AREVA

October 8, 2015
E-43104

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Subject: Application for Renewal and Revision to Certificate of Compliance No. 9233 for the Model No. TN-RAM Transportation Packaging, Response to Request for Additional Information (Docket No. 71-9233, TAC Nos. L25001 and L25002)

References: Letter from John Vera (NRC) to Paul Triska (AREVA TN), "Renewal and Amendment Application for Model No. TN-RAM - Request for Supplemental Information," September 14, 2015.

Letter E-41224, dated March 9, 2015, "Application for Revision 13 to Certificate of Compliance No. 9233 for the Model No. TN-RAM Transportation Packaging, Docket No. 71-9233."

This submittal provides responses to the request for additional information (RAI) forwarded by the NRC letter referenced above.

This submittal contains the following enclosures:

- Enclosure 1 provides each RAI item, followed by an AREVA TN response.
- Enclosure 2 provides the changed pages for the proprietary version of the TN-RAM Safety Analysis Report (SAR), Revision 15. The latest changed areas are indicated by revision bars in the right margin and italics for inserted text, with "Rev. 15" in the page header.
- Enclosure 3 provides the changed pages for the non-proprietary version of the SAR, Revision 15. The latest changed areas are indicated by revision bars in the right margin and italics for inserted text, with "Rev. 15" in the page header, with the proprietary information redacted. Enclosure 3 also provides non-proprietary versions of the SAR drawings provided in Enclosure 7.
- Enclosure 4 provides a listing of the shielding computer files that are contained in Enclosure 5.
- Enclosure 5 provides the computer files supporting the shielding analysis. This enclosure is proprietary.
- Enclosure 6 provides the proposed changes to CoC 9233, Revision 12. Changes from Enclosure 6 submitted previously show the latest changed areas indicated by revision bars to the right of the inserted or changed text, and italics for inserted text.

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- Enclosure 7 provides a complete set of the TN-RAM SAR drawings. In addition to the changed SAR pages resulting from the RAI responses, AREVA has revised 8 of the 10 SAR drawings listed in the CoC, and listed and contained in Chapter 1. The drawings were revised to improve clarity. No design changes were made; however, revision clouds were maintained from the previous revision. Because the originals of many of these drawings were of poor quality, these drawing revisions, which were newly created in a computer-based drawing system, enhance the clarity and details for the components of the TN-RAM packaging.
- Enclosure 8 provides an affidavit, in accordance with 10 CFR 2.390, specifically requesting that you withhold proprietary information included in Enclosures 2, 5, and 7 of this submittal from public disclosure. That information may not be used for any purpose other than to support the review of the application for revision to the TN-RAM CoC.

Based on communications with the NRC during the course of this licensing action, AREVA TN respectfully requests to be notified once the NRC has completed the safety review and determines that no additional information is required for issuance of the CoC, in order to submit a consolidated revision to the SAR (both the proprietary and the non-proprietary version), which incorporates all the changes completed during the course of this review.

Should the NRC staff require additional information to support review of this application, please do not hesitate to contact Mr. Glenn Mathues at 410-910-6538, or me at 410-910-6820.

Sincerely,

Paul H Triska

Paul Triska
Vice President, Technical Services

cc: John A. Vera, U.S. Nuclear Regulatory Commission
- One electronic copy (computer disk) of this letter and Enclosures 1, 2, 4, 6, 7, and 8
- One electronic copy (computer disk) of Enclosure 5

Enclosures:

1. RAI Responses
2. Changed Pages, TN-RAM SAR, Revision 15 (Proprietary)
3. Changed Pages and Revised Drawings, TN-RAM SAR, Revision 15 (Non-Proprietary)
4. Listing of Computer Files Contained in Enclosure 5
5. One Computer Disk Containing Shielding Computer Files (Proprietary)
6. Proposed Changes to CoC 9233, Revision 12
7. TN-RAM SAR Drawings (Proprietary)
8. Affidavit Pursuant to 10 CFR 2.390

Enclosure 1 to E-43104

RAI Responses

THERMAL EVALUATION

RAI 3-1

Explain how an emissivity value of 0.85 for weathered stainless steel surface is obtained and used in the thermal analysis of the TN-RAM package. Provide details of measurements and/or references to justify this value.

Page 3.5 of the safety analysis report (SAR) states that the external surfaces of the TN-RAM are assumed to have an emissivity of 0.85, a typical value for weathered stainless steel surfaces. However, the application does not provide any details on how this value is obtained (i.e. via measurement, approved code or standard, etc.)

The information is needed to determine compliance with Title 10 of the Code of Federal Regulations (10 CFR) 71.71 and 71.73.

AREVA TN Response to RAI 3-1

The emissivity value of 0.85 for weathered stainless steel surface is obtained from Table 5.2 of [1]. Page 3.5 of the TN-RAM SAR has been revised to add the reference for this emissivity.

References:

1. Kreith F., "Principles of Heat Transfer," 3rd Edition, Harper and Row Publishers, New York, 1973.

SAR Impact:

Section 3.2 has been revised as described in the response.

RAI 3-2

Clarify how assuming only radiation and gaseous conduction heat transfer in the thermal-shield air gap will result in bounding maximum temperatures for both normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

Page 3.8 of the SAR states that heat transfer across a 0.125 in air gap in the thermal shield is modeled as a combination of radiation and gaseous conduction. This approach may result in non-conservative temperatures during HAC conditions because it neglects convection through the air gap.

The information is needed to determine compliance with 10 CFR 71.73.

AREVA TN Response to RAI 3-2

During NCT, it is conservative to assume only radiation and gaseous conduction heat transfer in the thermal-shield air gap because it neglects the extra heat transfer due to the natural convection, therefore, resulting in higher maximum component temperatures.

During HAC, the natural convection heat transfer across this 0.125-inch air gap is considered insignificant compared to the conduction heat transfer. According to the discussion on Pages 4.58 and 4.59 of Handbook of Heat Transfer [1], for small Rayleigh Number (R_a), the heat transfer in the region between two concentric cylinders can be considered as conduction only because the fluid flow is sufficiently low. To prove that the convection can be neglected in the 0.125-inch air gap between the outer shell and thermal shield in TN-RAM transport cask during HAC conditions, the critical Rayleigh number ($R_{a,c}$) is calculated. If $R_a < R_{a,c}$, heat conduction dominates in this air gap, and convection can be neglected.

Equation 4.120 in [1] derives the Nusselt Number in a horizontal cylindrical annulus when the conduction layers do not overlap:

$$Nu_l = 0.603\overline{C}_l \frac{\ln(D_o / D_i) R_a^{1/4}}{[(L/D_i)^{3/5} + (L/D_o)^{3/5}]^{5/4}},$$

Where:

D_o = 51.5", diameter of the inner surface of the thermal shield;

D_i = 51.25", diameter of the outer surface of the outer shell;

L = $(D_o-D_i)/2$ = 0.125", thickness of the air gap between outer shell and thermal shield;

$\overline{C}_l = \frac{0.671}{[1+(0.492/\mathrm{Pr})^{9/16}]^{4/9}}$, function of Prandtl Number Pr;

$R_a = \frac{g\beta|T_o - T_i|L^3}{\nu^2}\mathrm{Pr}$, Rayleigh Number;

$\mathrm{Pr} = \mu C_p / k$, Prandtl Number;

g = 9.81 m/s^2, acceleration due to gravity;

$\beta = \frac{1}{T_m}$, coefficient of thermal expansion evaluated at mean temperature T_m;

T_m = $(T_o+T_i)/2$, mean temperature;
T_o, temperature on the inner surface of the thermal shield;
T_i, temperature on the outer surface of the outer shell;
μ, dynamic viscosity of air at T_m;
ν, kinetic viscosity of air at T_m;
C_p, specific heat of air at T_m;
k: thermal conductivity of air at T_m.

The conduction layers just touch when R_a falls to the critical value, $R_{a,c}$, at which Nu_l from the above equation equals 1. Therefore,

$$R_{a,c} = \left[0.603\overline{C}_l \frac{\ln(D_o/D_i)}{[(L/D_i)^{3/5} + (L/D_o)^{3/5}]^{5/4}} \right]^{-4}.$$

According to Table 3-7 in TN-RAM SAR Chapter 3, the maximum temperatures on the thermal shield outer surface and outer shell (T_i) during HAC are 1173 °F and 801 °F, respectively. This results in a maximum temperature gradient of 372 °F. However, to avoid any uncertainty, a maximum temperature gradient of 500 °F is considered to calculate $R_{a,c}$ for a range of temperatures as shown in Table RAI-3-2-1.

Table RAI-3-2-1
Calculation of Natural Convection Parameters in Thermal Shield Gap

T_i	T_o	T_m		k	β	μ	ρ	ν	C_p	Pr	C_l	$R_{a,c}$	R_a	Nu_l
(°F)	(°F)	(°F)	(K)	(W/m-K)	(1/K)	(kg/m-s)	(kg/m³)	(m²/s)	(J/kg-K)	(---)	(---)	(---)	(---)	(---)
450	950	700	644	0.0482	1.55 E-03	3.17 E-05	5.48 E-01	5.79 E-05	1061	0.70	5.14 E-01	8.90 E+04	2.82 E+01	0.1334
500	1000	750	672	0.0498	1.49 E-03	3.26 E-05	5.25 E-01	6.21 E-05	1067	0.70	5.14 E-01	8.90 E+04	2.35 E+01	0.1275
550	1050	800	700	0.0514	1.43 E-03	3.35 E-05	5.04 E-01	6.64 E-05	1073	0.70	5.14 E-01	8.90 E+04	1.98 E+01	0.1221
600	1100	850	728	0.0530	1.37 E-03	3.43 E-05	4.85 E-01	7.07 E-05	1079	0.70	5.14 E-01	8.90 E+04	1.68 E+01	0.1171
650	1150	900	755	0.0545	1.32 E-03	3.51 E-05	4.67 E-01	7.52 E-05	1086	0.70	5.14 E-01	8.90 E+04	1.43 E+01	0.1126
700	1200	950	783	0.0561	1.28 E-03	3.59 E-05	4.51 E-01	7.97 E-05	1092	0.70	5.14 E-01	8.89 E+04	1.23 E+01	0.1084
750	1250	1000	811	0.0576	1.23 E-03	3.67 E-05	4.35 E-01	8.44 E-05	1099	0.70	5.14 E-01	8.89 E+04	1.06 E+01	0.1045
800	1300	1050	839	0.0591	1.19 E-03	3.75 E-05	4.21 E-01	8.91 E-05	1105	0.70	5.14 E-01	8.88 E+04	9.19 E+00	0.1008

As shown in the above table, $R_a \ll R_{a,c}$ for all the range of the temperature 450 °F < Ti <800 °F. Therefore, it is valid to neglect the convection heat transfer across the air gap between the outer shell and the thermal shield in the thermal model.

References:

1. W. M. Rohsenow, J. P. Hartnett, and Y. I. Cho, Handbook of Heat Transfer, Third Edition, McGraw-Hill, 1998.

SAR Impact:

No changes as a result of this question.

RAI 3-3

Provide the maximum thermal stresses calculated as a result of the heat load increase for both NCT and HAC.

SAR Chapter 3 states that the heat load was increased to 500 watts but it does not appear the maximum stresses have been recalculated as a result of the temperature increase of the package.

The information is needed to determine compliance with 10 CFR 71.71 and 71.73.

AREVA TN Response to RAI 3-3

Prior revisions of the TN-RAM SAR used a more conservative methodology in computing the NCT and HAC temperatures, producing higher temperature estimates that were employed in the thermal stress analysis. Despite the increased heat load evaluated in the current application, the more accurate thermal methodology employed in Revision 14 results in lower calculated temperatures compared to prior approved revisions. The structural model was not changed in response to these lower expected temperatures and, thus, remains conservative.

Normal Conditions

The normal condition temperatures for the thermal analysis are reported in Table 3-1 of the TN-RAM SAR Revision 14, showing the evaluated maximum temperature of 148 °F. Previously approved revisions of the SAR (Revision 12) reported a higher expected temperature of 166 °F. This higher temperature, conservatively, remains the basis in the thermal stress analysis.

Accident Conditions

The calculated accident condition temperatures for the Revision 14 heat load thermal analysis are reported in Section 3.5.5 of the TN-RAM SAR Revision 14 and are shown below in comparison to the temperatures adopted for the Revision 12 structural thermal analysis:

	@ max individual		@ equilibrium	
	Revision 14	Revision 12	Revision 14	Revision 12
Inner shell	371 °F	411 °F	452 °F	460 °F
Outer shell	556 °F	560 °F	445 °F	470 °F
Lead shell	435 °F	473 °F	453 °F	460 °F

As the previous revision of Chapter 2 structural thermal stress analysis temperatures bound all of the Revision 14 thermal analysis expected temperatures, the existing structural analysis remains conservative for the increased heat load.

SAR Impact:

No changes as a result of this question.

SHIELDING EVALUATION

RAI 5-1

Discuss if there will be concentration of sources.

All of the shielding analyses performed for the TN-RAM assume that the source is uniformly distributed throughout the content. This assumption becomes non-conservative if a single part of the content is more highly activated than another. The staff notes that in response to RSI 5-1, the applicant stated that it included a specific activity limit in Section 1.2.3 of 10 Ci/kg. In its response it states: *"The purpose of this limit is to quantify the self-shielding credit taken in the analysis for normal conditions of transport (NCT). During loading, operators would calculate the total activity of the contents divided by the total mass of the contents."* Although this limit would ensure a certain amount of material to be present per activity, it does not control how the activity would be distributed throughout that content and would not prohibit highly concentrated source material within the presence of other low activity material.

Per the current shielding analyses, within the CoC, the staff will have to prohibit the TN-RAM from transporting concentrated source material and put a condition that contents activity shall be uniformly distributed.

If these requirements are too restrictive to meet the transportation needs for the TN-RAM, the applicant needs to provide additional information/analyses on how activity distribution is controlled. They should include and justify the limits on distribution of the activity and/or include operating procedures within Chapter 7 of the SAR that ensure that highly activated material cannot be concentrated within a single location within the package.

This information is needed to determine compliance with regulations in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-1

Non-fuel material and reactor-related components are activated due to neutron flux exposure. Composition of the material and the location in the reactor dictate the level of activation. The shielding evaluation has been revised to include evaluations for both uniform and non-uniform sources. These evaluations are intended to bound the range of specific activities expected for activated components.

The uniform concentration evaluation considers two configurations: One is where the activity is distributed in 3,000 kg of full density stainless steel. The other is distributed in stainless steel with reduced density of approximately 1.7 g/cm^3. When the source is distributed throughout the volume in low density material, higher external dose rates result versus the full density configurations. The distributed source term results in a specific activity of 10 Ci/kg.

The concentrated source is represented by activity uniformly distributed in a 1 kg sphere of stainless steel centered in the cask cavity. The maximum allowed activity is determined to be 2,800 Ci/kg. This bounds the case for contents where the activity is concentrated or part of a component is highly activated.

In addition, both the concentrated and distributed cases can be used together by taking advantage of the superposition principle.

Finally, control rod blades are explicitly modeled and are limited to a maximum of 32 Ci/cm.

Section 5.3.1 has been revised to include additional source configurations. Section 1.2.3 has been revised to specify the contents to account for concentrated activity which may exceed the specific activity for the uniformly distributed configuration. Sections 5.1.2, 5.4.4, 5.4.4.9, and 5.5.2, and Table 5-1 have been revised with conforming changes. The proposed Revision 13 CoC consistent with this response.

SAR Impact:

Sections 1.2.3, 5.1.2, 5.3.1, 5.4.4, 5.4.4.9, and 5.5.2, and Table 5-1 have been revised as described in the response.

The proposed Revision 13 CoC has been revised as described in the response.

RAI 5-2

Specify which bulk materials other than stainless steel that can be shipped as a content in the TN-RAM and either justify that stainless steel is representative or bounding when considering self-shielding or provide analyses with the other self-shielding medium(s).

The current proposed certificate of compliance (CoC) does not include a description of what the contents are made of, only its radioactive properties. The discussion in Section 5.3.1 *"Configuration of Source and Shielding,"* of the SAR states that the four source configurations are all modeled with stainless steel. Since the shielding analyses only model stainless steel, based on this the staff must limit the TN-RAM CoC contents to activated steel. However per Section 1.2.3 of the SAR, some typical contents are made of Zirconium and would be excluded if the staff limited the contents to activated steel. The applicant needs to state all of the bulk materials that could be shipped (excluding materials in trace amounts) and discuss if modeling stainless steel self-shielding is either representative or bounding for all these materials or provide additional or updated shielding analyses including consideration materials' self-shielding.

This information is needed to determine compliance with regulations in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-2

The configurations for NCT are analyzed with stainless steel. The activated contents provide some self-shielding. The limiting dose rates are calculated using cobalt-60 activity distributed in stainless steel at approximately 1.7 g/cm^3 or full density of 7.92 g/cm^3. The reduced density case bounds materials with densities as low as 1.7 g/cm^3.

For example, zirconium-based alloy materials used in nuclear power plants have a cobalt impurity level of 10 ppm. Stainless steel has a cobalt impurity level of 800 ppm. Assuming a similar activation the dose rates would be approximately 80 times lower for a similar configuration of zirconium as compared to the stainless steel. This does not include the fact that zirconium-based alloys have a density of 6.56 g/cm^3 versus stainless steel at 7.92 g/cm^3. If a zirconium-based alloy was loaded, the mass limit of the package would be exceeded to get the same quantity of cobalt-60 as stainless steel. The reduced density of the homogenized case bounds the lower density of zirconium-based alloys compared to stainless steel.

Materials other than steel must show equivalent shielding to stainless steel for cobalt-60 gammas.

In response to this RAI, the TN-RAM SAR has been revised to add new Section 5.4.4.5 to provide information about materials other than steel, and to add a subsequent new reference to Section 5.5.1.

SAR Impact:

Section 5.4.4.5 has been added and Section 5.5.1 has been revised as described in the response.

RAI 5-3

Clarify the shielding dimensions of the top (lid) and bottom of the TN-RAM package.

The drawings provided in the application are not clear. Staff reviews these drawings to determine whether models used to calculate external dose rates are consistent with actual package dimensions. Staff also performs independent evaluations using design information. The specific parts of the drawing that need clarification are the shielding components at the top and bottom of the package found in Drawing No. 990-702 "TN-RAM Packaging Shell Assembly."

a) The applicant should clarify the overall length of the TN-RAM cask with and without impact limiters. These numbers are not clear from the drawing.

b) The applicant needs to clarify the length of the lead shielding and its position within the overall cask length, i.e. how much additional steel/lead is above and below the shield. This value appears to be 105.06 inches, but is not clear, and it appears there is additional lead represented by the "X" shaped markings that are outside this line.

c) The applicant needs to clarify the size (height and radius) of the top (lid) and bottom lead shields. The applicant should include dimensions for the optional lid as well.

d) The applicant should clarify the thickness of stainless steel in the axial direction above and below each of the lead shields in the top and bottom of the cask. The applicant should include thickness of stainless steel in the lid and optional lid.

This information is needed in accordance with 10 CFR 71.33, 10 CFR 71.47 and 71.51(a)(2).

AREVA TN Response to RAI 5-3

The overall length of the TN-RAM cask is 129.38 inches (Drawing 990-701), which matches the shielding model (see surfaces 1014 and 1027 in the Monte-Carlo Neutron Particle (MCNP) models). The overall length of the TN-RAM package is 178.12 inches (same drawing as previously referenced). The shielding model for Revision 14 of the TN-RAM SAR was 178.14 inches (surfaces 1112 and 1115 in the MCNP model). The minor difference is the result of rounding and conversion from U.S. Customary to the International System of Units (SI), and has a negligible impact on the analysis.

The lead axially starts 10.15 inches from the top of the cask body (reference dimension at the upper left of the axial view on Drawing 990-702). The reference dimension 12.25 inches in the same location indicates the position of a weld. Detail F provides a closer view and is located on Drawing 990-703. Detail F does not show any lead. However, the 12.25-inch dimension corresponds directly to the full view of the cask on Drawing 990-702. In Detail F, part of a weld is shown in such a way that it will displace lead in the cask. This was approximated in the shielding model with additional stainless steel. The 105.06-inch dimension is not for the lead axially; it is the distance between the weld, located at 12.25 inches from the top of the cask, to a weld for the inner shell to the inner head (Items 3 and 5, respectively, on Drawing 990-703).

The lead shielding for the top lid is shown in Drawing 990-705. The diameter of the lead is 38.81 inches, which is derived from 39.81 inches minus two times 0.5 inch for the shell containing the lead. In the shielding models, the lid lead diameter was conservatively set at 38 inches with the 1/16-inch radial gap for fabrication. The thickness of the lead shielding in the lid is a 5.88-inch minimum, as shown in the side view of the lid on Drawing 990-705. Although the shielding model is consistent with this dimension, the other components of the lid were modeled at their nominal dimensions. This results in a false axial gap, which will not exist in the as-manufactured lid because the lead will be sized to fully fill the void.

The bottom lead shielding is a 5.69-inch minimum, as shown on Drawing 990-702. This was preserved in the shielding models with a similar false gap as that previously mentioned.

The optional lid is shown on Drawing 990-710. The axial lead thickness is a 5.68-inch minimum in Section C-C on the drawing. The shielding model is consistent with this dimension. The diameter of the lead was modeled to fully fill the void. The outer diameter of the shield disk is 39.81 inches. Item 5 in the bill of materials shows the shield disk shell as 0.5 inch thick. Therefore, the lead is 38.81 inches in diameter. The shielding models are consistent with this dimension.

The bottom of the TN-RAM cask has 3 inches of steel: 2.5 inches from the outer bottom plate (Item 7 on Drawing 990-703) and 0.5 inch from the inner head (Note 7 on Drawing 990-703).

With the lid, the TN-RAM has 3 inches of steel at the top of the cask: 2.5 inches from the lid flange and 0.5 inch from the lid bottom plate (Drawing 990-705). There is a relief of 0.12 inch in the lid flange to mate with the machined face at the top of the cask for bolting. This does not impact the amount of material shielding the cask axially at the top.

With the optional lid, the TN-RAM has 3.375 inches of steel at the top of the cask: 2.5 inches from the lid flange, 0.375 inch from the shield disk top cover, and 0.5 inch from the shield disk bottom plate (Drawing 990-710).

For the steel at the top and the bottom of the package in both configurations, the shielding models are consistent with the drawings as applicable.

In response to this RAI, eight of the ten drawings in Chapter 1 have been revised to provide additional clarity. Section 5.4.4 has been revised with conforming changes.

SAR Impact:

Eight of ten drawings in Chapter 1 and Section 5.4.4 have been revised as described in the response.

RAI 5-4

Justify the following configurations chosen for the evaluation for the "normally occupied space."

The 5 meter dose rate represents the "normally occupied space" per 10 CFR 71.47(b)(4). The applicant should justify this evaluation is appropriate by addressing the following:

a) Footnote 1 to Table 5-12 of the SAR states: "These tallies are averaged over a large surface to show that an operator in the vicinity of the package will experience less than 2 mrem/h." The applicant should explain what is meant by "large surface" and justify that this is appropriate.

b) For a horizontally oriented cask the "top" and "bottom" dose rates are evaluated. The staff does not understand why the top disk source is not limiting for this evaluation. The applicant should discuss any factors that would cause the homogenized cylinder to produce higher dose rates for this evaluation.

c) The operating procedures discuss vertical shipment of this cask. The applicant should evaluate the dose rate for the "normally occupied space" when the cask is oriented vertically and they also need to justify the choice of the source modeling configuration (top disk, homogenized, etc.).

This information is needed to determine compliance with 10 CFR 71.47.

AREVA TN Response to RAI 5-4

a) The TN-RAM SAR has been revised in response to this RAI by changing the assumed distance to be taken at the front end of the trailer, only considering the normally occupied space from the top of the package, and the surface tally was replaced with a mesh tally to show there are no streaming effects at the presumed distance to the normally occupied space. The distance from the front of the package to the end of the trailer is approximately 152 inches (386.08 cm) from the front of the trailer. The package is transported with the lid end facing the direction of travel. An additional case was performed with the bounding configuration to determine the maximum dose rate for this new tally.

b) New information providing an explanation of why certain cases of orientation are bounding has been added to Section 5.4.4.7 of the TN-RAM SAR. The effects of self-shielding and source distribution are discussed in the newly added Section 5.4.4.7.

c) The package is transported horizontally, lid end forward on a specially designed, three axle trailer. The package is handled vertically for loading and unloading only. An example is as follows: the package is loaded, vertically, in a spent fuel pool at a 10 CFR Part 50 site. The package is secured to the trailer, horizontally, before the package leaves the 10 CFR Part 50 site. For the entire 10 CFR Part 71 transport, the package is horizontal. Once at the disposal site, and only after it is off public highways, the package is oriented vertically for unloading.

In response to this RAI, the TN-RAM SAR has been revised to add new Sections 5.4.4.6 and 5.4.4.7. Sections 5.3.1, 5.4.4, 5.5.2, and Table 5-1 have been revised with conforming changes.

SAR Impact:

Sections 5.4.4.6 and 5.4.4.7 have been added as described in the response.

Sections 5.3.1, 5.4.4, and 5.5.2 have been revised as described in the response.

Table 5-1 has been revised as described in the response.

RAI 5-5

Justify the results in Table 5-12 of the SAR.

The applicant needs to provide justification for the following:

a. Staff is not clear on how the homogenized cylinder shows higher radial dose rates than the annulus since the applicant is evaluating dose rate by averaging tallies around the entire radius. Section 5.4.4 of the SAR states: *"There is no angular segmentation for any tally."*

b. The staff expects that the disk at the bottom to produce the highest dose rates calculated at the bottom of the package in all cases, however, Table 5-12 of the SAR shows that the homogenized cylinder gives a higher dose rate at 2 meters. The applicant should justify why the homogenized cylinder shows higher dose rates at the bottom than the bottom disk.

This information is needed to determine compliance with 10 CFR 71.47.

AREVA TN Response to RAI 5-5

a) Comparing the homogenized case against the annular case requires consideration of two, separate competing factors: source distribution and material density. Although the source distribution is isotropic within the source volume for both cases, the annular case has a density of 7.92 g/cm^3, while the homogenized case has a density of 1.71 g/cm^3. The self-shielding from the increased density effect is more significant than the source distribution with respect to the external dose rates around the package. The isotropic source distribution means gammas that are directed inward are more effectively shielded on the other side, as well in the annular case. For the bottom dose rates, the self-shielding is, again, more significant than the source concentration. Section 5.4.4.7 has been added to the SAR for clarification in response to this question.

b) Angular segmentation was not included because the package is angularly symmetric except for the trunnions and the cavity drain. The trunnions add more shielding material than the lead that is displaced. Streaming through the cavity drain was not considered credible because the contents are confined in a secondary container. A case has been performed with a mesh tally, 4 cm x 4 cm everywhere, to show there are no streaming effects.

SAR Impact:

Section 5.4.4.7 has been added as described in the response.

RAI 5-6

Justify the source geometry for HAC.

Section 5.3.1 states: *"For the HAC evaluation, the source was placed inside the package using the homogenized source dimensions and location."* Although the staff is aware that there is no self-shielding evaluated during HAC, as discussed in Section 5.3.1 of the SAR, the applicant should justify that this conservatism is enough to compensate for any source concentration that may occur during HAC. Other packages that show large margins to HAC dose rate limits do not credit source distribution (i.e. they use a point or line source as appropriate).

This information is needed to determine compliance with 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-6

Source concentration under HAC is expected to increase the average density of the material within the secondary container. This would increase the self-shielding effect, ultimately reducing dose rates. It is not credible to assume radioactive material would concentrate without an increase in the average density of the contents. Section 5.4.4.2 of the TN-RAM SAR has been revised to include additional discussion and analysis in response to this question. New cases have been added where the homogenized case has been compressed by a factor of 3, axially, while taking no credit for self-shielding for the HAC analysis. Results show that the dose rate limits are met, while dose rates increase depending on how the source was concentrated. Sections 5.1.2, 5.3.1, 5.4.4, and Table 5-15 have been revised with conforming changes in response to this RAI.

SAR Impact:

Sections 5.1.2, 5.3.1, and 5.4.4 have been revised as described in the response.

Table 5-15 has been revised as described in the response.

RAI 5-7

Justify the size of the segments for the mesh tallies (detectors) used to evaluate the dose rates and justify that streaming was adequately accounted for under NCT and HAC.

Section 5.4.4 states: *"Radial tallies are segmented axially between 20 and 22 cm. Axial tallies are segmented radially approximately 22 cm."* The applicant should justify that these segments are small enough to evaluate the effects of streaming. The staff is interested in the area in the axial and radial directions between the lead shielding in the cask body and the lid. The area above the lead shielding is of specific importance during HAC shielding evaluation where there is lead slump. In discussing streaming effects, the applicant should justify that the source configuration selected for this evaluation gives the highest dose rate (i.e. a more concentrated source, like the disk source at the top would exaggerate the effects of streaming more than the homogenous source, etc.).

This information is needed to determine compliance with 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-7

Lead slump is not credible based on the analysis in Section 2.7.1.1 of the TN-RAM SAR. However, a non-credible lead slump assumption was included in the analysis in Chapter 5 Revision 13 of the TN-RAM SAR, and has subsequently been removed in this revision for consistency.

A sensitivity case was performed with segmented tallies, 4 cm x 4 cm everywhere, to demonstrate there is no streaming. Section 5.4.4.10 has been added to the TN-RAM SAR, in response to this question, to explicitly discuss streaming. Sections 5.1.2, 5.3.1, 5.4.4, and Table 5-15 have been revised with conforming changes in response to this RAI.

It should be noted that the secondary container has lifting and handling equipment at the top of the cask that would keep any source bearing material away from the top of the cask. Even under HAC, it is reasonable to assume that the equipment will still keep the top of the secondary container away from the postulated, non-credible lead slump.

SAR Impact:

Section 5.4.4.10 has been added and Sections 5.1.2, 5.3.1, and 5.4.4 have been revised as described in the response.

Table 5-15 has been revised as described in the response.

RAI 5-8

Discuss the use of variance reduction and how this was used in conjunction with the mesh tally and that all locations around the cask (including areas around streaming paths) were appropriately considered in the biasing.

Section 5.4.1 of the SAR states: *"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 applicant should discuss how the importances were developed for each of the various tally locations (axial, radial, streaming paths, etc.) and justify that the variance reduction does not create any non-physical results.

This information is needed to determine compliance with 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-8

The variance reduction technique was a simple, brute-force method of doubling the importance of the histories for every mean free path of an average Co-60 energy gamma ray in steel or lead. No variance reduction was required in air or in the wood of the impact limiters. The various TN-RAM configurations are modeled in MCNP as concentric, cylindrical volumes, where the importances are increased from the inner to the outer volumes. The importances in this case only serve to accelerate the problem. The associated tally variance indicates whether the tally is well converged or not. For mesh tallies, smoothness of the results indicates how well the results have converged and how reliable they are. For results presented in the TN-RAM SAR, the relative uncertainty was below 10 percent, which meets the criteria for reliable results in the MCNP5 v1.4 manual.

SAR Impact:

No changes as a result of this question.

RAI 5-9

Clarify the source configurations described in Table 5-12 of the SAR.

In addition to the four source configurations described in Section 5.3.1 of the SAR, dose rate results for a 5^{th} source configuration are listed in Table 5-12 SAR. The configuration that is not described in Section 5.3.1 of the SAR is "cylinder." The applicant should provide details on what this configuration is.

This information is needed to determine compliance with 10 CFR 71.33, 10 CFR 71.47 and 71.51(a)(2).

AREVA TN Response to RAI 5-9

This configuration was inadvertently added to the TN-RAM SAR from the calculation. Within the calculation, additional work was performed to determine bounding dose rates. Only specific configurations, which resulted in bounding dose rates, were included in the TN-RAM SAR. The subject configuration did not produce bounding dose rates. TN-RAM SAR Table 5-12 has been revised to remove this configuration and Section 5.4.1 has been revised for conforming changes.

SAR Impact:

Section 5.4.1 has been revised as described in the response.

Table 5-12 has been revised as described in the response.

RAI 5-10

Update HAC shielding evaluations to account for deformation of the impact limiter due to the tests in 10 CFR 71.73.

Section 5.3.1 of the SAR states: *"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."* Locations for the dose rate tallies under HAC are all in relation to nominal (non-deformed) impact limiter dimensions. Section 3.5.1 of the SAR states that there would be a deformation from the 30 foot drop with a crush depth of 12.48 inches on the side and 9.05 inches in the axial direction. There would be additional deformation of the impact limiter as a result of charring from the fire and even though the stainless steel shell would still be present, the applicant would need to further demonstrate that the shell alone could support the weight of the package given the loss of material consumed by the fire. The applicant should update the HAC shielding evaluations to account for the deformation of the impact limiter from drop tests and fire. The applicant should justify that the amount of deformation is appropriate to account for these tests.

This information is needed to determine compliance with 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-10

The datum of the dose rates for HAC in Section 5.4.4.2 of the TN-RAM SAR was intended to be 1 m from the cask. In the MCNP models, the impact limiters were removed for the HAC analysis as shown in Figure 5-4. No credit was to be taken for the impact limiters. The MCNP models included tallies both 1 m from the cask and 1 m from the package. The subject results were taken from the wrong tally. Table 5-2 of the TN-RAM SAR has been revised to correct this error, and Section 5.1.2 has been revised with conforming changes.

SAR Impact:

Section 5.1.2 has been revised as described in the response.

Table 5-2 has been revised as described in the response.

RAI 5-11

Clarify the contents of the package.

The draft CoC includes "2,727 A_2" as an allowable content. A limit of "2,727 A_2" is ambiguous. The gamma source term in the shielding evaluation is based on 30,000 Ci Co-60 with equivalence to other gamma emitting nuclides, as discussed in Section 5.5.3 of the SAR. However, there are no analyses for alpha, beta or neutron sources. Since alpha and beta radiations are typically not challenging to the shielding employed in this package, the staff can only assume that 2,727 A_2 was meant for these radiation sources only.

Based on the shielding analyses as provided, the staff can only approve the following authorized contents in the CoC: 2,727 A_2 for alpha and beta sources only (assuming the additional information requested in RAI 5-13 is provided), with gamma sources limited to 30,000 Ci Co-60 or equivalent.

The applicant should clarify the limit of 2,727 A_2 from the draft CoC, and provide additional analyses justifying the shipment of up to 2,727 A_2 of gamma and neutron sources, if this is what this limit was intended for.

This information is to determine compliance with 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-11

The proposed draft CoC and the SAR have been revised to clarify that the allowable content as a function of A_2 is to be limited to alpha and beta emitting radionuclides. A limit of 3,000 A_2 has been selected, which is the maximum for a category II Type B package. Justification for this value is provided in new TN-RAM SAR Sections 5.2.3 and 5.4.4.11. AREVA TN agrees with the staff's proposed limits for gamma emitting sources using the equivalence as described in Section 5.5.3 of the revised TN-RAM SAR.

In addition, the response to RAI 5-12 addresses the analysis for neutron emitters and the response to RAI 5-13 addresses the analysis for beta emitters.

SAR Impact:

Sections 5.3.2 and 5.4.4.11 have been added as described in the response.

RAI 5-12

Discuss the potential for neutron sources or justify why an evaluation is not needed.

Section 5.2.2 of the SAR states: *"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."* Although insignificant, the currently proposed contents descriptions in Section 1.2.3 of the SAR include neutron sources. Some nuclides are gamma and neutron emitters. Since it would be impractical to include a limit of zero neutron sources within the CoC, a small quantitative limit must be included for neutron emitting sources as well as an analyses that justifies the limit. Examples of language used to establish neutron source limits used in other CoC's shipping similar contents are provided below:

"A maximum total package neutron source of $1x10^5$ neutrons/second for materials that produce neutrons (other than fissile materials) through any means, including spontaneous fission, alpha-neutron reactions, and gamma-neutron reactions."

"A maximum total package neutron source of $3.5\ 10^{-6}$ Ci/g for materials that produce neutrons (other than fissile materials) through any means, including spontaneous fission, alpha-neutron reactions, and gamma-neutron reactions."

Alternatively, an appropriate evaluation or justification (with quantitative as well as qualitative support) for not needing an evaluation should be provided. Any evaluation or justification should address important factors such as the radionuclides that may be present, distribution of the radionuclides and contents compositions. Alpha-n reactions in the contents should also be addressed.

This information is needed to determine compliance with 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-12

The TN-RAM SAR has been revised to include an analysis of a neutron source contained within the cask. Section 5.2.2 has been revised to discuss the neutron source used in the model: 1×10^6 neutrons/s are used as the source. Section 5.4.4.8 has been added to the SAR to discuss the results of the neutron case. The maximum dose rate resulting from the neutrons is 1.51 mrem/h on the surface of the cask, although this dose rate is inside the trunnion, which is a consequence of how the tally is configured. At two meters from the package, the maximum dose rate is 0.08 mrem/h. Section 5.4.1 and Tables 5-16 and 5-17 have been revised with conforming changes.

SAR Impact:

Sections 5.2.2 and 5.4.1 have been revised and Section 5.4.4.8 has been added as described in the response.

Tables 5-16 and 5-17 have been revised as described in the response.

RAI 5-13

Justify, with an evaluation, that 2,727 A_2 is an acceptable content quantity limit for beta-emitting nuclides addressing the potential for significant generation of Bremsstrahlung.

For at least some beta-emitting nuclides, Bremsstrahlung may be significant as a source of radiation exposure from the package. This concern is particularly for those nuclides that emit high energy betas and the proposed content quantity limit allows for significant quantities of those nuclides to be transported. An example is P-32 with a maximum beta energy of 1.71 MeV (the average is 695 keV), emitted with each decay, and an A_2 value comparable to that of Co-60 (14 curies vs. 11 curies). A quantitative, as well as qualitative, justification is needed.

This information is needed to determine compliance with 10 CFR 71.47 and 10 CFR 71.51(a)(2).

AREVA TN Response to RAI 5-13

An evaluation was performed for 3,000 A_2 of ^{32}P to quantify the external dose rates as a result of bremsstrahlung radiation. The TN-RAM SAR has been revised to include this analysis. The source used is discussed in new Section 5.2.3 of the SAR. Results are described in new Section 5.4.4.11 of the SAR. The new A_2 limit is discussed in the response to RAI 5-11.

SAR Impact:

Sections 5.2.3 and 5.4.4.11 have been added as described in the response.

Non-Proprietary

SAFETY ANALYSIS REPORT for the TN-RAM

E-10621

October 2015

Revision *15*

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

TN-RAM SAR
REVISION LOG
E-10621

Rev. No.	Date	Description
14	5/21/15	Revised pages as follows: SAR cover sheet SAR page 1-6 SAR pages 3-2, 3-4, 3-7, 3-14, 3-16, 3-17, 3-24, 3-28, 3-30 SAR pages 5-i, 5-ii, 5-1, 5-4 through 5-6, 5-8 through 5-10, 5-12, 5-14 through 5-17, 5-20a, 5-21 through 5-24, 5-26, 5-27, 5-27a, 5-28 through 5-30, 5-33, 5-34
15	*10/9/15*	*Revised pages as follows:* *SAR cover sheet* *SAR pages 1-6, 1-11* *SAR page 3-5* *SAR pages 5-i through 5-iii, 5-2 through 5-6, 5-8, 5-9, 5-10, 5-11, 5-12, 5-14, 5-16, 5-18 through 5-21, 5-26, 5-32* *New pages as follows:* *Revision Log page 5* *SAR pages 5-8a, 5-10a, 5-10b, 5-27b, 5-27c, 5-27d, 5-35, 5-36* *Revised drawings as follows:* *Drawing 990-701* *Drawing 990-702* *Drawing 990-703* *Drawing 990-704* *Drawing 990-705* *Drawing 990-706* *Drawing 990-707* *Drawing 990-708* *New drawings as follows:* *None*

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 *gamma emitting* radioactive material is limited to a maximum of 30,000 Ci cobalt-60 or equivalent as described in Section 5.2.1. *The quantity of alpha and beta emitting radionuclides is limited to 3,000* A_2. 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 *of Co-60 or equivalent. Concentrated sources are limited to 2,800 Ci/kg of Co-60 or equivalent. Control rod blades and local power range monitors are limited to 32 Ci/cm of Co-60 or equivalent. If concentrated sources are mixed with nearly homogenous sources, the following relation should hold:*

$$\frac{DistributedActivity}{30000Ci}+\frac{Concentrated}{2800Ci}\leq 1$$

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

1.3 Appendix

TN-RAM DRAWINGS / DOCUMENTS

DWG/DOC'T NO.	TITLE	REVISION
990-701	TN-RAM Packaging Assembly	*10*
990-702	Shell Assembly	*9*
990-703	Shell Parts List & Details	*11*
990-704	Shell Details	*7*
990-705	Lid Assembly & Parts List	*8*
990-706	Lid Details	*5*
990-707	Impact Limiter Assembly	*5*
990-708	Impact Limiter Details & Parts List	*9*
990-709	Impact Limiter Attachment Bolt	2
990-710	Optional Lid Details	2
E-10615	Lead Pouring Requirements	0

1 OF 1 SHEET	990-701	DRAWING NO.

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M

INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
990-701	NONE	1 OF 1	10

SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M	
INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4	SAFETY ANALYSIS REPORT
Proprietary Property of Transnuclear, Inc. This drawing may not be disclosed to others in whole or in part, or used for other than the transmitted purpose without written permission of Transnuclear, Inc.	TN-RAM PACKAGING SHELL ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
990-702	NONE	1 OF 1	9

DRAWING NO. 990-702 SHEET 1 OF 1

PROPRIETARY AND
SECURITY RELATED INFORMATION
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INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
SHELL
PARTS LIST & DETAILS

DRAWING NO.	SCALE	SHEET	REVISION
990-703	NONE	1 OF 1	11

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INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
SHELL DETAILS

DRAWING NO.	SCALE	SHEET	REVISION
990-704	NONE	1 OF 1	7

DRAWING NO. 990-704 SHEET 1 OF 1

DRAWING NO. 990-705 SHEET 1 OF 1

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INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
LID
ASSEMBLY & PARTS LIST

DRAWING NO.	SCALE	SHEET	REVISION
990-705	NONE	1 OF 1	8

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INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
LID
DETAILS

DRAWING NO.	SCALE	SHEET	REVISION
990-706	NONE	1 OF 1	5

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INTERPRETATION OF WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT

TN-RAM PACKAGING
IMPACT LIMITER
ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
990-707	NONE	1 OF 1	5

DRAWING NO. 990-707 SHEET 1 OF 1

990-708 1 OF 1

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SAFETY ANALYSIS REPORT
TN-RAM PACKAGING
IMPACT LIMITER
DETAILS & PARTS LIST

DRAWING NO.	SCALE	SHEET	REVISION
990-708	NONE	1 OF 1	9

3.2 THERMAL PROPERTIES OF MATERIALS

Table 3-2 lists the thermal properties of materials used in the thermal analyses. The values are listed as given in the corresponding references. The analysis uses interpolated values when appropriate for intermediate temperatures where the temperature dependency of a specific parameter is deemed significant. The interpolation assumes a linear relationship between the reported values.

Thermal radiation effects at the external surface of the packaging are considered. The external surfaces of the TN-RAM are assumed to have an emissivity of 0.85, a typical value for weathered stainless steel surfaces *obtained from Table 5.2 of [3-2]*. For solar absorptivity, a conservative value of 1 is used.

CHAPTER FIVE
SHIELDING EVALUATION
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CHAPTER FIVE
SHIELDING EVALUATION

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CHAPTER FIVE
SHIELDING EVALUATION

LIST OF FIGURES

5.1 DESCRIPTION OF SHIELDING DESIGN

The TN-RAM package is a Type B shipping cask with steel inner and outer shells. Bulk lead poured between the shells during fabrication is used for shielding radially and axially at the bottom. The lid contains lead for shielding at the top. Impact limiters at the top and bottom are used to provide protection for drops. Four trunnions at the top and two trunnions at the bottom are used for handling and support the cask when it is transported. A cavity drain facilitates the removal of water after loading. A vent through the lid is used for operations as required.

No credit is taken for the secondary container in the TN-RAM package to meet the shielding requirements.

5.1.1 Design Features

The TN-RAM cask contains steel and lead in the radial and axial directions to provide gamma shielding. The inner shell has 0.75 inches of steel radially and 0.5 inches of steel at the bottom. The outer shell has 1.5 inches of steel radially and 2.5 inches of steel at the bottom. Between the shells, lead is poured with a minimum of 5.75 inches radially and 5.69 inches at the bottom. Shielding at the top is provided by either lid option. There are a total of 3 inches of steel and 5.88 inches minimum of lead in the original lid. The optional lid has a total of 3.375 inches of steel and 5.68 inches minimum of lead. A thermal shield between the impact limiters is 0.25 inches thick and provides additional radial shielding.

More detail is provided in Section 5.3.

5.1.2 Summary Table of Maximum Radiation Levels

Normal conditions of transport (NCT) dose rates are computed for an exclusive-use transport in an open vehicle. Therefore, the following limits apply:

- 10 CFR 71.47(b)(1): the external surface of the package must be below 200 mrem/h,
- 10 CFR 71.47(b)(2): the outer surface of the vehicle must be below 200 mrem/h,
- 10 CFR 71.47(b)(3): any point 2 m from the outer lateral surfaces of the vehicle must be below 10 mrem/h, and
- 10 CFR 71.47(b)(4): any normally occupied space must be below 2 mrem/h unless personnel follows the requirements of 10 CFR 20.1502.

Normally occupied space *is* assumed to be *152 inches* from *the top* of the package.

The NCT surface dose rates use the top and bottom of the impact limiter as the basis for the surface of the package axially. The radial surface of the cask is the basis for the side *surface* dose rate. The 2 m dose rate basis is from the extents of the impact limiters in all directions. The maximum NCT dose rates are shown in Table 5-1.

Maximum dose rates for a normally occupied space which is assumed to be *152 inches* from the top of the TN-RAM package are shown in Table 5-1

Hypothetical accident conditions (HAC) external dose rates are computed using the surfaces of the cask as the basis for the 1 m distance as prescribed by 10 CFR 71.51(a)(2). Compliance with release doses per 10 CFR 71.51(a)(1) and 71.51(a)(2) is shown in Chapter 4. The maximum external HAC dose rates are shown in Table 5-2.

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:

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

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:

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

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. *However, a source of $1\mathrm{x}10^6$ neutrons per second is evaluated. The distribution of the neutron source is the same as the gamma source. The neutron source is based on a Watt fission spectrum for Cm-244.*

5.2.3 Beta Source

The TN-RAM package is evaluated to transport 3,000 A_2 of beta emitting radionuclides. Beta emitters can create bremsstrahlung radiation as the electrons are attenuated through high Z materials. Therefore, a source of 3,000 A_2 of phosphorus-32 is evaluated to determine the impact of bremsstrahlung. The distribution of the source is radially outward from the inner surface of the inner shell to amplify the effect. The betas are modeled at the maximum emission energy of phosphorus-32: 1.71066 MeV.

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 *not* analyzed; per the discussion in Section 2.7.1.1, lead slump is not expected.

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

Six 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 1.71g/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 *fourth* 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 fifth configuration is a one kg sphere at the center of the cavity. The purpose of this model is to quantify the maximum specific activity which meets the 10 CFR 71.47 requirements. The source is modeled as a stainless steel sphere at full density with a radius of 3.112 cm. Note that the analysis is performed with a higher activity and scaled down to establish a limit of 2800 Ci/kg.

The sixth configuration is an array of control rod blades (CRB) in the cavity. The CRBs are too long to fit the cavity; they must be cut in half for transport. The CRBs were modeled to preserve the mass. The CRB is based on 53.0 kg of stainless steel and 5.0 kg of B_4C with a cross section of 0.773 cm x 25.4 cm taken over 144 inches. The purpose of this configuration is to determine the maximum activity per unit length along the cask. Note that the analysis is performed with a higher activity and scaled down to establish a limit of 32 Ci/cm.

The *first* 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. *The final two configurations are shown in Figure 5-8.*

For the HAC evaluation, the source was placed inside the package using the homogenized source dimensions and location. An axial cross section view of the TN-RAM package for HAC is shown in Figure 5-4. *Compression of the source was considered for the HAC analysis.*

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 *all* tallies. The importance of the particles increases as the particles traverse the shielding materials. *The mean free path of an average cobalt-60 gamma ray in lead or steel was used as the distance where the importance doubled.* 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.

No source biasing was used in any model.

The acceptance criterion was the same as specified in the MCNP5 manual: variance below 10% is considered reliable for non-point detector tallies.

5.4.2 Input and Output Data

A sample input file is provided in *Section* 5.5.2.

5.4.3 Flux-to-Dose-Rate Conversion

The ANSI/ANS 6.1.1-1977 flux-to-dose-rate conversion factors for gamma rays *and neutrons* are used in this evaluation [5-1]. The factors are shown *for gammas* in Table 5-11 *and for neutrons in Table 5-17.*

5.4.4 External Radiation Levels

Dose rates are calculated using the mesh tally feature of MCNP5. *For the homogenized, annulus, disk top, and disk bottom, the 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 beta case used tallies similar to the annulus, disk top, and disk bottom. For the neutron, secondary gamma, point, and CRB evaluations, the tallies were segmented axially and angularly to be 4 cm x 4 cm to investigate if streaming exists. Axial tallies were Cartesian with 4 cm x 4 cm voxels, except for the tally for the normally occupied space, which was 8 cm x 8 cm. HAC radial tallies were segmented axially 4 cm with no angular segmentation. HAC axial tallies were segmented radially 4 cm with no angular segmentation.* 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.

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 *CRB* case has the maximum dose rate of *9.22* mrem/h. This dose rate is below the limit of 10 mrem/h. *T*he relative uncertainty is *six* percent, which is approximately 0.*6* mrem/h. The dose rate is 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 *2.10* mrem/h with the *homogenized* source configuration, which is below the limit of 10 mrem/h.

The maximum radial surface dose rate occurred with the *point source* configuration and was *194* 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 *152 inches* from *the front* end of the package. The maximum dose rate was *0.773* mrem/h with *the* 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-*15*. All dose rates in this table are taken 1 m from the external surface of the cask. *Compression of the source was investigated for HAC. The original source was the same as the NCT homogenized source. The source was then compressed by a factor of 3 and shifted toward the top or bottom in the axial direction to determine the resulting dose rates at 1 m from the surface of the cask. This reduction in height was from 282.66 cm to 94.22 cm.* The maximum radial dose rate is *752* mrem/h, which is below the 10 CFR 71.51(a)(2) limit of 1,000 mrem/h. *This dose rate occurs above the lead shielding directly below the lid. The secondary container, which was not modeled, would prevent source bearing contents from being in this area.* The maximum top HAC dose rate is *245* mrem/h, which is below the limit of 1,000 mrem/h. *This occurs when the source is compressed towards the top of the cask.* The maximum bottom HAC dose rate is *307* mrem/h, which is below the limit of 1,000 mrem/h. *This occurs when the source is compressed towards the bottom of the cask.*

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.

5.4.4.5 Materials other than stainless steel

The material for the homogenized case was stainless steel. However, with a density of 1.71 g/cm^3, it bounds other materials with densities between this value and the full density of stainless steel. For example, zirconium-based alloys have a density approximately 6.56 g/cm^3. This density is greater than the homogenized case; therefore, it is bounded. Additionally, stainless steel may have cobalt impurity levels as high as 2000 ppm. Zirconium-based alloys have a cobalt impurity level of 10 ppm [5-4]. Even if the same mass of material had the same fluence, the dose rates resulting from the zirconium based alloys would be much lower than the stainless steel.

5.4.4.6 Normally occupied spaces

The TN-RAM package is transported on a specially designed, three-axle semi-trailer. For the purpose of evaluating the requirements of 10 CFR 71.47(b)(4), the normally occupied space was considered to be at the front end of the trailer, 152 inches from the top end of the package. The package is only transported horizontally, lid end first. No credit is taken for shielding from the prime mover.

5.4.4.7 Self-shielding versus source distribution

The homogenized configuration bounds the disk top, disk bottom, and the annulus configuration. For these four configurations, the source was distributed uniformly throughout the source volume. However, the homogenized case had a density of approximately 1.71 g/cm³ rather than the other three cases, which were modeled at 7.92 g/cm³. The MCNP reported mean free path of the gammas in the homogenized configuration was 7.7 cm. However, the MCNP reported mean free path in the annulus configuration was 1.67 cm. The reduced density is a more important factor rather than the source distribution.

An additional conclusion can be made with this information. If the source concentrates during NCT or HAC, the dose rates can be expected to be the same or lower.

5.4.4.8 Neutron and secondary gammas

With a source of $1x10^6$ neutrons/s, the maximum dose rate on the surface of the package is 1.51 mrem/h. However, this dose rate is inside the trunnion due to the nature of the tally. Other dose rates for this system are all less than 0.1 mrem/h. The maximum dose rate as a result of secondary gammas is 4.30E-03 mrem/h. The NCT results are shown in Table 5-16. No HAC evaluation was performed because the effectiveness of the package to shield neutrons is not reduced after the HAC.

Therefore, the neutron limit is acceptable for incidental radionuclide contamination that generates neutrons. No self-shielding was credited in the neutron and secondary gamma analysis.

5.4.4.9 CRB and point source configuration

The limit of the activity for the CRB configuration is 32 Ci/cm. The limit of the activity for the point source configuration is 2800 Ci/kg.

5.4.4.10 Streaming

Streaming was investigated using the CRB case. The fine mesh tally over the entire system was an excellent candidate for plotting to determine if any streaming paths were not captured by the coarse mesh tallies. The two-meter tally radially around the system was used for this plot. The values were scaled as described in Section 5.4.4.9. Figure 5-9 shows the tally plotted in two dimensions with the dose rate as a function of color. The abscissa is the distance in z from the bottom of the tally to the top. The ordinate is the rotation around the package where one equals

360 degrees. The smoothness in the figure suggests no streaming paths were missed in the analysis.

5.4.4.11 Beta Emission

Beta emission was considered using the source described in Section 5.2.3. The electrons were simulated with MCNP5 applied to the inner surface of the cavity with the maximum emission energy of phosphorus-32. The distribution of the source was isotropic on the surface, but directed radially outward. No self-shielding was included in the model. The source was only modeled radially. High Z materials create bremsstrahlung radiation. The radial dimension of the cask presents the highest opportunity for interaction because the most material is in the radial direction. The maximum dose rate on the radial surface of the cask was 3.08 ± 8% mrem/h. The maximum dose rate 2 m from the radial surface of the package was 0.122 ± 16% mrem/h.

5.5 APPENDIX

5.5.1 References

5-1 American Nuclear Society, "American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors," ANSI/ANS-6.1.1-1997 (N666), LaGrange Park, Illinois.

5-2 McConn Jr, R. J. et al., "Compendium of Material Composition Data for Radiation Transport Modeling," PNNL-15870, Revision 1, Pacific Northwest National Laboratory, March 2011.

5-3 X-5 Monte Carlo Team, "MCNP—A General Monte Carlo N-Particle Transport Code," Version 5. Los Alamos National Laboratory, April 2003. Available from RSICC as Software Package C00730MNYCP00.

5-4 Ludwig, S.B. and J.P Renier. "Standard- and Extended-Burnup PWR and BWR Reactor Models for the ORIGEN2 Computer Code," ORNL/TM-11018, Oak Ridge National Laboratory, December 1989.

Proprietary Information Withheld Pursuant to 10 CFR 2.390

Proprietary Information Withheld Pursuant to 10 CFR 2.390

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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

Table 5-1
Summary of NCT Maximum Dose Rates

	Dose rate (mrem/h)	Relative 1σ uncertainty	Limit (mrem/h)	Configuration
	Surface			
Side	*194*	*0.01*	*200*	*Point*
Top	*11.7*	*0.03*	*200*	*Disk Top*
Bottom	*20.0*	*0.04*	*200*	*Disk, Bottom*
	2 m			
Side	*9.22*	*0.06*	*10*	*CRB*
Top	*1.82*	*0.06*	*10*	*Disk, Top*
Bottom	*2.10*	*0.09*	*10*	*Disk, Bottom*
	152" from the top of the package			
Top	*0.773*	*0.07*	*2*	*Homogenized*

Table 5-2
Summary of HAC Maximum Dose Rates

	Dose rate (mrem/h)	Relative 1σ uncertainty	Limit (mrem/h)
	1 m		
Side	*752*	0.01	1000
Top	*245*	*0.07*	1000
Bottom	*307*	*0.09*	1000

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	*Dose rate (mrem/h)*	*Relative 1σ uncertainty*
	Annulus		***Disk, Top***		**Disk, *Bottom***		***Homogenized Cylinder***		***CRB***		***Point***	
	2 meters											
radial max:	8.96	0.01	*5.13*	0.01	*2.36*	*0.02*	*9.07*	*0.02*	*9.22*	*0.06*	*6.91*	*0.05*
top max:	1.68	0.08	*1.82*	*0.06*	*0.41*	*0.17*	*1.72*	*0.10*	*1.50*	*0.15*	*1.79*	*0.07*
bottom max:	1.74	0.06	*0.43*	*0.12*	*1.99*	*0.05*	*2.10*	*0.09*	*1.84*	*0.13*	*1.78*	*0.14*
	Surface											
radial max:	101	0.01	*107.3*	*0.01*	*69.8*	*0.01*	*96.8*	*0.01*	*183*	*0.02*	*194*	*0.01*
top max:	10.3	0.05	*11.71*	*0.03*	*1.73*	*0.09*	*11.3*	*0.06*	*7.70*	*0.04*	*4.61*	*0.04*
bottom max:	17.5	0.05	*3.06*	*0.07*	*20.0*	*0.04*	*19.8*	*0.07*	*13.4*	*0.05*	*10.8*	*0.03*
	***152" from the top* impact limiter**											
top *max*:	*Not calculated*						*0.773*	*0.07*	*0.688*	*0.08*	*0.585*	*0.52*

Table 5-15
Summary of All HAC Configurations

	Dose rate (mrem/h)	Relative 1σ uncertainty	Dose rate (mrem/h)	Relative 1σ uncertainty	Dose rate (mrem/h)	Relative 1σ uncertainty
	Full		Compressed Top		Compressed Bottom	
1 m radial	258	0.01	752	0.01	223	0.01
1 m top	144	0.09	245	0.07	47.4	0.16
1 m bottom	200	0.15	81.1	0.08	307	0.09

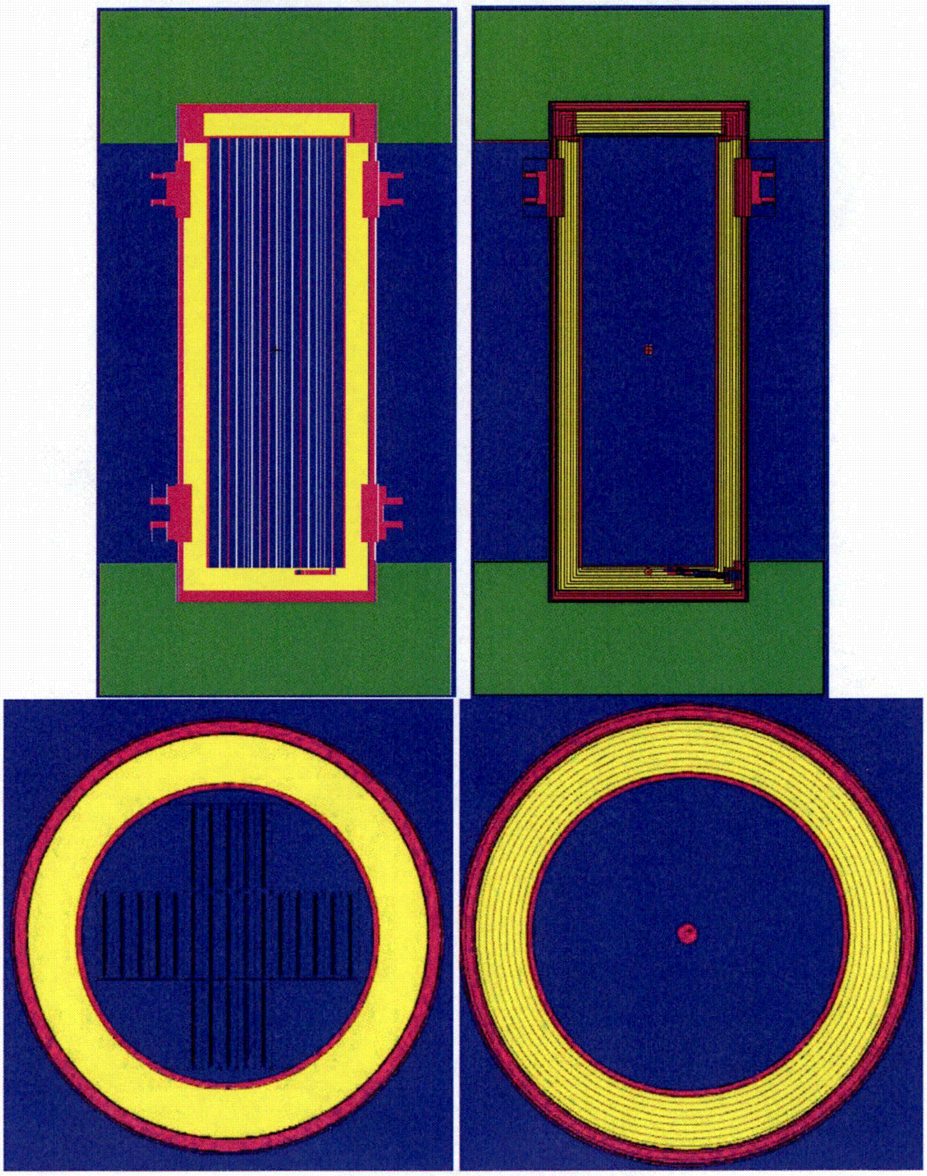
Table 5-16
Neutron and Secondary Gamma NCT Dose Rates

	Dose rate (mrem/h)	***Relative 1σ uncertainty***	***Dose rate (mrem/h)***	***Relative 1σ uncertainty***
	Neutron		***Secondary Gamma***	
	2 meters			
radial max:	*0.0814*	*0.02*	*1.97E-04*	*0.05*
top max:	*0.0110*	*0.06*	*2.29E-04*	*0.05*
bottom max:	*0.0109*	*0.06*	*2.61E-04*	*0.05*
	Surface			
radial max:	*1.51*	*0.01*	*2.93E-03*	*0.02*
top max:	*0.0109*	*0.03*	*3.21E-03*	*0.02*
bottom max:	*0.0635*	*0.02*	*4.30E-03*	*0.02*
	152" from the top impact limiter			
top max:	*5.27E-03*	*0.04*	*7.64E-05*	*0.04*

Table 5-17
ANSI/ANS 6.1.1-1977 Neutron Flux-to-Dose-Rate Conversion Factors

Energy (MeV)	*mrem/h/n/(s cm^2)*
2.50E-08	3.67E-03
1.00E-07	3.67E-03
1.00E-06	4.46E-03
1.00E-05	4.54E-03
1.00E-04	4.18E-03
1.00E-03	3.76E-03
1.00E-02	3.56E-03
1.00E-01	2.17E-02
5.00E-01	9.26E-02
1	1.32E-01
2.5	1.25E-01
5	1.56E-01
7	1.47E-01
10	1.47E-01
14	2.08E-01
20	2.27E-01

Figure 5-5
Deleted



Left: CRBs, Right: Point Source

Figure 5-8
Additional Source Configurations

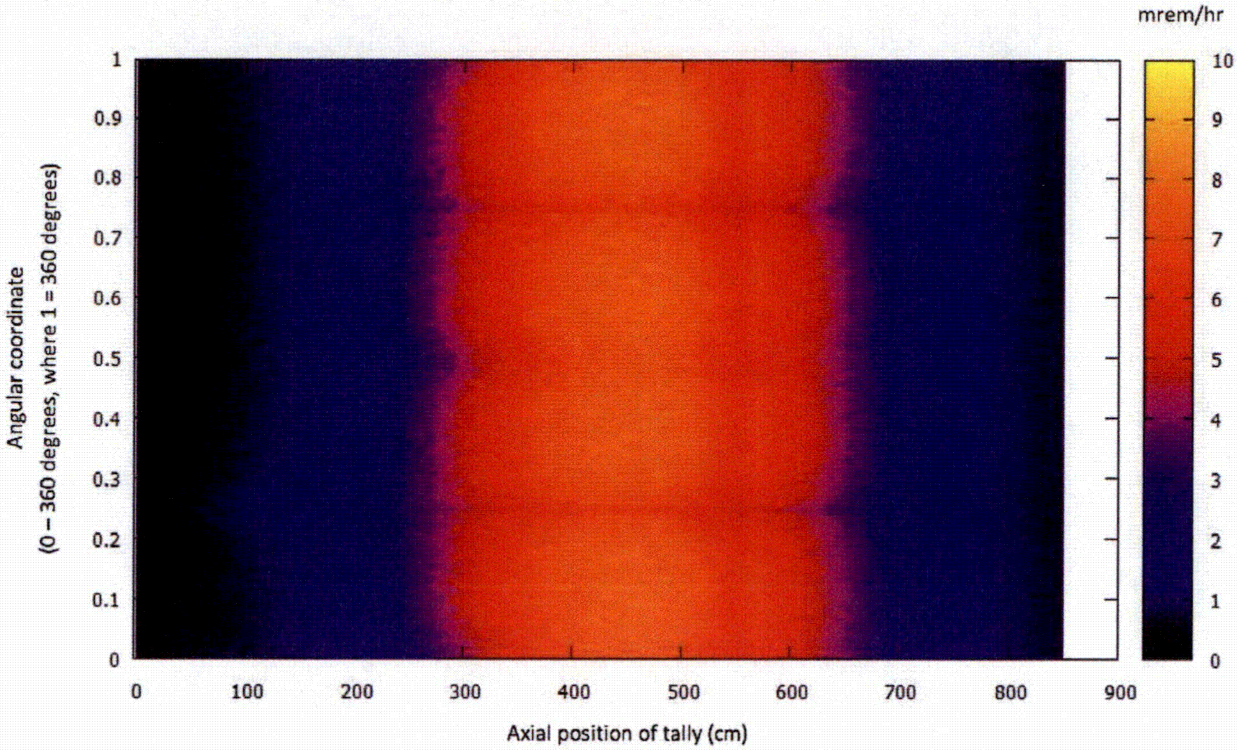


Figure 5-9
CRB 2-meter Radial Tally Results

Enclosure 4 to E-43104

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 computer disk* (103 MB)	**Shielding**	TN-RAM NCT	Folder: *beta* Bremsstrahlung analysis	3
		TN-RAM NCT	Folder: *crb* Explicit control rod blade analysis	3
		TN-RAM HAC	Folder: *hac bottom* HAC with source compressed at the bottom	3
		TN-RAM HAC	Folder: *hac top* HAC with the source compressed at the top	3
		TN-RAM HAC	Folder: *hac full* HAC with the source configuration the same as the homogenous case	3
		TN-RAM NCT	Folder: *homogenized* Case used for fine mesh tally at the normally occupied space	3
		TN-RAM NCT	Folder: *neutron* Neutron analysis	3
		TN-RAM NCT	Folder: *point* Point source analysis	3
		TN-RAM NCT	Folder: *secondary gamma* Secondary gamma as a result of the neutron source	3

Enclosure 6 to E-43104

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.~~ AREVA Inc. application dated ~~March 8, 2005~~ March 9, 2015, as supplemented.

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	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	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.~~

Insert 1(as shown on page 4 of this enclosure

(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 **2** (as shown on page **5** 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: ***TBD***

3000 A_2., Gamma emitting radionuclides are limited to 30,000 Ci of ^{60}Co or equivalent as shown by the following equation:

AREVA Inc.

REFERENCES

~~Transnuclear, Inc.~~, application dated ~~March 8, 2005.~~ March 9, 2015

~~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):

(3) Drawings

990-701	*TN-RAM Packaging Assembly*	*10*
990-702	*Shell Assembly*	*9*
990-703	*Shell Parts List & Details*	*11*
990-704	*Shell Details*	*7*
990-705	*Lid Assembly & Parts List*	*8*
990-706	*Lid Details*	*5*
990-707	*Impact Limiter Assembly*	*5*
990-708	*Impact Limiter Details & Parts List*	*9*
990-709	*Impact Limiter Attachment Bolt*	*2*
990-710	*Optional Lid Details*	*2*

Insert 2 (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*, Section 5.5.3,* of the TN-RAM Safety Analysis Report provides the basis for the equation and these values.

The *distributed* average *specific* activity of the contents is limited to 10 Ci/kg *of Co-60 or equivalent. Concentrated sources are limited to 2800 Ci/kg of Co-60 or equivalent. CRBs and LPRMs are limited to 32 Ci/cm of Co-60 or equivalent. If concentrated sources are mixed with nearly homogenous sources, the following relation should hold:*

$$\frac{Distributed\ Activity}{30\ 000\ Ci} + \sum_i \frac{(Concentrated\ Activity)_i}{2800\ Ci} \leq 1$$

Materials other than stainless steel must show shielding equivalence to stainless steel for Co-60.

Alpha and beta emitting radionuclides are limited to 3000 A_2.

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

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

**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, 5, and 7 is listed below:

- Enclosure 2 – Portions of the Changed Pages, TN-RAM SAR, Revision 15
- Enclosure 5 - Shielding Computer Files
- Enclosure 7 – TN-RAM SAR Drawings

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 includes certain portions of the safety analysis report, shielding computer files, and the SAR drawings related to the design of the TN-RAM radioactive material 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 radioactive material 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 8th day of October, 2015.

Notary Public
My Commission Expires ___/___/

LAUREN MCKEE
Notary Public-Maryland
Anne Arundel County
My Commission Expires
February 12, 2019

LAUREN MCKEE NOTARY PUBLIC ANNE ARUNDEL COUNTY MD