UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 20, 2016

Mr. Paul Triska
Vice President, Technical Services
AREVA Inc.
7135 Minstrel Way, Ste. 300
Columbia, MD 21045

SUBJECT: REVISION NO. 13 OF CERTIFICATE OF COMPLIANCE NO. 9233, DOCKET NO. 71-9233

Dear Mr. Triska:

As requested by your renewal and amendment application dated March 9, 2015, as supplemented May 21, October 8, and November 20, 2015, enclosed is Certificate of Compliance No. 9233, Revision No. 13, for the Model No. TN-RAM transportation package. The applicant submitted a consolidated application on December 8, 2015. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's safety evaluation report is also enclosed.

The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471. Those on the attached list have been registered as users of the package under the general license provisions of 10 CFR 71.17 or 49 CFR 173.471.

Upon removal of Enclosure 3, this document is uncontrolled.

If you have any questions regarding this certificate, please contact me or Norma García Santos of my staff at (301) 415-6999.

Sincerely,

/RA/

Steve Ruffin, Acting Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9233
CAC No. L25001 and L25002

Enclosures:
1. Certificate of Compliance
No. 9233, Rev. No. 13
2. Safety Evaluation Report
3. Registered Users List

cc w/encls 1 & 2: R. Boyle, U.S. DOT
J. Shuler, U.S. DOE
c/o L.F. Gelder
Registered Users

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ADAMS Package No.:
Cover Letter ADAMS Accession No.:
CoC ADAMS Accession No.:

This closes CAC. Nos. L25001 and L25002.

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SAFETY EVALUATION REPORT
Docket No. 71-9233
Model No. TN-RAM
Certificate of Compliance No. 9233
Revision No. 13

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SAFETY EVALUATION REPORT
Docket No. 71-9233
Model No. TN-RAM
Certificate of Compliance No. 9233
Revision No. 13

SUMMARY

By application dated March 9, 2015, as supplemented May 21, October 8, and November 20, 2015, AREVA-TN Inc. (AREVA-TN or the applicant) requested renewal and a revision to Certificate of Compliance No. 9233, for the Model No. TN-RAM transportation package. The applicant submitted a consolidated application on December 8, 2015. As part of the revision request, the application requested to increase:

1. the limit for the maximum activity from 1,272 A_2 to 3,000 A_2, and
2. the maximum allowable decay heat load from 300 watts to 500 watts.

The certificate has been updated to Revision No. 13 to reflect these changes.

The staff reviewed the application to determine whether the package meets the regulatory requirements of Title 10 of the *Code of Federal Regulations* Part 71 (10 CFR Part 71) and fulfills the criteria in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," (NRC 1999) as well as associated U.S. Nuclear Regulatory Commission (NRC) guidance documents. The staff focused its review on the changes to the application using the guidance in Chapter 3, "Thermal Review," and Chapter 5, "Shielding Review," of NUREG-1609 (NRC 1999).

EVALUATION

The TN-RAM packaging components are the following:

1. the package body,
2. the lid,
3. the trunnions,
4. the thermal shield, and
5. the impact limiters.

The package body consists of cylindrical stainless steel shells which surround a lead shell. The lid also contains lead surrounded by stainless steel plates. The applicant requested a change in the payload to be transported in the Model No. TN-RAM. The applicant stated that the TN-RAM package is transported as an exclusive use shipment. The following sections summarize the staff evaluation.

1.0 General Description of the Package

This evaluation includes a description of the changes to the application related to the revision request of the Model No. TN-RAM. Due to design changes, the applicant revised the following licensing drawings:

1. 990-701, Revision 10
2. 990-702, Revision 9
3. 990-703, Revision 11
4. 990-704, Revision 7
5. 990-705, Revision 8
6. 990-706, Revision 5
7. 990-707, Revision 5
8. 990-708, Revision 9

The staff reviewed these drawings and the appropriate sections in the application (related to the shielding design) and determined that the text and sketches were consistent in the application. The staff finds that the revised drawings meet the requirements of 10 CFR 71.33.

3.0 Thermal Evaluation

The staff reviewed the proposed changes to the Model No. TN-RAM shipping package to verify that:

1. the applicant adequately evaluated the thermal performance of the package for the tests specified under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), and

2. the package design satisfies the thermal requirements in 10 CFR Part 71.

The thermal evaluation provided in the application includes analysis for the following boundary conditions for NCT:

1. Steady-state conditions at an ambient temperature of 100 degrees Fahrenheit (ºF) without insolation in still air, as defined in 10 CFR 71.43(g), for limiting the maximum accessible package surface temperature to not exceed 185ºF for exclusive use shipments.

2. Steady-state conditions at an ambient temperature of 100ºF with insolation in still air, as defined in 10 CFR 71.71(c)(1).

3. Steady-state conditions at an ambient temperature of -40ºF without insolation in still air, as described in 10 CFR 71.71(c)(2).

Also, the thermal evaluation provided in the application includes the following sequence of events during HAC:

1. Steady-state, pre-fire conditions at an ambient temperature of 100ºF with insolation in still air, as defined in 10 CFR 71.73(b).

2. Transient conditions in sufficiently quiescent ambient conditions to provide an average emissivity coefficient of at least 0.9 at an ambient temperature of 1,475ºF, without insolation, for 30 minutes and with a package surface emissivity of at least 0.8 and an external convection coefficient based on a fire environment, as defined in 10 CFR 71.73(c)(4).

3. Transient, post-fire conditions at an ambient temperature of 100ºF with insolation in still air, as described in 10 CFR 71.73(c)(4), until maximum temperatures for all package components have been achieved.

3.1 Description of Thermal Design

The application provides a general description of the TN-RAM thermal design. The TN-RAM is designed to passively reject payload decay heat under NCT and HAC while maintaining appropriate packaging temperatures and pressures within specified limits. The total decay heat load of the radioactive material is limited to a maximum of 500 watts. The staff verified that the application provided summary tables of maximum temperatures and pressures.

The staff reviewed the applicant's description of its thermal design, specified thermal loads, and summary tables of temperatures and pressures and confirmed that it is consistent with the guidance specified in Chapter 3 of NUREG-1609. Therefore, the staff finds that the description of the thermal design meets the thermal requirements of 10 CFR Part 71.

3.2 Material Properties and Component Specifications

Section 3.2 of the application includes material thermal properties for the TN-RAM components. The applicant states that the materials present in the package include stainless steel, lead, wood, and air. The staff reviewed the thermal properties provided in the application which include thermal conductivity, density, heat capacity, emissivity, and absorptivity. Section 3.3 of the application includes a summary limiting temperatures for the TN-RAM components. The applicant also provided separate limiting temperatures for NCT and the HAC fire. For the thermal evaluation, the staff reviewed the references provided by the applicant, the properties of the material, and confirmed that the properties were either determined experimentally or by referencing approved codes and standards [(American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section II (Materials), Part D (Properties)]. The staff reviewed the component specifications and verified that the structural analysis performed in Chapter 2 of the application demonstrates that materials stresses are within acceptable limits for the design limiting temperatures for the TN-RAM components.

The staff reviewed the material properties and component specifications used in the thermal evaluation and concludes that these provide a sufficient basis for the evaluation of the package against the thermal requirements of 10 CFR Part 71.

3.3 Thermal Model

To evaluate the thermal performance of the Model No. TN-RAM shipping package, the applicant developed a three-dimensional (3-D) finite element model using ANSYS code. ANSYS is a general purpose finite element computer code, which can be used to perform steady state or transient thermal analyses. The model represents the top-half of the packaging and includes the body, lid, trunnions, thermal shield, and impact limiters. The applicant stated that because of the symmetry of the package, it is only necessary to model a 45 degree (45°) sector of the entire package. Since the thermal model developed by the applicant's is three dimensional, it allows heat transfer in the radial, circumferential, and axial directions. The heat flux is applied along the cavity wall surfaces (lid and package body). Solar radiation is considered as a constant heat flux applied on the outer surface of the transfer package. The amount of the solar heat flux over a 12-hour solar day, as defined in 10 CFR Part 71, is averaged over a 24-hour period to calculate the solar heat flux.

The staff reviewed the following information developed by the applicant:

1. thermal models,
2. thermal properties,
3. assumptions and boundary conditions applied to the model.

Based on the heat transfer characteristics of the analyzed geometry, the staff determined the analysis adequately captures the physics of the heat transfer problem posed by the applicant's design. The staff reviewed the methods used in thermal evaluation and concludes that the description is sufficient and consistent with Chapter 3 of NUREG-1609, to allow an independent review of the thermal design.

3.4 Thermal Evaluation under Normal Conditions of Transport

3.4.1 Heat and Cold

The applicant used the thermal model described in Section 3.3 of this safety evaluation to perform the package thermal evaluation under normal conditions of transport and subject to solar insolation. Table 3.4 of the application summarizes the NCT results. All the maximum predicted temperatures for exposure at 100°F are below the allowable limit and have sufficient margin.

The applicant stated that the TN-RAM package is an exclusive use shipment, such that the 10 CFR 71.43(g) requirement of 185°F maximum temperature at the accessible surface of the package is applicable. The thermal analysis performed by applicant shows that the maximum temperature of the accessible surface of the package (109°F) is below the specified 185°F limit which satisfies the regulatory requirement.

The applicant stated that the minimum temperature distribution for the TN-RAM shipping package will occur with no decay heat load and an ambient air temperature of -40ºF per 10 CFR 71.71(c)(2). The applicant assumed that all packaging components would reach the -40ºF temperature under steady state conditions. For a package with the thermal capacitances of the TN-RAM shipping package, prolonged exposure to low temperature environments is required to significantly depress package temperatures. The applicant stated that the -40ºF temperature is within the package's allowable temperature limits for the temperature sensitive components according to Section 3.3 of the application, "Technical Specifications of Components."

3.4.2 Maximum Normal Operating Pressure

The applicant calculated a maximum TN-RAM package pressure at the end of a shipment for a bounding maximum thermal load of 500 watts of 6.38 pounds per square inch gauge (psig). The application states that the maximum design pressure of the TN-RAM shipping package is 30 psig. The applicant's calculated pressure is well below the maximum design pressure. The applicant used the ideal gas law in combination with the average cavity gas temperature to calculate the maximum normal operating pressure and the staff finds the approach and calculations acceptable.

3.4.3 Maximum Thermal Stresses

Chapter 2 of the application includes a discussion of the maximum thermal stresses during NCT. The staff reviewed the package design, construction, and preparation for shipment and concludes that the package material and component temperatures will not exceed the specified allowable limits during NCT consistent with the tests specified in 10 CFR 71.71.

3.5 Thermal Evaluation under Hypothetical Accident Conditions

3.5.1 Initial Conditions

The applicant states that the initial temperature distribution within the TN-RAM shipping package prior to the HAC fire is based on an ambient temperature of 100ºF in still air, as defined in 10 CFR 71.73(b), and 12-hour solar insolation values (per 10 CFR 71) averaged over 24 hours. The staff confirmed that all temperatures used as initial conditions are at their maximum values, per the NCT analysis. The applicant modified the thermal model used to evaluate the HAC fire event (as compared to the NCT model) to include the 30-foot free drop and 1-meter puncture drop damage to the impact limiters. In addition, the HAC thermal model addresses the effect of impact limiter wood thermal degradation and resulting external char layer. Damage from these two HAC drop scenarios and char reduction of the wood are included in the HAC thermal model.

3.5.2 Fire Test Conditions

The applicant used the TN-RAM thermal model described earlier to determine the temperature distribution of the package during the fire accident specified in 10 CFR Part 71. The applicant simulated a 30-minute fully engulfing fire at 1,475°F followed by a sufficient cooling period to ensure reaching maximum local temperatures.

A transient calculation was performed with heating from a constant 1,475°F-fire for 30 minutes followed by cooling. The calculation started from the temperature profile obtained NCT with insolation. No solar insolation was applied in the transient calculation during the heating phase of the fire test. However, insolation was applied during the cooling phase following the fire. A bounding convection coefficient of 4.5 British thermal units per hour-square foot-degrees Fahrenheit (Btu/hr-ft^2-°F) is considered during burning period based on data from Gregory, et al., “Thermal Measurements in a Series of Long Pool Fires,” SANDIA Report, SAND 85-0196, TTC-0659, 1987.

3.5.3 Maximum Temperatures and Pressures

Table 3.7 of the application includes the maximum temperatures experienced by the components of the TN-RAM shipping package calculated by the applicant under a HAC fire event described earlier. The staff confirmed that all the temperatures predicted during the HAC are below the component allowable limits. The applicant calculated a maximum pressure of 29.12 psig based on a calculated gas averaged temperature of 500°F during HAC. This calculated pressure is below the pressure of 30 psig (used in Chapter 2 of the application to calculate wall stresses), and is, therefore, acceptable.

3.5.4 Maximum Thermal Stresses

Chapter 2 of the application includes a discussion addressing the maximum thermal stresses during a HAC fire event. The staff has reviewed the package design, construction, and preparation for shipment and concludes that the package material and component temperatures will not exceed the specified allowable short time limits during HAC consistent with the tests specified in 10 CFR 71.73.

<u>3.6 Evaluation Findings</u>

Based on review of the statements and representations in the application, the staff concludes that the applicant adequately described and evaluated the Model No. TN-RAM shipping package thermal design, and the thermal performance of the package meets the thermal requirements of 10 CFR Part 71.

5.0 SHIELDING

The applicant requested an increase in maximum allowable activity as well as add more specific definitions to their contents in response to issues raised in NRC's Regulatory Issue Summary RIS 2013-04 (NRC 2013).

The applicant describes the allowable contents of the TN-RAM in Section 1.2.3 of the application as follows:

> "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 contents limit for all radionuclides is 3,000 A_2. The radioactive material is primarily in the form of neutron activated metals, or metal oxides in solid form."

Where A_2 is specified in Table A-1 of Appendix A of 10 CFR Part 71. This is an increase in contents from the previous approved level of 1,272 A_2.

The purpose of the shielding review is to verify that the package design meets the external radiation requirements of 10 CFR Part 71 for NCT and HAC.

<u>5.1 Description of Shielding Design</u>

5.1.1 Design Features

The shielding design features of the TN-RAM include a steel-lead-steel package body with steel-lead-steel lids. Wood impact limiters are attached at both ends of the package. Figure 1-1 of the applicant's safety analysis report includes the general arrangement of the TN-RAM package (AREVA 2015). The applicant specified detailed dimensions of the shielding features of the package in licensing Drawing Nos. 990-701, Revision 10, 990-702, Revision 9, 990-705, Revision 8, 909-707, Revision 5, and 990-710, Revision 2. The staff reviewed these drawings as well as the general information chapter (Chapter 1) in the application and the information on the shielding design in Chapter 5 of the application and determined that the text, sketches, and modeled representation of the package are consistent throughout the application.

The overall dimensions of the packaging are approximately 178 inches long and 92 inches in diameter with the impact limiters installed. The TN-RAM package contains steel and lead in the radial and axial directions for 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. Lead is poured between the shells with a minimum of 5.75 inches radially and 5.69 inches at the bottom. An optional closure lid can also be used in the packaging. Shielding at the top of the package is provided by either lid. In the standard lid, there are a total of 3 inches of steel and 5.88 inches minimum of lead. The optional lead has a total of 3.375 inches of steel and 5.68 inches minimum of lead.

The TN-RAM requires using a secondary container as shoring. The applicant did not credit:

1. the secondary container for radiation attenuation to meet the regulatory dose rate limits, nor
2. the presence of the secondary container for shoring material away from streaming paths.

The staff finds that the figures, licensing drawings, and discussion describing the shielding features are adequate to support an in-depth evaluation.

5.1.2 Summary Table of Maximum Radiation Levels

Table 5.1 of the application includes the maximum normal condition of transport (NCT) dose rates and Table 5.2 of the application provides the HAC maximum dose rates.

The staff finds that the summary table shows that the package meets the regulatory dose rate limits in 10 CFR 71.47 for exclusive use shipments and the dose rate limits for HAC specified in 10 CFR 71.51(a)(2).

5.2 Radiation Source

5.2.1 Gamma Radiation

The primary content for the TN-RAM is activated steel. The nuclide of concern from activated steel is Cobalt-60 (^{60}Co), therefore the applicant has assumed ^{60}Co as the source of gamma radiation. The TN-RAM has a limit of 30,000 Curies (Ci) of ^{60}Co or equivalent, with equivalency determined by evaluating the limiting source geometry at a range of energies. Section 5.5.3 of the application includes the details of this analysis. The applicant evaluated the maximum activity limit (in gammas per second) that produces a dose rate of 8.90 millirems per hour (mrem/hr) at 2 meters at discrete energies from 1 to 16 mega electron volts (MeV). Table 5-14 of the application includes the results of this evaluation. A user shall conservatively use the next highest gamma in the table to estimate the sum of the activity (gammas per second) fractions of all gammas emitted. The staff finds this method acceptable for determining the maximum allowable gamma contents in the package.

5.2.2 Neutron Radiation

Although the TN-RAM is not authorized for shipping significant neutron sources, assuming a neutron source of zero is not practical. Therefore, the applicant evaluated a small neutron source using the watt fission spectrum for Curium-244 (^{244}Cm) at 1×10^6 neutrons/second. This source produced a negligible dose rate at the package surface. The staff finds that this approach adequately represents the possible neutron source term including spontaneous fission, alpha-neutron reactions, and gamma-neutron reactions.

5.2.3 Alpha and Beta Radiation

Alpha and beta radiation is easily stopped by the materials within the package and, therefore, the staff finds adopting 3,000 an A_2 quantity as an appropriate limit for these radiations. The limit for a structural Category I package is 3,000 times an A_2 quantity. The applicant also:

1. considered the possibility of bremsstrahlung from high energy beta radiation by evaluating a source of 3,000 times an A_2 quantity of Phosphours-32, and
2. conservatively assumed that all betas were emitted at the maximum energy.

The applicant evaluated the external dose rate due to bremsstrahlung and it was negligible.

5.3 Shielding Model

The staff reviewed the structural and thermal sections of the application. The staff finds that the shielding model appropriately represents NCT and HAC, as discussed in the following subsections.

5.3.1 Source and Shielding Configuration

The staff verified that the applicant used dimensions consistent with those in the drawings of the TN-RAM package in their model to calculate external dose rates. The applicant used nominal package dimensions to model the TN-RAM package body with the exception of the lead shield, which was modeled at its minimum thickness. During this review, the staff considered the conservative assumptions within the analysis such as:

1. evaluating 5% margin to the regulatory limit,
2. neglecting the shielding material within the liner,
3. neglecting self-shielding of any materials less dense than steel, and
4. using higher energy limits for mixed energy gamma sources.

The staff finds that using nominal dimensions is a non-conservative assumption as applicants should account for possible loss of shielding due to the manufacturing tolerances. In this application, however, the staff found nominal dimensions of all other package components acceptable.

5.3.1.1 Normal Conditions of Transport

Each shipment in the TN-RAM has unique contents and it is not practical to model the contents for every shipment. Therefore, the applicant evaluated several bounding geometries. The main assumptions for this evaluation included the following:

1. *Source* - For these geometries, the applicant modeled 3,000 kilograms (kg) of stainless steel with the ^{60}Co gamma source evenly distributed throughout the steel. The maximum gross weight of the contents is 4,309 kg. (This mass includes the required secondary container. Since the secondary container has no requirements on mass or size, there is no specific requirement that the content be limited to the modeled weight of 3,000 kg.)

2. *Activity* - Although the content mass could be greater than 3,000 kg, the applicant restricted the contents to less than or equal to 10 Ci of ^{60}Co or equivalent per kilogram. With a total activity limit of 30,000 Ci ^{60}Co or equivalent, the specific activity limit ensures that self-shielding material would be present up to the amount analyzed and additional self-shielding material would only be conservative as it just adds additional self-shielding material.

3. *Cavity Volume* - Based on the geometry of the contents, it could fill the volume leaving voids in random places. These voids are not practical to model. Therefore, for simplicity, the applicant assumed that the package's cavity volume was filled with steel, but artificially reducing the density in order to not exceed 3,000 kg. This case was the homogenized case and also the limiting case.

The following sections include a discussion of the staff's evaluation of the approach proposed by the applicant.

A. Bounding Geometries

The applicant modeled various source geometries to determine a limiting geometry for evaluating external dose rates. These geometries included:

1. an annulus of 3,000 kg of the full density steel around the periphery of the cavity that ran the axial length of the cavity. This assumes that there are not voids within the content and is conservative as it concentrates the source closer to the detector in the radial direction.
2. a full density steel "disk" on both the top and bottom of the cavity.

These geometries are un-realistic but conservative as the contents would not take the form of full density steel and would actually be multiple smaller steel components distributed in some form throughout the cavity. Although it is possible to model more bounding geometries, the staff finds that these are relatively bounding geometries for the types of contents typically shipped as discussed in Section 1.2.3 of the application. The probability for users loading maximum activity in a more limiting geometry is very low, because of the measurement dose rate requirements prior to shipment. The staff has reasonable assurance that the geometries modeled by the applicant are bounded by the conservative assumptions within the analysis such as:

1. evaluating 5% margin to the regulatory limit,
2. neglecting the shielding material within the liner,
3. neglecting self-shielding of any materials less dense than steel, and
4. using higher energy limits for mixed energy gamma sources.

Since the applicant only models stainless steel, loading lower density self-shielding materials would provide less attenuation than steel and would be non-conservative (dose rates would be higher than analyzed). Therefore, the certificate of compliance allows the presence of lower density material, however it restricts loading of this material to negligible source and does not allow it to be credited in the specific activity (10 Ci/kg) limit. The words proposed by the applicant are as follows:

> "Localized regions of low-density material (e.g., B_4C in a control rod blade) are acceptable if the low-density regions contain negligible source. The mass of any low-density regions shall not be credited in the specific activity calculation."

The staff finds this conservative and acceptable.

B. Definition of "Distributed Throughout" Material

Although the 30,000 Ci of ^{60}Co or equivalent and the 10 Ci/kg specific activity limit serve to ensure that there is enough self-shielding material present, each limit\parameter does not alone ensure that the distribution of activity within the content is appropriate. The applicant analyzed the source gammas as homogenously distributed within the steel self-shielding medium. This analytical assumption would be non-conservative if the radioactivity was highly concentrated and outside (or near the periphery of) the shielding medium. To restrict allowable contents to those that are relatively homogenous in source and self-shielding, the staff added a condition to the certificate of compliance to define and describe "distributed throughout" contents. Specifically each loaded component must meet the following:

> "…Radioactive source and self-shielding material shall be distributed throughout. This means the material can be divided into ten or more equal volumes. The volume of each portion shall be no greater than 0.1 m^3. The specific activity of each volume must be assessed (through measurements, calculations, or process knowledge) and compared. Specific activity differences between any two volumes shall not vary by more than a factor of 10."

This definition is in alignment with Section 4.2.3 in NUREG-1608, "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects" (NRC 1998). The staff recognizes that the TN-RAM is designed to ship material with higher activity than LSA (low specific activity) or SCO (surface contaminated object). For the proposed and authorized contents of the TN-RAM, the staff found this definition of "distributed throughout" acceptable, since it is based on IAEA's advisory material and, in principle, applicable for this package. Also, although this definition allows specific activity to vary by as much as a factor of 10 and was formulated with LSA and SCO in mind, the staff still finds it acceptable for the TN-RAM contents. The staff based its acceptability on several factors:

1. The requirement in 10 CFR 71.87(j) is to ensure that the package meets the dose rate regulatory limits prior to shipment. This ensures that, at the time of shipment, the package meets regulatory dose rate limits. Pre-shipment measurements would not account for any increases in external dose rates due to movement or settling of contents during shipment and are not acceptable alone as means for demonstrating compliance with regulatory dose rates in 10 CFR 71.47. However, pre-shipment measurements would prevent any packages exceeding limits upon loading from being transported. In RIS 2014-04 (NRC 2013), the staff discusses that pre-shipment measurements can assist to account for uncertainties. In this case, it may prevent packages that exceed limits (due to extreme cases of non-uniformity) from being shipped.

2. Section 1.2.3 of the application mentions that the package is normally filled to capacity, which prevents shifting of the contents during transport and that (if the container is not full) appropriate component spacers or shoring will be used to prevent shifting of the contents.

3. Components loaded into the TN-RAM are typically much smaller than the 0.1 m^3 in volume specified in the NUREG-1608 definition and, therefore, by dividing each component into 10 equal volumes should ensure more homogeneity than if it were applied over larger regions. Larger components are less likely to reconfigure.

4. The applicant made conservative assumptions within the analysis (see Section 5.3.1 of this safety evaluation report). These conservatisms reduce external dose rates and provide a safety margin for any increases in external dose rates due to reconfiguration.

5. The package's external dose rate is limited at the 2 meter location. This means that this is the location closest to the measurement corresponding to the regulatory limit. The staff believes that if there are localized hot-spots, reconfiguration of this material would likely cause localized changes in surface dose rates (where there is greater margin to the limit) and would not significantly affect dose rates at 2 meters from the truck surface. Although it is possible to postulate a reconfiguration that significantly affects dose rates at 2 meters, the staff has reasonable assurance that (with the combination of the TN-RAM loading limits and the other factors) the possibility of content reconfiguration is negligible.

Taking the above factors into consideration as a whole, the staff has reasonable assurance that the NUREG-1608 definition of "distributed throughout" provides and adequate description of homogeneity of source and self-shielding (such that redistribution of contents) to prevent the package from exceeding the regulatory dose rate limits for NCT in 10 CFR 71.47.

C. Optional Lid

The TN-RAM has an optional lid design. The difference between the optional lid and the original lid is that the optional lid has 0.2 inches less lead, but has an additional 0.375 inches of steel. The applicant performed an analysis using the homogenized source distribution with both lids and compared the dose rates in Figure 5-6 of the application. The applicant's results showed that the analysis of the standard lid bounds the analysis of the optional lid. The staff finds that the applicant accounted for the possibility of using the optional lid, and finds the use of either lid acceptable for all allowable contents.

5.3.1.2 <u>Normally Occupied Space</u>

The applicant performed an analysis of the normally occupied space to meet the requirement in 10 CFR 71.47(b)(4). The applicant discusses this analysis in Section 5.4.4.6 of the application. The applicant states that the TN-RAM is always transported horizontally with the lid end first on a specially designed three-axle semi-trailer. The applicant evaluated the normally occupied space as 152 inches from the top of the package and did not credit any shielding from the vehicle. The most limiting source geometry was the disk source moved to the top (lid end) of the package. The staff finds this evaluation acceptable.

5.3.1.3 <u>Hypothetical Accident Conditions</u>

Section 5.4.4.2 of the application includes a discussion of the HAC modeling assumptions. Under HAC, the applicant evaluated a few source geometries. The applicant assumes that the limiting geometry has the source homogeneously distributed in a volume that fills the entire diameter of the cavity and 1/3 of the cavity height placed at the top of the cavity (where there is potential for streaming over the lead shield). The applicant models no self-shielding material, as noted in Section 5.3.1 of the application. The staff finds this model conservative as it accounts for some compression of the source and assumes no self-shielding (the self-shielding material provides significant attenuation of the source).

Under HAC the applicant assumes that there was no lead slump and does not assume there was no reduction in the shielding due to the puncture incident. Although the applicant submitted information in Section 2.7.1.1 of the application about lead slump, the staff did not find that this information was conclusive enough to preclude the possibility of lead slump. In addition, the discussion on the puncture event in Section 2.7.2 of the application does not specifically evaluate how much, if any, of the outer radial shell would be punctured, and, consequently, the amount of shielding material that may be lost or displaced. However, considering the conservative source modeling (assuming no self-shielding material), the staff has reasonable assurance that this assumption compensates for any reduction in shielding due to lead slump or puncture. All other HAC tests have effects isolated to the impact limiter and the applicant assumes that the impact limiters are absent under HAC. The staff finds the applicant's HAC model and assumptions acceptable.

5.3.1.4 <u>Streaming Paths</u>

The secondary container should shore the radioactive contents away from streaming paths. However, there are no required specifications for the secondary container. Therefore, the applicant evaluated the possibility for streaming in the TN-RAM as if there were no secondary container.

Streaming is possible around the lead shield near the lid of the package. A discontinuity exists in the lead shield and only steel is present. The applicant used the top disk model for the source. This model concentrates the source toward the streaming path (more than the other source geometries). The applicant notes that it axially and angularly segmented the MCNP shielding code tallies (see Section 5.4.1 of this safety evaluation) to be 4 x 4 cm in order to evaluate streaming. The applicant found that there was an increase in dose rates due to streaming at the surface of the package. Table 5-1 of the application includes this location at the limiting surface dose rate. At 2 meters, the applicant found that dose rates increased locally in the area of streaming, but did not correspond to the location of the maximum dose rates. The staff finds that the applicant adequately accounted for streaming in its shielding model.

Bottom Drain

There is a drain at the bottom of the package that goes through the lead shield. The applicant modeled this explicitly within the shielding model and although dose rates increased due to the reduced lead due to this drain, this area is not the limiting dose rate location. The staff found that the applicant has appropriately considered the bottom drain in its model.

5.3.2 Material Properties

All of the steel in the applicant's package model is assumed to be Type 304 stainless steel, including the source. The staff finds the assumptions acceptable because this is the same type of steel specified for the materials of construction for the package in the licensing drawings. Also, since source material may vary and there are no significant differences in the shielding properties of steel, the staff finds that assuming Type 304 stainless steel adequately represents different types of steel. The staff verified the modeling of steel within the input files, reviewed the input file, and verified that the lead was appropriately represented. The applicant also modeled the air and balsa within the impact limiters and the staff finds these representations acceptable.

5.4 Shielding Evaluation

5.4.1 Methods

The applicant performed shielding calculations with MCNP, version 5. MCNP is a 3-D Monte Carlo transport code developed and maintained by Los Alamos National Laboratory. The code's capabilities include modeling of and determining dose rates from package design features where radiation streaming may be a concern. This code extensively is used by industry for shielding calculations. Based on the code's capabilities and its extensive application in industry (ensuring the code is well-vetted), the staff finds using the MCNP, version 5, code acceptable for the licensing action requested on the application.

5.4.2 Input and Output Data

The applicant provided input and output files for the MCNP calculations used to determine the external dose rate of the TN-RAM package. The staff reviewed a representative input file and finds that the information regarding material properties and dimensions used in the calculations is consistent with descriptions and drawings given in the application. The staff also reviewed a representative output file. The staff achieved a proper convergence with the calculated dose rates reported in the application.

5.4.3 Flux-to-Dose-Rate Conversion

The applicant used conversion factors that were derived from the ANSI/ANS 6.1.1-1977 standard. The staff found this acceptable because these are the recommended factors per the guidance in NUREG-1609 (NRC 1999).

5.4.4 External Radiation Levels

Under NCT the applicant uses the top and bottom of the impact limiter as the basis for establishing package dose rate limits for the surface of the package axially. Although the applicant did consider any deformation of the impact limiter, it is the staff's judgment, based on similar packages, that there is minimal deformation associated with NCT. In addition, the TN-RAM has its highest external dose rates at the side (radial direction) of the package and not in the axial direction. Therefore, the staff finds that accounting for the deformation of the impact limiter would not exceed external dose rates regulatory limits.

The applicant evaluated dose rates around the surface of the package by segmenting the surface tallies into 20 to 22 centimeters (cm) bins. However, to evaluate the dose rate around the streaming path, the applicant further segmented the bins into 4 cm by 4 cm. The maximum calculated surface dose rate was 106 mrem/hr with an uncertainty of 0.1%. This dose rate was from the top (lid direction) disk source geometry. The location of this dose rate was at the radial surface of the package near the lid due where there was streaming. The staff finds that the applicant evaluated the dose rate on the surface of the package at realistic and appropriate locations in agreement with the requirements in 10 CFR 71.47(b)(1).

The applicant evaluates the dose rate at 2 meters in all directions from the impact limiters. The staff finds this location appropriate per the requirement in 10 CFR 71.47(b)(2), which defines the

2 meter limit with respect to the vehicle edge. The applicant also used segmented tallies of 20 to 22 cm for the 2 meter dose rate evaluations. The staff finds using larger tally segments acceptable, since the dose rate is more homogenous. The maximum 2 meter dose rate was at the side (radial direction) of the package using the homogenous source geometry and was 8.91 mrem/hr with an uncertainty of 1%.

The applicant evaluated the dose rate of the normally occupied space as 152 inches from the top of the package. The staff finds this location appropriate per the requirement in 10 CFR 71.47(b)(4). As discussed in this regulation, for a private carrier, exposed personnel under the carrier's control do not have to wear radiation dosimetry devices in conformance with 10 CFR 20.1502.

For HAC external dose rates limits, the applicant evaluates external dose at 1 meter from the surfaces of the package. The staff finds this location appropriate for evaluating HAC dose rates per 10 CFR 71.51(a)(2). The maximum HAC dose rate was 752 mrem/hr [at the side (radial direction) of the package, toward the axial center of the package].

All calculated dose rate limits are below those of the regulatory limits in 10 CFR 71.47 and 10 CFR 71.51(a)(2) for NCT and HAC respectively. The staff found these acceptable.

5.5 Staff Calculations

The staff performed independent calculations of the TN-RAM using the MONACO/MAVRIC Shielding Code package. The staff used the SCALE, 6.2 Beta 4 version, which supports a continuous energy source and the gamma lines of ^{60}Co can be modeled explicitly. Although the staff is using the Beta version of this code, the current release of SCALE 6.1 does not allow gamma lines to be modeled exactly and instead must be within a group structure. This causes much higher uncertainties in the external dose rate for sources with single (or very few) energy lines. The staff confirmed the applicant's results by modeling the package independently and using the design information in the drawings and the application. The staff also modeled other possible limiting source geometries and found that these produced statistically equivalent results. The staff finds that the package meets the external dose rate requirements in 10 CFR Part 71.

5.6 Evaluation Findings

Based on its review of the statements and representations in the application and independent confirmatory calculations, the staff has reasonable assurance that the applicant adequately described and evaluated the shielding design and that the package meets the external radiation requirements of 10 CFR Part 71.

REFERENCES

(NRC 1998) NUREG-1608, "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects," July 1998.

(NRC 1999) NUREG-1609, Standard Review Plan for Transportation Packages for Radioactive Material, March 1999 (http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1609/final/index.html).

(NRC 2013) NRC Regulatory Issue Summary 2013-04, "Content Specification and Shielding Evaluations for Type B Transportation Packages," April 23, 2013. (ADAMS Accession No. ML13036A135)

(AREVA 2015) AREVA Inc., "Safety Analysis Report of for the TN-RAM," December 2015. (ADAMS Accession Nos. (Proprietary): ML15344A131, ML15344A132; Non-Proprietary: ML15344A129, 15344A130)

CONDITIONS

The following changes have been made to the certificate of compliance:

- Condition No. 3.b, has been revised with the document corresponding to the consolidated application submitted on December 8, 2015.

- Condition No. 5(a)(3) has been revised as follows to reflect revisions to the licensing drawings:

  "The packaging is constructed in accordance with Transnuclear, Inc. Drawing Nos. 990-701, Rev. 10; 990-702, Rev. 9; 990-703, Rev. 11; 990-704, Rev. 7; 990-705, Rev. 8; 990-706, Rev. 5; 990-707, Rev. 5; 990-708, Rev. 9; ; …"

- Condition No. 5(b)(1) has been revised to :

  "Type and Form of Material…

  > Radioactive source and self-shielding material shall be distributed throughout. This means the material can be divided into ten or more equal volumes. The volume of each portion shall be no greater than 0.1 m^3. The specific activity of each volume must be assessed (through measurements, calculations, or process knowledge) and compared. Specific activity differences between any two volumes shall not vary by more than a factor of 10.
  >
  > Materials other than steel must show shielding equivalence or better to steel for ^{60}Co. Localized regions of low-density material (e.g., B_4C in a control rod blade) are acceptable if the low-density regions contain negligible source. The mass of any low-density regions shall not be credited in the specific activity calculation."

- Condition No. 5(b)(2) has been revised to:

  > "(i) …The combined quantity of all radioactive material per package is limited to 3,000 times an A_2 quantity (as determined by using Table A-1 of Appendix A to 10 CFR Part 71).
  >
  > Pure Alpha and Beta emitting nuclides are limited to 3,000 times an A_2 quantity. Significant neutron sources are not allowed.
  >
  > The maximum total package neutron source is 1 x 10^6 neutrons/second for materials that produce neutrons (other than fissile neutrons) through

any means, including spontaneous fission, alpha-neutron reactions, and gamma-neutron reactions.

(ii) Gamma emitting radionuclides are limited to a combined total of 30,000 Ci of ^{60}Co or equivalent as determined by the following equation:

$$\sum_i \frac{S_i(E)}{ActivityLimit_i(E)} \leq 1$$

Where *E* is the 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. For gammas with energies that do not correspond exactly to one of the energies in the table, the $Activity\ Limit_i\ (E)$ used shall correspond to the next highest energy. Limits can be found in the following table:

Energy (MeV)	**Activity Limit (γ/s)**
0.6	7.62×10^{17}
0.8	1.25×10^{17}
1	2.03×10^{16}
1.1732	4.49×10^{15}
1.3325	1.47×10^{15}
1.5	6.15×10^{14}
1.75	2.40×10^{14}
2	1.25×10^{14}
2.5	5.52×10^{13}
3	3.42×10^{13}
3.5	2.55×10^{13}
4	2.14×10^{13}
4.5	1.90×10^{13}
5	1.78×10^{13}
6	1.66×10^{13}
8	1.58×10^{13}
10	1.49×10^{13}

The average specific activity of discrete components is limited to 10 Ci/kg of ^{60}Co or equivalent.

Materials other than steel must show shielding equivalence or better to steel for ^{60}Co. Localized regions of low-density material (e.g., B_4C in a control rod blade) are acceptable if the low-density regions contain negligible source. The mass of any low-density regions shall not be credited in the specific activity calculation.

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

- Condition No. 10 has been revised to:

  “Expiration date: January 31, 2021.”

The “References” section of the certificate of compliance has been updated to include the consolidated application dated December 8, 2015 as part of the revision request.

CONCLUSION

Based on the statements and representations in the amendment request, the staff finds that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9233, Revision No. 13.