the package. The energy dependent values represent the dose rate of a single gamma ray of the particular energy emitted from the cask. The source configuration was the same as the homogenized case.

Using the same tally and source configuration, 30 kCi of cobalt-60 was modeled to determine the dose rate at the response function tally. This formed the dose rate basis of the response functions. The dose rate divided by the response functions generated the "Activity Limit" column in Table 5-14. However, the response function predicted the maximum activity of 2.47E+15 γ/s for cobalt-60, while the maximum activity of 2.22E+15 γ/s was estimated by using the Monte Carlo N-Particle (MCNP) model. Therefore, the activity limits predicted by using the response functions were scaled down by the ratio of the maximum cobalt-60 activity estimated by using the MCNP model to the maximum cobalt-60 activity predicted by using the response function. This resulted in a 10% reduction for the activity limits, which is shown in the "Adjusted Activity Limit" column in Table 5-14. The predicted dose rates are shown in the final column with the adjusted activity.

Table 5-1
Summary of NCT Maximum Dose Rates

	Dose rate (mrem/h)	Relative 1σ uncertainty	Limit (mrem/h)	Configuration
	Surface			
Side	*107*	0.01	200	*Disk, Top*
Top	*11.7*	0.0*3*	200	*Disk, Top*
Bottom	*20.0*	0.0*4*	200	Disk, Bottom
	2 m			
Side	*9.07*	0.02	10	*Homogenized*
Top	*1.82*	0.0*6*	10	Disk, Top
Bottom	*1.99*	0.0*5*	10	Disk, Bottom
	5 m			
Top	*0.24*	0.01	2	*Homogenized*
Bottom	*0.21*	0.0*2*	2	*Homogenized*

Table 5-2
Summary of HAC Maximum Dose Rates

	Dose rate (mrem/h)	Relative 1σ uncertainty	Limit (mrem/h)
	1 m		
Side	*354*	0.01	1000
Top	*126*	0.02	1000
Bottom	*171*	0.03	1000

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Table 5-7
Annulus Source Geometric Description

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Table 5-8
Stainless Steel Material Composition

Element	Stainless Steel (weight fraction)
Carbon	0.04
Silicon	0.5
Phosphorous	0.023
Sulfur	0.015
Chromium	19
Manganese	1
Iron	70.172
Nickel	9.25
Density	7.92 g/cm^3

Table 5-9
Dry Air Material Composition

Element	Air (weight fraction)
Carbon	0.0124
Nitrogen	75.5268
Oxygen	23.1781
Argon	1.2827
Density	0.0012 g/cm^3

Table 5-10
Balsa Material Composition

Element	Balsa (atoms/b·cm)
Hydrogen	$5.94 \cdot 10^{-3}$
Carbon	$3.57 \cdot 10^{-3}$
Oxygen	$2.97 \cdot 10^{-3}$
Density	0.16 g/cm^3

Table 5-12
Summary of All NCT Configurations

	Dose rate (mrem/h)	*Relative 1σ uncertainty*	*Dose rate (mrem/h)*	*Relative 1σ uncertainty*	*Dose rate (mrem/h)*	*Relative 1σ uncertainty*	*Dose rate (mrem/h)*	*Relative 1σ uncertainty*	*Dose rate (mrem/h)*	*Relative 1σ uncertainty*
	Annulus		*Cylinder*		*Disk, Top*		*Disk, Bottom*		*Homogenized Cylinder*	
	2 meters									
radial max:	8.96	0.01	7.17	0.01	5.13	0.01	2.36	0.02	9.07	0.02
top max:	1.68	0.08	0.86	0.09	1.82	0.06	0.41	0.17	1.72	0.10
bottom max:	1.74	0.06	0.76	0.08	0.43	0.12	1.99	0.05	2.10	0.09
	Surface									
radial max:	101	0.01	70.9	0.01	107	0.01	69.8	0.01	96.8	0.01
top max:	10.3	0.05	5.01	0.06	11.7	0.03	1.73	0.09	11.3	0.06
bottom max:	17.5	0.05	8.45	0.06	3.06	0.07	20.0	0.04	19.8	0.07
	5 meters from the ends of the impact limiters[1]									
top average:	0.24	0.01	0.16	0.01	0.20	0.01	0.03	0.02	0.24	0.01
bottom average:	0.20	0.01	0.12	0.01	0.08	0.02	0.13	0.02	0.21	0.02

1. These tallies are averaged over a large surface to show that an operator in the vicinity of the package with experience less than 2 mrem/h.

Table 5-13
Deleted

Table 5-14
Response Functions and Activity Limits by Energy

Energy (MeV)	Response (mrem/h/γ/s)	Relative Uncertainty	Activity (γ/s)	Dose Rate (mrem/h)	Scaling Factor	Adjusted Activity (γ/s)	New Dose Rate (mrem/h)
1	3.81E-16	0.0741	2.27E+16	8.64	0.90	2.04E+16	7.77
1.17	2.00E-15	0.0423	4.31E+15	8.64	0.90	3.88E+15	7.77
1.25	3.50E-15	0.0325	2.47E+15	8.64	0.90	2.22E+15	7.77
1.33	6.13E-15	0.0262	1.41E+15	8.64	0.90	1.27E+15	7.77
2	7.05E-14	0.0101	1.23E+14	8.64	0.90	1.10E+14	7.77
2.5	1.60E-13	0.0077	5.39E+13	8.64	0.90	4.85E+13	7.77
3	2.62E-13	0.0066	3.30E+13	8.64	0.90	2.97E+13	7.77
4	4.18E-13	0.0060	2.07E+13	8.64	0.90	1.86E+13	7.77
5	5.02E-13	0.0059	1.72E+13	8.64	0.90	1.55E+13	7.77
6	5.27E-13	0.0059	1.64E+13	8.64	0.90	1.47E+13	7.77
10	5.95E-13	0.0056	1.45E+13	8.64	0.90	1.31E+13	7.77

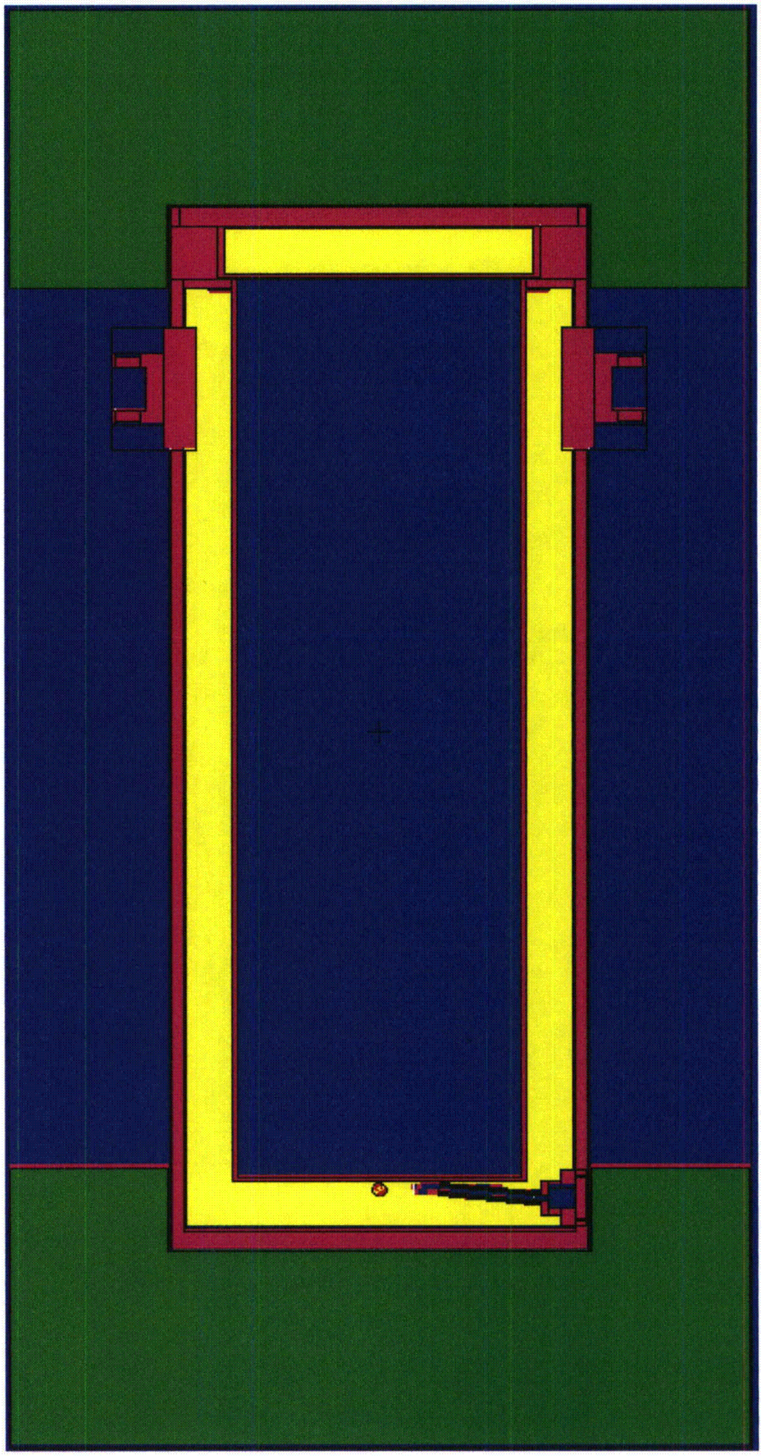
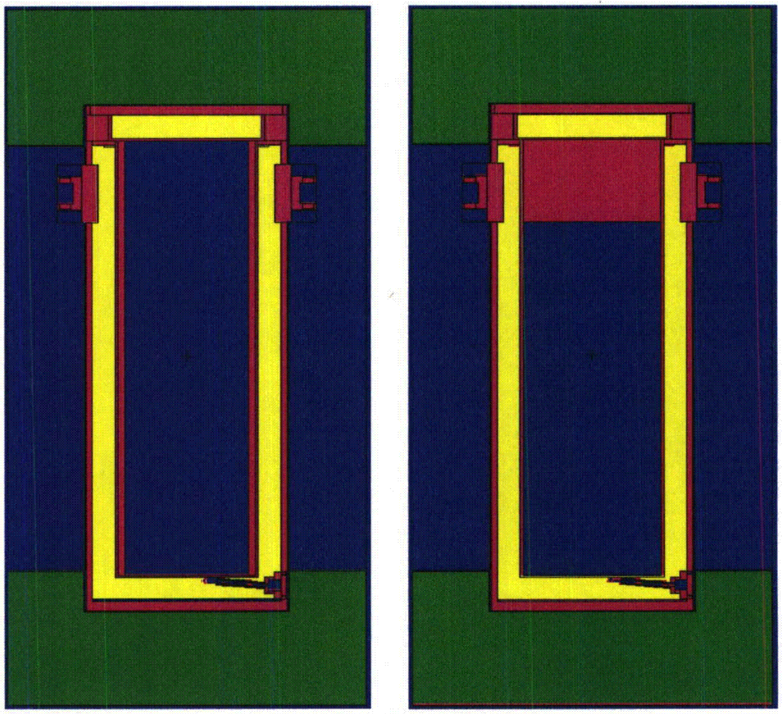
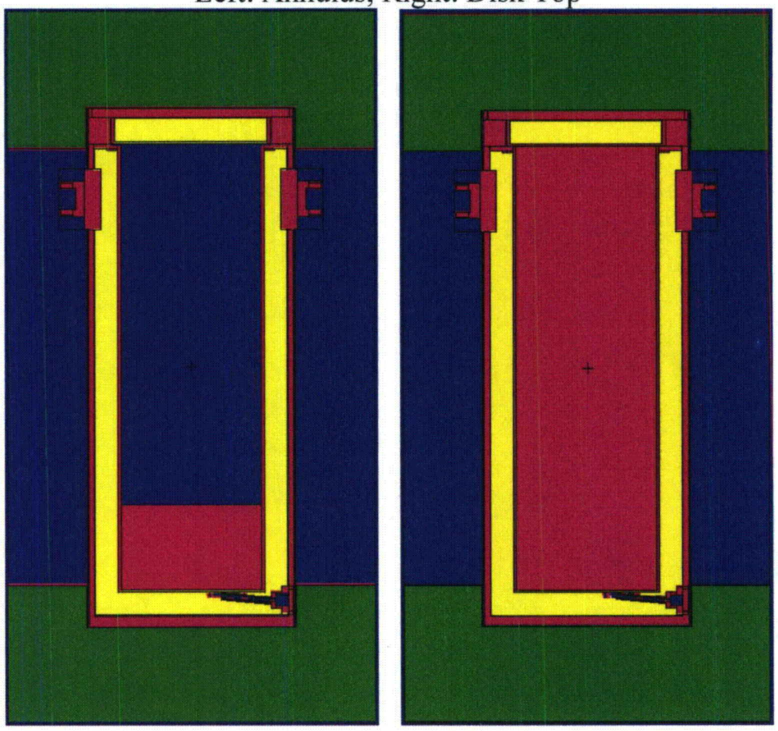


Figure 5-1
TN-RAM NCT Model

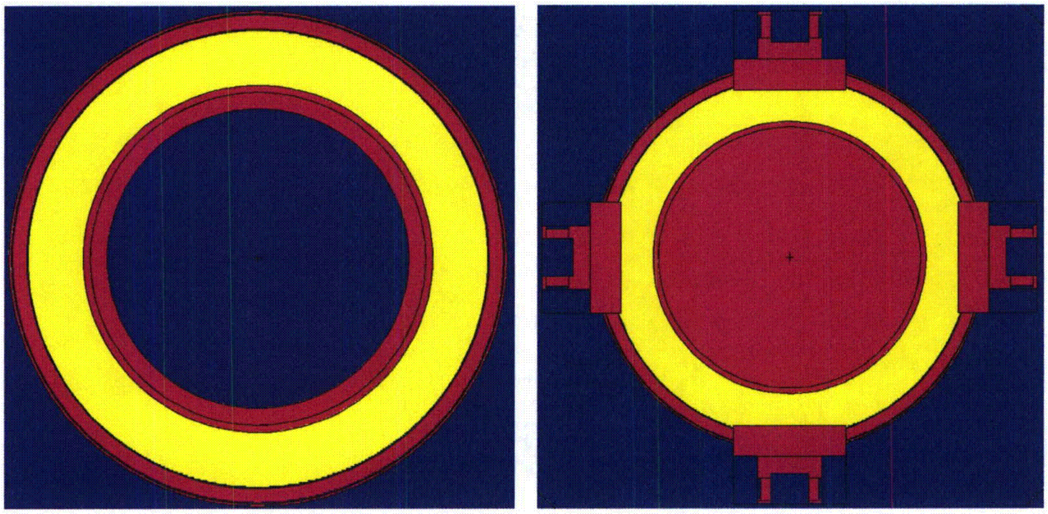


Left: Annulus, Right: Disk Top

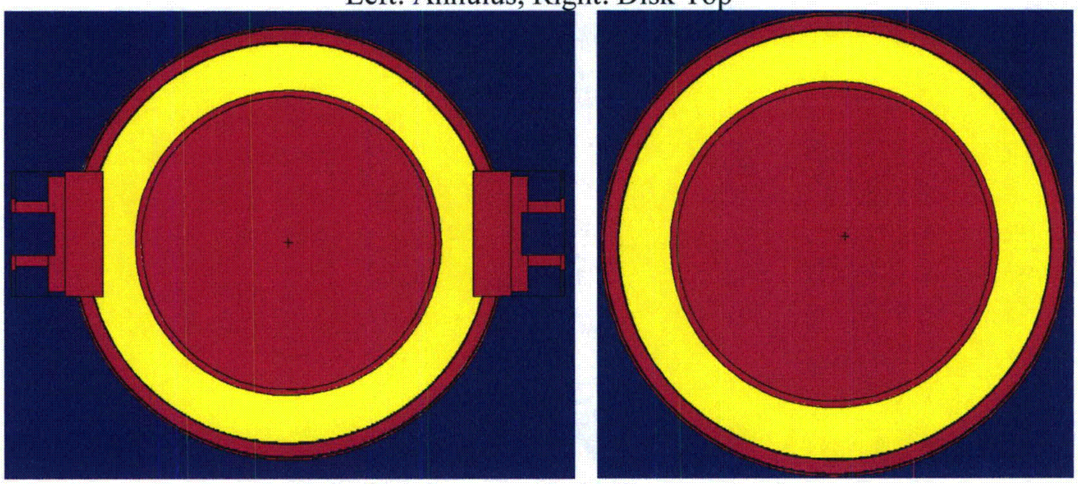


Left: Disk Bottom, Right: Homogenized

Figure 5-2
Source Configurations—Axial View



Left: Annulus, Right: Disk Top



Left: Disk Bottom, Right Homogenized

Figure 5-3
Source Configurations—Radial View

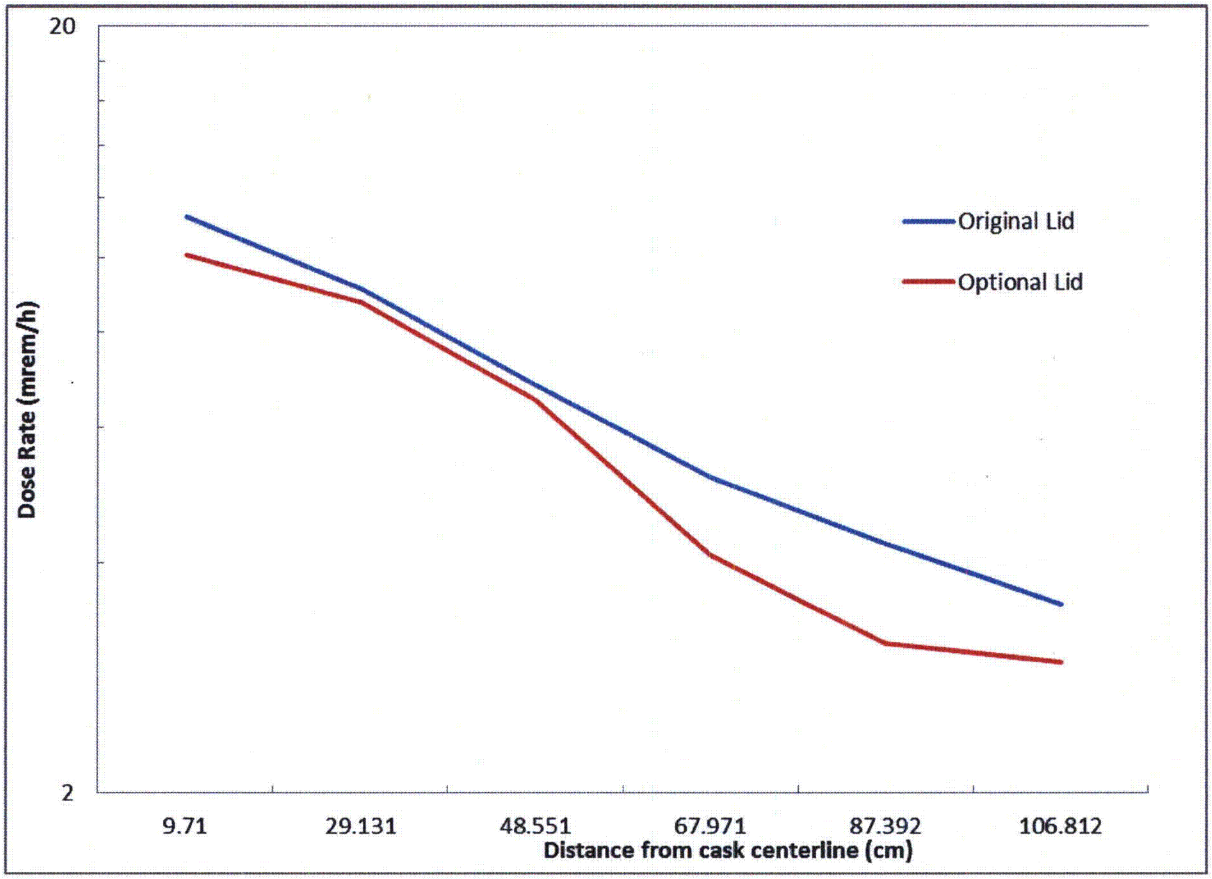


Figure 5-6
Lid Comparison

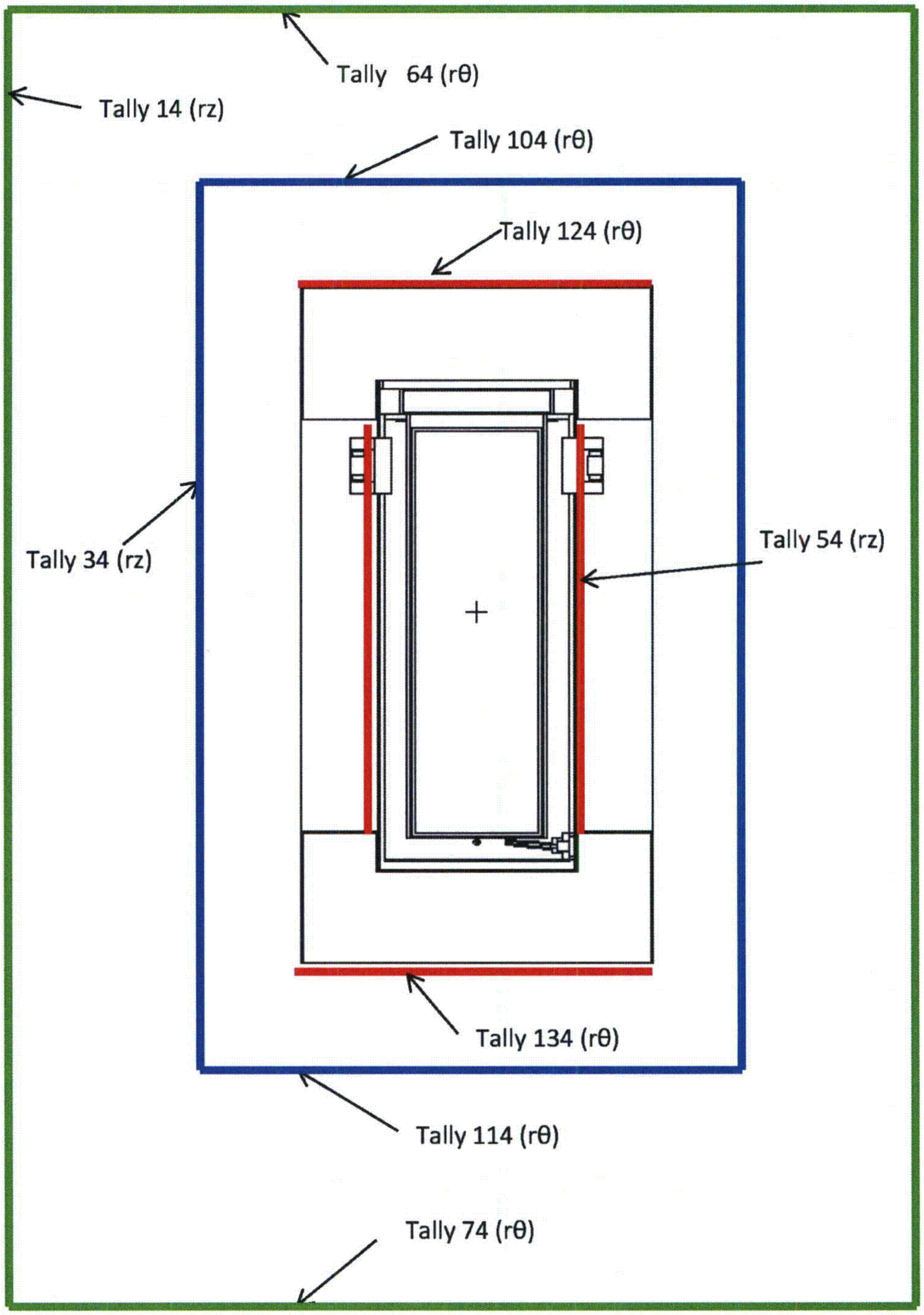


Figure 5-7
Tally Locations

Enclosure 4 to E-41950

Listing of Computer Files Contained in Enclosure 5

Listing of Computer Files Contained in Enclosure 5
(All files are Proprietary)

Disk ID No. (size)	Discipline	System/Component	File Series (topics)	Number of files
Enclosure 5 *One DVD* (1.76 MB)	**Shielding**	TN-RAM NCT	Folder: *annulus* Annulus source configuration	3
		TN-RAM NCT	Folder: *disk top* Disk top source configuration	3
		TN-RAM NCT	Folder: *disk bottom* Disk bottom source configuration	3
		TN-RAM NCT	Folder: *homogenized cylinder* Homogenized cylinder source configuration	3
		TN-RAM HAC	Folder: *hac lead slump* Voided cavity with postulated lead slump	3
		TN-RAM NCT	Folder: *optional lid* Optional lid results for comparison	3
		TN-RAM NCT	Folder: *response functions* Response function results	2
		TN-RAM NCT	Folder: *dose check* Dose rate check for response functions	2
Enclosure 5 *One DVD* (194 MB)	**Thermal**	TN_RAM_NCT_NoInso_500W_SET1	Steady state analysis with 500 W for NCT without insolation	26
		TN_RAM_BASKET_NCT_500W_SET1	Steady state analysis with 500 W for NCT with insolation modeled with homogenized payload	26

Enclosure 6 to E-41950

Proposed Changes to CoC 9233, Revision 12

NRC FORM 618
(8-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIAL PACKAGES

a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE		PAGES
9233	~~12~~ 13	71-9233	USA/9233/B(U)-96	1	OF	3

2. PREAMBLE

a. This certificate is issued to certify that the package (packaging and contents) described in Item 5 below meets the applicable safety standards set forth in Title 10, Code of Federal Regulations, Part 71, "Packaging and Transportation of Radioactive Material."

b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

a. ISSUED TO *(Name and Address)*

AREVA Inc.
7135 Minstrel Way, Suite 300
Columbia, MD 21045

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION

~~Transnuclear, Inc.~~ application dated ~~March 8, 2005~~, as supplemented.

AREVA Inc.

March 9, 2015

4. CONDITIONS

This certificate is conditional upon fulfilling the requirements of 10 CFR Part 71, as applicable, and the conditions specified below.

5.

(a) Packaging

(1) Model No.: TN-RAM

(2) Description

The package is a steel encased lead shielded cask with wood impact limiters attached at both ends. The cask is a right circular cylinder. The overall dimensions of the packaging are approximately 178 inches long and 92 inches diameter with the impact limiters installed. The cask body is approximately 129 inches long with an outer diameter of 51 inches. The cask cavity has a length of approximately 111 inches and an inside diameter of 35 inches. The cask body is made of a 0.75-inch stainless steel inner shell, a 5.88-inch thick lead annulus, a 1.5-inch thick stainless steel outer shell, a 0.5-inch thick inner bottom plate and a 2.5-inch thick outside bottom plate. The lead shielding is approximately 6 inches thick in the bottom end of the cask. The outer shell of the cask body is covered with a stainless steel thermal shield. The closure lid consists of a 2.5-inch thick outer stainless steel plate and a 0.5-inch thick inner stainless steel plate separated by approximately 6 inches of lead shielding. An optional lid, with the lead shielding in the form of a separate shielding disk, can also be used. The lid is secured by sixteen 1.5-inch diameter closure bolts. Two concentric silicone O-rings are installed in grooves on the underside of the lid. The cask is equipped with a sealed leak test port between the O-rings, a vent port in the closure lid and a sealed drain port in the bottom of the cask. Each impact limiter is attached to the cask by eight 1.75-inch diameter bolts. The cask is equipped with 6 trunnions, four at the top and two at the bottom. The gross weight of the package is approximately 80,000 pounds, including maximum contents of 9,500 pounds.

NRC FORM 618
(8-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIAL PACKAGES

a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE	PAGES
9233	~~12~~ 13	71-9233	USA/9233/B(U)-96	2 OF	3

5.(a) Packaging (continued)

(3) Drawings

The packaging is constructed in accordance with Transnuclear, Inc. Drawing Nos. 990-701, Rev. 9; 990-702, Rev. 8; 990-703, Rev. 10; 990-704, Rev. 6; 990-705, Rev. 7; 990-706, Rev. 4; 990-707, Rev. 4; 990-708, Rev. 8; 990-709, Rev. 2; and 990-710, Rev. 2.

(b) Contents

(1) Type and Form of Material

Dry irradiated and contaminated non-fuel-bearing solid materials contained within a secondary container. ← No powdered, solid material is authorized.

(2) Maximum quantity of material per package

Greater than Type A quantities of radioactive material which may include fissile material provided that the fissile material does not exceed the mass limits of 10 CFR 71.15. The contents may not exceed ~~1,272 times an A_2 quantity. The decay heat of the contents may not exceed 300 watts. The maximum gross weight of the contents, secondary container, and shoring is limited to 9,500 pounds.~~ ← Insert 1 (as shown on page 4 of this enclosure.

6. As appropriate, shoring must be used in the secondary container sufficient to prevent significant movement of the contents under accident conditions.

7. Both the inner cask cavity and the secondary container must be free of water when the package is delivered to a carrier for transport.

8. In addition to the requirements of Subpart G of 10 CFR Part 71:

(a) Prior to each shipment, the lid seals must be inspected. The seals must be replaced with new seals if inspection shows any defects or every 12 months, whichever occurs first;

(b) The package shall be prepared for shipment and operated in accordance with the Operating Procedures of Section 7.0 of the application; and

(c) The package must meet the Acceptance Tests and Maintenance Program of Section 8.0 of the application.

9. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

10. Expiration date: April 30, 2020

the least of 30,000 Ci of ^{60}Co, 2727 A_2, or equivalency as shown by the following equation:

NRC FORM 618 (8-2000) 10 CFR 71	CERTIFICATE OF COMPLIANCE FOR RADIOACTIVE MATERIAL PACKAGES		U.S. NUCLEAR REGULATORY COMMISSION	
a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE / PAGES
9233	~~12~~ 13	71-9233	USA/9233/B(U)-96	3 OF 3

AREVA Inc.

REFERENCES

March 9, 2015

~~Transnuclear, Inc.~~, application dated ~~March 8, 2005.~~

~~Supplements dated: May 4, 2007; October 19, 2007; September 30, 2008; February 16, 2009 and March 15, 2010; January 27, 2014, and June 11, 2014.~~

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Timothy Lupold, Acting Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Date: TBD

Insert 1 (for Page 2 of 3 to CoC):

$$\sum_i \frac{S_i(E)}{Activity\ Limit_i(E)} < 1$$

where E is the weighted average energy of the gamma emitter, $S_i(E)$ is the source strength of the gamma emitter, and $Activity\ Limit_i(E)$ is the limit in gammas per second as a function of energy. Limits can be found in the following table:

Energy (MeV)	Adjusted Activity (γ/s)
1	2.04E+16
1.17	3.88E+15
1.25	2.22E+15
1.33	1.27E+15
2	1.10E+14
2.5	4.85E+13
3	2.97E+13
4	1.86E+13
5	1.55E+13
6	1.47E+13
10	1.31E+13

Chapter 5 of the TN-RAM Safety Analysis Report provides the basis for the equation and these values.

The average activity of the contents is limited to 10 Ci/kg.

The decay heat of the contents may not exceed 500 W.

The maximum gross weight of the contents, which include the secondary container and shoring, is limited to 9500 lb (4309 kg).

Enclosure 7 to E-41950

Affidavit Pursuant to 10 CFR 2.390

AFFIDAVIT PURSUANT
TO 10 CFR 2.390

AREVA Inc.)
State of Maryland) SS.
County of Howard)

I, Paul Triska, depose and say that I am a Vice President of AREVA Inc., duly authorized to execute this affidavit, and have reviewed or caused to have reviewed the information that is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is contained in Enclosures 2 and 5 and is listed below:

- Enclosure 2 – Portions of the changed pages, TN-RAM SAR, Revision 14
- Enclosure 5 - Thermal and Shielding Computer Files

These documents have been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by AREVA Inc. in designating information as a trade secret, privileged, or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure involves certain portions of the safety analysis report analysis and the thermal and shielding computer files related to the design of the TN-RAM transportation packaging, which are owned and are held in confidence by AREVA Inc.

2) The information is of a type customarily held in confidence by AREVA Inc. and not customarily disclosed to the public. AREVA Inc. has a rational basis for determining the types of information customarily held in confidence by it.

3) Public disclosure of the information is likely to cause substantial harm to the competitive position of AREVA Inc. because the information consists of descriptions of the design and analysis of the TN-RAM transportation package, the application of which provides a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with AREVA Inc., take marketing or other actions to improve their product's position or impair the position of AREVA Inc.'s product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

Further the deponent sayeth not.

Paul Triska
Vice President, AREVA Inc.

Subscribed and sworn to me before this 21st day of May, 2015.

Notary Public
My Commission Expires 10 / 17 / 2015