CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIAL PACKAGES

1. a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE		PAGE
9384	0	71-9384	USA/9384/B(U)-96	1	OF	4

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)*

Robatel Technologies, LLC
5115 Bernard Drive
Suite 304
Roanoke, VA 24018

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION

Robatel Technologies, LLC, application, Revision No. 3, dated May 30, 2025.

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.: RT-200

(2) Description

The Model RT-200 packaging is a cylindrical body comprised of a double layer stainless-steel shell and the annular space between the shells is filled with lead. A thin layer of ceramic fiber insulation, which is surrounded by stainless-steel, is adjacent to the shell of the cylindrical body. The base of the packaging consists of a one-piece stainless-steel rear forging. This forging is connected to the inner shell with full penetration welds and to the outer shell with partial penetration welds. The inside height of the cylindrical body is 4570 mm (179.92 in) high and 1100 mm (43.31 in) for the inner diameter. The external body dimensions are 1590 mm (62.60 in) in diameter and 5250 mm (206.69 in) high. This cylindrical body serves as the containment boundary of the package.

The primary stainless-steel lid is fastened to the packaging body with thirty (30) stainless-steel M42 bolts.

Impact limiters are overall cylindrical in shape. They cover and protect the two ends of the cask during impact and extend from the front and rear beyond the body and the cask lid. The two impact limiters (front and rear) have an outside diameter of 2520 mm (99.21 in). The front and rear impact limiters extend 440 mm (17.32 in) beyond the primary lid and the base of the packaging. The impact limiter external shells are stainless-steel, and the volume inside the shell is filled with preformed rigid foam.

The impact limiters are bolted to the lid or the rear of the cask with eight (8) equally spaced M42 bolts.

5(a)(2) Packaging Description (Continued)

The maximum gross weight of the packages 76,500 kg. The nominal (empty) weight of the packaging is 62,997 kg.

(3) Drawings

The packaging is constructed and assembled in accordance with Robatel Technologies, LLC, Drawing Nos.:

RT-200 PC 001, Sheets 5-13, Rev. E - RT-200 Without Content

RT-200 PC 002, Sheets 1-4, Rev. E - RT-200 With Content No. 1

AS-SC-SK03, Rev. C – Activated Services Storage Container Overall Assembly Sheet 1/1

(b) Contents

(1) Type and form of material:

(i) Content No. 1 - Solid irradiated and contaminated non-fuel-bearing materials and stellite boxes in storage containers.

(ii) Content No. 2 - Miscellaneous solid irradiated and contaminated non-fuel-bearing hardware in secondary containers.

(2) Maximum quantity of material per package

(i) Maximum quantity of material within Content No. 1 (including 3 storage containers) is limited to 30,000 Ci and 3,000 A_2.

(ii) Maximum quantity of material within Content No. 2 is limited to 30,000 Ci and 3,000 A_2 and 10Ci/kg (0.37 TBq/kg) of Co-60 equivalent.

(iii) The contents described in 5(b)(1)(i) and 5(b)(1)(ii) may contain fissile material provided the quantity of material does not exceed the exempt quantity under 10 CFR 71.15.

(iv) Maximum decay heat:

(1) Content No. 1: 1,200 watts

(2) Content No. 2: 1,200 watts

(v) Maximum weight of contents:

(1) Content No. 1: 8,400 kg including storage containers, disposable insert and dedicated basket.

(2) Content No. 2: 8,400 kg including secondary containers and component spacers or shoring.

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

(a) The package must be prepared for shipment and operated in accordance with the Operating Procedures of Chapter 7 of the application,

(b) The packaging must be tested and maintained in accordance with the acceptance tests and maintenance program described in Chapter 8 of the application.

7. The weight of water must be excluded when determining the Ci/g of content limits.

8. For Content No. 1 only, the source distribution must not shift during NCT.

9. The package shall be transported exclusive use only.

10. No air shipment is authorized.

11. Flammable gas (e.g., hydrogen) concentration is limited to less than 5% by volume.

12. Material that presents other risks than those related to its radioactive features is prohibited, including explosives, non-radioactive pyrophoric materials, and corrosives (pH less than 2 or greater than 12.5), pyrophoric radionuclides and materials that may auto-ignite or undergo phase transformation at temperatures less than 140°C, with the exception of water.

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

14. Expiration date: June 30, 2030.

REFERENCES

Robatel Technologies, LLC, application, Revision No. 3, May 30, 2025.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Signed by Diaz-Sanabria, Yoira
on 06/13/25

Yoira Diaz-Sanabria, Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Date: June 13, 2025

SAFETY EVALUATION REPORT
Docket No. 71-9384
Model RT-200 Cask Type B(U) Package
Certificate of Compliance No. 9384
Revision No. 0

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SAFETY EVALUATION REPORT
Model RT-200 Cask Type B(U) Package
Certificate of Compliance No. 9384
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SUMMARY

By application dated February 27, 2024, as supplemented October 30, 2024, February 28, 2025, and May 30, 2025, Robatel Technologies, LLC, requested a certificate of compliance (CoC) for the Model RT-200 Cask Type B(U) Package (hereinafter Model RT-200) for the shipment of radioactive material.

The Model RT-200 package consists of a stainless-steel and lead cylindrical shipping cask with a pair of cylindrical foam-filled impact limiters installed on each end. The cylindrical cask body consists of an outer stainless-steel shell and an inner stainless-steel plate. The annular space between the shells is filled with lead. The rear of the cask consists of a stainless-steel forging. The lid consists of a stainless-steel forging and is fastened to the cask body with round head hex bolts.

The two impact limiters consist of stainless-steel casings filled with foam. Each impact limiter is fastened to the cask with round head hex bolts. These bolts are secured in pairs with bolt securing plates and safety seals.

Pressure test ports are provided to facilitate leak testing of the package. Vent and drain ports are provided for draining water and venting pressures within the containment cavity which may be generated during transport and prior to lid removal.

The maximum gross weight of the Model RT-200, including impact limiters, is 76,500 kilograms (kg). Authorized contents include solid irradiated and contaminated non-fuel-bearing materials and stellite boxes in storage containers, and miscellaneous solid irradiated and contaminated non-fuel-bearing hardware. The Model RT-200 is designed to transport radioactive materials in quantities not to exceed 3,000 A_2 and 30,000 curies (Ci).

The Model RT-200 package was evaluated against the regulatory standards in 10 CFR Part 71, “Packaging and Transportation of Radioactive Material.” The analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, and shielding protection under normal and accident conditions.

The NRC staff reviewed the application using the guidance in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report," (ML20234A651). Based on the statements and representations in the application, and the conditions listed in the certificate of compliance, the staff concludes that the package meets the requirements of 10 CFR Part 71.

1.0 GENERAL INFORMATION

The Model RT-200 cask is a Type B (U)-96 package designed and engineered to package and transport solid irradiated and contaminated non-fuel-bearing materials and stellite boxes in storage containers, and miscellaneous solid irradiated and contaminated non-fuel-bearing hardware.

1.1 Packaging

The Model RT-200 packaging is a cylindrical body comprised of a double layer stainless-steel shell and a ceramic insulation layer in between. The annular space between the shells is filled with lead. The base of the packaging consists of a one-piece stainless-steel rear forging. The inside height of the cylindrical body is 4570 mm (179.92 in) high and 1100 mm (43.31 in) for the inner diameter. The external body dimensions are 1590 mm (62.60 in) in diameter and 5250 mm (206.69 in) high. This cylindrical body serves as the containment boundary of the package. The primary stainless-steel lid is fastened to the packaging body with thirty (30) stainless-steel M42 bolts.

Impact limiters are overall cylindrical in shape. They cover and protect the two ends of the cask during impact and extend from the front and rear beyond the body and the cask lid. The two impact limiters (front and rear) have an outside diameter of 2520 mm (99.21 in). The front and rear impact limiters extend 440 mm (17.32 in) beyond the primary lid and the base of the packaging. The impact limiter external shells are stainless-steel, and the volume inside the shell is filled with rigid foam. The impact limiters are bolted to the lid or the rear of the cask with eight (8) equally spaced M42 bolts.

The approximate weights of the Model RT-200 packaging are the following:

Nominal Empty Packaging Weight:	62,997 kg
Maximum Gross Weight of the Package:	76,500 kg

1.2 Contents

The authorized contents that can be carried in the Model RT-200 packaging are the following:

Content No. 1	Solid irradiated and contaminated non-fuel-bearing materials and stellite boxes in storage containers
Content No. 2	Miscellaneous solid irradiated and contaminated non-fuel-bearing hardware in secondary containers

1.2.1 Content No. 1

Content No. 1 is solid and is mainly metallic hardware that has been irradiated and/or contaminated contained within storage containers (SCs) packed into the Model RT-200 using a dedicated disposable insert and associated basket. Up to three SCs can be loaded into the packaging.

The maximum quantity of fissile material within Content No. 1 (total of 3 SCs) is limited to 15 grams.

The maximum decay heat of the Model RT-200 Content No. 1 is limited to 1,200 watts (W) total.

The maximum quantity of payload material including contents, SCs, the disposable insert, and its dedicated basket is 8,400 kg.

The maximum total activity of Content No. 1 (including 3 SCs) is limited to 30,000 Ci and 3,000 A_2.

1.2.2 Content No. 2

Content No. 2 may contain irradiated and contaminated non-fuel-bearing solid hardware. 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.

Content No. 2 materials can be packed into secondary containers or shoring to be loaded inside the Model RT-200 cask.

Material that is subject to chemical, galvanic or other reactions is prohibited within Content No. 2. Material that presents other risks than those related to its radioactive features is prohibited for Content No. 2 (i.e., explosives, non-radioactive pyrophoric materials, corrosives, pyrophoric radionuclides and materials that may auto-ignite or undergo phase transformation at temperatures less than 140°C).

The maximum decay heat of the Model RT-200 Content No. 2 is limited to 1,200 W.

The maximum quantity of payload material including the radioactive materials of Content No. 2 as well as the secondary containers and the appropriate component spacers or shoring is 8,400 kg.

The maximum quantity of material within Content No. 2 is limited to 30,000 Ci and 3,000 A_2.

1.3 Materials

The Model RT-200 cask is comprised of a cylindrical cask body, front forging, bottom forging, vent and drain port cover plate assemblies, lid assembly, and front and rear cylindrical impact limiters.

The cask body is comprised of a stainless-steel inner and outer shell with lead shielding in between the two shells.

The front forging and bottom forging are fabricated from stainless-steel, and each contains a port for venting and draining respectively. The vent and drain cover plate assemblies are each comprised of a stainless-steel cover plate, internal ethylene propylene diene monomer (EPDM) O-ring, external EPDM O-ring, leak test port assembly, and six (6) stainless-steel M16 bolts. The leak test port assembly is comprised of a stainless-steel control plug and an EPDM O-ring. The lid assembly is comprised of a stainless-steel lid, internal EPDM O-ring, external EPDM O-ring, leak test port assembly, and thirty (30) stainless-steel M42 bolts. The front and rear impact limiters are comprised of stainless-steel casings filled with foam. The impact limiter foam is a rigid polyurethane foam.

1.4 Drawings

The Model RT-200 packaging is constructed and assembled in accordance with Robatel Technologies, LLC, Drawing Nos:

RT-200 PC 001, Sheets 5-13, Rev. E - RT-200 Without Content

RT-200 PC 002, Sheets 1-4, Rev. E - RT-200 With Content No. 1

AS-SC-SK03, Rev. C – Activated Services Storage Container Overall Assembly Sheet 1/1

1.5 Evaluation Findings

A general description of the Model RT-200 package is presented in chapter 1 of the package application, with special attention to design and operating characteristics and principal safety considerations. Drawings for structures, systems, and components important to safety are included in section 1.3 of the application.

The package application identifies Robatel Technologies, LLC, Quality Assurance Program Description 10 CFR Part 71 Subpart H for Packaging and Transportation of Radioactive Material, Revision 4, dated August 11, 2021.

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model RT-200 package against 10 CFR Part 71 requirements, for each technical discipline.

2.0 STRUCTURAL EVALUATION

The objective of the structural evaluation is to verify that the applicant has adequately analyzed the structural performance of the transportation package (cask, contents and impact limiters) so that it meets the performance requirements in the regulations of 10 CFR Part 71, “Packaging and Transportation of Radioactive Material.”

The staff performed the review in accordance with the applicable chapters in NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report.”

2.1 Structural Design Description

The major components of the package are the following: (a) cylindrical body of the package consistent of shell, lid, and lifting and tie-down trunnions, and (b) two (front and end) impact limiters. These components are designed so that the structural responses of the package meet the 10 CFR Part 71 requirements.

2.1.1 Details of Structural Design

The cylindrical body of the packaging is comprised of a double layer stainless-steel shell and a ceramic insulation layer in between. The annular space between the shells is filled with lead. The base of the packaging consists of a one-piece stainless-steel rear forging. The inside height of the cylindrical body is 4570 mm (179.92 in) high and 1100 mm (43.31 in) for the inner diameter. The external body dimensions are 1590 mm (62.60 in) in diameter and 5250 mm (206.69 in) high. This cylindrical body serves as the containment boundary of the package. The primary stainless-steel lid is fastened to the packaging body with thirty (30) stainless-steel M42 bolts.

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The staff reviewed the description of the package and drawings provided by the applicant for completeness and accuracy. The staff concludes that the geometry, dimensions, material, components, notes, and fabrication details of the package were adequately described in the application.

2.1.2 Design Criteria

The Model RT-200 package is designed to meet the criteria specified in 10 CFR 71.43 “General standards for all packages,” 10 CFR 71.45 “Lifting and tie-down standards,” 10 CFR 71.47 “External radiation standards for all packages,” and 10 CFR 71.51 “Additional requirements for type B packages.” As specified in the 10 CFR 71.51, as a type B package, this Model RT-200 package is designed to meet the 10 CFR 71.71 “Normal conditions of transport” and 71.73 “Hypothetical accident conditions” test requirements to maintain the containment structural integrity for Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC). These criteria were discussed in sections 2.4 “General Requirements for All Packages” and section 2.5 “Lifting and Tie-Down Standards for All Packages” of the application and were used to evaluate the structural performance of the package.

The applicant used the following design codes to design the package. The containment boundary is evaluated based on the American Society of Mechanical Engineers (ASME) Code requirements for Level A and D service and is consistent with Regulatory Guide (RG) 7.6 “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” Revision 1, dated March 1978 (ML003739418) which provides design criteria based on the ASME Boiler and Pressure Vessel (B&PV) Code, section III “Rules for Construction of Nuclear Facility Components.” Therefore, the applicant used the allowable stress values for NCT Service Level A Limits and HAC Service Level D Limits. Table 2.1-1 of the SAR lists the allowable stresses for various stress components under NCT and HAC loading conditions. The bolt allowable limits including the stress under NCT, the stress under NCT with fatigue impact, and the stress under HAC are in accordance with NUREG/CR-6007 “Stress Analysis of Closure Bolts for Shipping Casks.”

The staff reviewed the structural design criteria presented in section 2.1.2 of the SAR in accordance with NUREG-2216. The staff found that the Model RT-200 cask system design criteria meet the NRC design criteria requirement for transportation package specified in RG 7.6

and NUREG/CR-6007. Therefore, the staff determines that the Model RT-200 cask system design criteria provide the assurance that the structural performance of the cask system will meet the desired regulatory safety objectives.

2.1.3 Weights and Centers of Gravity

The nominal weights and centers of gravity are provided in appendix 1.3.2 of the SAR. These weights are utilized in the structural evaluations to demonstrate compliance with NCT and HAC requirements. The staff reviewed the weights and centers of gravity information and found that the information provided in the application provides sufficient details to satisfy the package description requirement listed in 10 CFR 71.33. Therefore, the staff concludes that the package complies with the 10 CFR 71.33 requirement.

2.1.4 Identification of Codes and Standards for Package Design

The design category of the packaging is determined by the quantity of the radioactive material shipped in the package. The quantity of the radioactive material is normally defined by two values including A_2 and Ci. The A_2 value is defined as the maximum activity of radioactive material in 10 CFR 71.4 and listed in appendix A of 10 CFR 71. The unit Ci stands for "curie," and is used to measure the radioactivity of a substance. The Model RT-200 is designed to transport radioactive materials in normal form in quantities less than 3,000 A_2 and not exceeding 30,000 Ci as stated in section 1.1 “Introduction” of the application. Consequently, the package is designed as a type B, category II, package in accordance with RG 7.11 “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with A Maximum Wall Thickness of 4 Inches (0.1 m),” dated June 1991 (ML003739413). The applicant chose ASME codes and standards for the design of the package based on the guidance provided in RG 7.6, which is consistent with ASME B&PV section III, subsection NB, and NUREG/CR-3854 “Fabrication Criteria for Shipping Containers,” dated March 1985 (ML20100F724), for packages transporting category II contents in which the package category is classified based on the type and quantity of the radioactive material being transported in the package. As such, the package containment system is fabricated in accordance with the ASME Code, section III, subsection NCD, while the tie-downs are fabricated in accordance with subsection NF. The fabrication, examination, and inspection of the containment boundary components of a category II package are evaluated per ASME B&PV section III, subsection NCD.

In addition, RG 7.8 “Load Combinations for The Structural Analysis of Shipping Casks,” dated May 1977 (ML13064A084), is used in identifying the load combinations to be used in the package design evaluation, and NUREG/CR-6007 is followed for the bolt evaluations.

Based on the review of the codes and standards presented in section 2.1.4 of the application, the staff finds that the codes and standards identified by the applicant are appropriate to evaluate the structural performance of the package under NCT and HAC conditions to meet the regulatory requirements of 10 CFR 71.31(c).

2.2 Fabrication and Examination

2.2.1 Fabrication

As indicated in section 2.1.4 above, all containment components are fabricated, examined, and inspected in accordance with ASME B&PV section III, subsection NCD. In addition, all non-containment components are fabricated, examined, and inspected in accordance with ASME B&PV section III, subsection NF.

Based on a review of the application which defined the limit of the maximum radioactive materials the package is designed for, the staff finds the codes used by the applicant for fabrication is consistent with the code listed in NUREG/CR-3854 which use ASME B&PV section III, subsection NCD, for all containment components and subsection NF for all non-containment components. Therefore, the staff concludes that the fabrication methods for the package identified in the application is acceptable.

2.2.2 Examination

All containment components are fabricated, examined, and inspected in accordance with ASME B&PV section III, subsection NCD. All non-containment components are fabricated, examined, and inspected in accordance with ASME B&PV section III, subsection NF.

The applicant provided acceptance tests and maintenance programs in chapter 8 of the application that included requirements for visual examinations and measurements as well as weld examinations to be performed on the package.

The staff found that the ASME codes, which the applicant utilized for the examination, are consistent with NUREG-2216 and provided detailed description of the examination requirements. Therefore, the examination requirements provide the assurance that the structural performance of the cask system will meet the desired regulatory safety objectives.

2.3 General Requirements for All Packages

2.3.1 Minimum Package Size

The applicant stated that the smallest overall dimension of the cask body is 150 cm (59.1 in), which is larger than the minimum size requirement in 10 CFR 71.43(a) of 10 cm (4.0 in). Therefore, the staff determines that the package meets the regulatory requirements of 10 CFR 71.43(a).

2.3.2 Tamper-Indicating Features

The package incorporates tamper-indicating seals that are attached to the impact limiter bolts to ensure that removal of the impact limiter by unauthorized individuals can be detected. These seals, when breached, will indicate that the package has been tampered with and satisfy the seal requirement of 10 CFR 71.43(b). Therefore, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.43(b).

2.3.3 Positive Closures

The lid and cover plate of the packaging are secured by multiple bolts. These bolts are tightened to a set torque value that cannot be inadvertently loosened. In addition, the applicant performed a stress analysis for the bolts to demonstrate that the bolts can maintain positive closure during operation. These design and analysis ensured that the containment system is securely closed using the package closure system as specified in the 10 CFR 71.43(c). Therefore, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.43(c).

2.4 Lifting and Tie-Down Standards for All Packages

2.4.1 Lifting Devices

The completed package is lifted using trunnions. Two sets of trunnions are used for handling the Model RT-200 cask. They are a set of lifting trunnions that are bolted to the front forging of the cask and another set of supporting trunnions that are welded to the rear of the cask body. Two cask body lifting cases are considered in the design of the trunnions. In the first case, only the two top trunnions are used for a vertical lift position only. In the second case, all four trunnions are used for the cask in non-vertical lift positions.

During package assembly lifting, other lifting devices are used for components lifting and positioning such as lifting rings. The front/rear impact limiters are also moved with a lifting belt for lifting purposes.

The staff noted that the lifting devices are designed to lift more than six (6) times the cask weight and maintain the material stress less than the yield stress. Therefore, this design satisfied the requirement of 10 CFR 71.45. The staff also noted that the lifting device is designed for more than ten (10) times the cask weight and maintains the material stress less than the ultimate stress. This approach satisfies the stress design requirement in ANSI N14.6-1993, “American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 pounds (4,500 kg) or More for Nuclear Materials.” Based on the above, the staff concluded that the package design approach for the lifting device is acceptable and satisfies the ANSI N14.6 code requirement and the 10 CFR 71.45(a) requirement.

Five (5) lifting conditions were considered in the SAR. In each condition, the lifting components in the critical loading path are evaluated and the results are summarized:

(i) The cask body lifting is evaluated for each of the two lifting load cases described before. The results show that in the event of the load case 1, a minimum safety factor of 1.7 is ensured and in the event of the load case 2, a minimum safety factor of 1.3 is ensured.

(ii) The lid for the working load limit in the lifting rings and for the tear-out stresses in the lid from the lifting activities are evaluated. With a critical load factor of 2.0, the lifting rings achieved a safety factor of 3.1. The lid’s threaded hole is 69 mm (2.72 in) and is larger than the 29.4mm (1.16 in) of the required length of engagement preventing the stripping of the internal thread.

(iii) The impact limiters are lifted using two devices: a surrounding belt fitted with a lifting eye on each extremity and a pair of lifting eyes. With a critical load factor of 2, a stress design factor relative to tensile yield strength of 3, and a stress design factor relative to ultimate tensile strength of 5, the lifting belt achieved a safety factor of 1.03 for yield strength and 1.9 for ultimate tensile strength.

(iv) The lifting of the disposable insert is performed with two components: (1) the lifting eye fitted on top of the insert, and (2) the four lifting pins that support the weight of the storage containers at the bottom end of the disposable insert. The safety factors for lifting eye on the yield and the ultimate tensile strength are 1.2 and 2.2 respectively. The safety factors for lifting pin on the yield and the ultimate tensile strength are 1.8 and 3.2 respectively.

(v) The operations involving the lifting and handling of the basket are considered critical and analyzed with a critical load factor of 2. The basket lifting ring achieved a safety factor of 3.0.

The fatigue analyses are performed for cases (i), (ii), and (iii). Since the disposable insert is only used once per transport operation, no fatigue analysis is conducted for case (iv). Since the normal transport operations do not involve lifting and handling of the basket, no fatigue analysis is conducted for case (v) as well.

The evaluation results showed that the calculated factors of safety are larger than the required factor of safety of 3 for yielding stress check and factor of safety of 10 for ultimate stress check. The staff reviewed the analysis results of the lifting device evaluation and determined that the packaging meets the regulatory requirements of 10 CFR 71.45(a).

2.4.2 Tie-Down Devices

The packaging uses two (2) sets of trunnions welded at the front and at the rear of the cask body external shell for tie-down purposes. Both sets of trunnions are designed to securely position the packaging and absorb the latitudinal, longitudinal, and vertical forces as required by 10 CFR 71.45. The bolted lifting trunnions described in section 2.5.1 are not used for tie-down due to their interferences with the front impact limiter.

The applicant evaluated the tie-down trunnions to demonstrate that these structural members of the packaging can withstand the required loads without impairing the safety of the packaging. The tie-down trunnion safety factor results are 1.9 for bending and 1.3 for compression and tension as shown in the table 2.5-2 in the SAR. The results of the evaluation demonstrated that the tie-down trunnions have acceptable margins of safety for the considerations of 2g accelerations in vertical direction, 5g accelerations in transverse to travel direction and 10g in the direction of travel per 10 CFR 71.45(b).

Based on the findings in the package tie-down device evaluation, the staff determines that the applicant complies with the regulatory requirements under 10 CFR 71.45(b).

2.5 Normal Conditions of Transport (NCT)

The applicant used the most penalizing results of the structural analysis to demonstrate the capability of the Model RT-200 cask’s design to meet the regulatory requirements in the context of the NCT load and load combinations specified in 10 CFR Part 71 and RG 7.8. The applicable NCT load and load combinations used for analysis are listed in the application in table 2.6-1 and table 2.6-2, respectively.

The staff reviewed the data listed in tables 2.6-1 and 2.6-2 in the application and found that the load cases and the load combinations in these two tables cover all load cases specified in 10 CFR 71.71 and the load combinations specified in RG 7.8.

The drop analyses are performed in two steps in the application. The first step is to derive the acceleration in terms of the g value of the crushing force and the second step is to apply the g value to the finite element analysis to determine the stress demand of the structural components of the cask body.

The stress results are evaluated on seventeen (17) selected node locations including four locations where gross structural discontinuities are presented. These stress results are linearized and classified according to the ASME Code classification rules in section III.3, WB-3200. Two categories of stress origins have been defined in the application. The first one is the “mechanical loads” category which includes the combination of internal pressure, bolt preload and all impact loads including inertia. The second one is the “thermal loads” category which includes the thermal gradients and temperature differences between adjacent components produced by the thermal environment conditions. A secondary differentiation is done between the membrane and the bending stress for all stress result locations.

2.5.1 Heat

The applicant performed a thermal analysis for the packaging body and closure lids to demonstrate the structural adequacy of the design for the temperatures specified in 10 CFR 71.71(c)(1). The analysis and the calculation are described in section 2.6.1.1 through section 2.6.1.3. The analysis result and the staff evaluation are presented in section 2.6.1.4.

2.5.1.1 Summary of Pressure and Temperatures

Chapter 3 of the application presents the maximum normal operating pressure evaluation as well as the maximum component temperature evaluation for NCT. The pressure and temperatures were utilized to determine the stress allowable for the material used in the structural evaluation for NCT.

2.5.1.2 Differential Thermal Expansion

The Model RT-200 is evaluated for differential thermal expansion as described in section 2.6.7 of the application in combination with the other regulatory specified individual loading condition.

2.5.1.3 Stress Calculations

Using an ANSYS finite element model, the applicant analyzed the package with the range of primary plus secondary stresses for the combined normal events (including heat, cold, normal operating pressure, 0.3-meter [1 foot] end drop, 0.3-meter [1 foot] side, and 0.3-meter [1 foot] corner drop conditions) to satisfy the requirements of RG 7.6.

2.5.1.4 Comparison with Allowable Stresses

The applicant compared the calculated stress intensities with the material allowable limits for NCT and HAC conditions. The detailed thermal analysis and its results are presented in chapter 3 of the application. The applicant provided a brief summary of the thermal analysis in section 2.6.1 of the application. The detailed results are presented in appendix 9.3.2 of calculation RT-200 NTE 2004.

The staff reviewed the analysis input and the results and finds that the stress intensity is calculated at the temperature defined in 10 CFR 71.71(c)(1). The staff found that the stress results at critical components are within the allowable limits of the material, and the comparison results show that the margins of safety are all positive. Therefore, the staff determines that the packaging heat load calculated in the application meets the regulatory requirements of 10 CFR 71.71(c)(1) and the package design is structurally adequate for the heat load combined with other loads resulting from applicable events. Therefore, the staff concludes that the package satisfies the regulatory requirements of 10 CFR 71.71(c)(1).

2.5.2 Cold

The regulatory requirements of 10 CFR 71.71(c)(2) require that the package be subjected to an initial ambient temperature of -40°C (-40°F) in still air and shade. The applicant performed a thermal evaluation for the Model RT-200 package in accordance with the temperatures specified in 10 CFR 71.71(c)(2) to demonstrate the structural adequacy of the package. Chapter 3 of the application provides a thermal evaluation for cold conditions using the methodology discussed in section 2.6.1 of the application.

The staff reviewed the results of the applicant's analysis presented in appendix 9.3.2 of RT-200 NTE 2004 and found that the calculated margins of safety are all positive. Therefore, the staff concludes that the packaging maintained the structural integrity when subject to the cold ambient temperature defined in 10 CFR 71.71(c)(2) and therefore satisfies the regulatory requirements of 10 CFR 71.71(c)(2).

2.5.3 Reduced External Pressure

The regulatory requirements of 10 CFR 71.71(c)(3) require that the package be subjected to a reduced external pressure of 24 kPa (3.5 lbf/in^2) absolute. The applicant considers this load condition is bounded by the free drop analyses performed at hot thermal environment in which a maximal internal pressure is applied in conjunction with a zero external pressure. The staff concludes that the reduced pressure used by the applicant is more critical than the reduced external pressure defined in 10 CFR 71.71 (c)(3). Therefore, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.71(c)(3).

2.5.4 Increased External Pressure

The applicant stated that an increased external pressure of 140 kPa (20 lbf/in^2), as specified in 10 CFR 71.71(c)(4), has a negligible effect on the package because of the thick outer shell and end closures of the package. Because the current shell thickness has the ability to maintain the structural integrity under HAC which impose the external pressure at order of magnitude larger than the 140kPa, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.71(c)(4).

2.5.5 Vibration

The applicant evaluated the Model RT-200 package for maximum expected severities of shocks and the highest levels of truck input vibration. The truck introduced resultant acceleration is 3.98g and 0.62g for the shock and vibration, respectively. Both shocks and vibration loads are negligible compared to the g-loads applied in the NCT free drop loading combinations. Therefore, these load conditions are not considered in the load combinations under NCT.

However, the package may be subjected to a cycle range typically associated with high-cycle fatigue during transportation. Therefore, the applicant performed vibration evaluations for both impact limiter's tightening bolts and the closure bolts, which are used for the closing of both the lid and the cover plates during transport. The results of the evaluation are provided in appendix

2.12.3.2 and appendix 2.12.3.7 of the application. The results of the evaluation show that the stresses in the bolts are well below the endurance limit of the material; therefore, both the impact limiter's tightening bolts and the closure bolts are not subjected to transport-related fatigue damage during their service life.

The applicant also evaluated both the lid's threads and the welded trunnions due to vibration loads of normally incident to transport. The results of the evaluation provided in appendix 2.12.3.3 and appendix 2.12.3.4 of the application.

The staff reviewed the calculation steps for the bolt analysis and the result. The staff noticed that using the calculated alternating stress intensity and the fatigue curve in ASME section III, figure I-9.2, the stress in the lid's thread, trunnion, and the weld are well below the material endurance limit. Therefore, the staff concludes that both the lid's threads and the welded trunnions are not subjected to transport-related fatigue damage during their service life. Therefore, the staff determines that the requirements of 10 CFR 71.71(c)(5) for normal vibration incidents and shock loading conditions during transport are met.

2.5.6 Water Spray

The regulatory requirements of 10 CFR 71.71(c)(6) require that the package must be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour. The water spray test is primarily intended for packaging relying on material that absorb water and/or are softened by water material. The packaging outer layer is designed to be fabricated entirely of metal. Thus, the staff determines that the water spray test has no impact on the packaging, and the packaging satisfies the regulatory requirements of 10 CFR 71.71(c)(6).

2.5.7 NCT Free Drop

The applicant evaluated the package for the free drop requirements of 10 CFR 71.71 by a combination of classical hand calculations, and finite element analysis. The evaluations included the qualification of the cover bolt design for the combined effects of free drop impact force, internal pressures, thermal stress, and bolt preload using the methodology provided in NUREG/CR-6007. Analyses were performed in three orientations – end, side, and center of gravity over corner. Each of the three free drop loadings is analyzed in combination with two sets of environmental conditions, as shown in the load combination summary of RG 7.8.

2.5.7.1 NCT Free Drop Analysis Methodology

The load combinations corresponding to the ASME service levels are shown in table 2.6-2 of the application. Stress intensities caused by thermal loads and mechanical loads are combined before comparing to the stress allowable described in section 2.2 of the application.

Two different numerical models of the cask were used. One is for a two-dimensional (2D) axisymmetric model including all major components except bolts and washers, for the thermal stress evaluation. The other one is for a three-dimensional (3D) (180° axisymmetric) model simulating the entire cask utilizing the axisymmetric feature of the cask. This 3D model includes all major components, which are utilized for the transient structural evaluation. All applicable loads are applied through boundary conditions, simulating the loading conditions the cask body will experience during normal and accident transport conditions.

For the various drop scenarios, the cask is evaluated in 2-step analysis. The 1st step is to derive the impact limiter reaction force and the deceleration of the cask body using the basic physics principles such as Newton's 2nd law of motion which define the force equal to mass times acceleration. This derivation is performed at a short time step for the simulation. The output of the impact limiter reaction during the drop served as the input of the 2nd analysis step. The 2nd step is to use the 3D model to perform a transient structural analysis to simulate the impact to the cask body. The bolt prestress, internal pressure, and inertia loading conditions are applied to the cask model as loading conditions and the impact load is applied as a transient load to simulate the impact. Displacement boundary conditions are applied to complete the symmetry features of the cask and ensure no rigid body motion during the analysis.

The complete 3D model includes the following parts: the stainless-steel inner shell and outer shell, the stainless-steel bottom and top forging and the closure lid, the stainless-steel bolts and washers, and the lead shielding layer between the inner and outer shells. 3D solid elements and contact element pairs are used to simulate the cask in the friction conditions. The applicant also performed a mesh sensitivity study and documented the result in appendix 2 of calculation RT-200 NTE 2004 to ensure a good compromise between run time and results precision.

The 2D model is developed for thermal analysis using 2D plate elements and contact elements.

The staff reviewed the free drop analysis cases and the analysis methodology of using the two-step drop analysis. The staff finds that the analysis cases satisfy the required free drop cases required by 10 CFR 71.71(c)(7) and the approach taken is consistent with the expected behavior of the package in drop scenarios. In addition, the staff considers the fact that this method of analysis was confirmed by the 3/10th scale model drop tests performed for the approved Model RT-100 package, which used the same method and foam material (FR-3740). Based on these findings, the staff concludes that the analysis methodology for the package under all drop conditions are acceptable.

2.5.7.2 NCT Free Drop Analysis Results

The nodal stress results are extracted at seventeen (17) locations on the cask body in both 3D and 2D models. Figures 2.6-8 through 2.6-28 in the application show the stress intensity contour plot result of different structural components in NCT. Table 2.12-4 through table 2.12-6 listed the safety margins for all NCT drop conditions. These tables documented the safety margin for the primary membrane stress (Pm), primary membrane plus primary bending stress (Pm+Pb), and the primary plus secondary stress (Pm+Pb+Q) in accordance with the criteria presented in RG 7.6.

The staff reviewed the analysis results and verified that the most critically stressed component, among the seventeen locations, is at location "08" for NCT end drop, at location "11" for NCT side drop, and at location "07" for NCT corner drop. The staff observed that the safety margins in all locations are all larger than zero. Based on these findings, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.71(c)(7).

2.5.8 Corner Drop

The corner drop test is not applicable because (i) the Model RT-200 package is composed of materials other than fiberboard or wood, and (ii) its weight exceeds 100 kg. As such, the regulatory requirements of 10 CFR 71.71(c)(8) do not apply to the Model RT-200 package.

2.5.9 Compression

The compression test is not applicable because the packaging weight is greater than 5,000 kg (11,000 lb). As such, the regulatory requirements of 10 CFR 71.71(c)(9) do not apply to the Model RT-200 package.

2.5.10 Penetration

The Model RT-200 package was not tested for penetration based on the statement provided in RG 7.8, which states that the penetration test of 10 CFR 71.71 is not considered by the NRC staff to have structural significance for large shipping casks (except for unprotected valves and rupture disks) and is not considered as a general requirement.

The Model RT-200 package has no unprotected valves or rupture disks that could be affected by normal conditions of transport. Thus, the staff consider that the packaging is in compliance with the regulatory requirements of 10 CFR 71.71(c)(10).

2.6 Hypothetical Accident Conditions (HAC)

The evaluation of the package for HAC conditions was done by analytical methods. The applicant described the details of its 3D finite element model in section 2.6 in the application and used the same 3D (180° axisymmetric) finite element model as the one used for the NCT loading conditions, as discussed in section 2.6 above.

The applicant used the same two-step approach for the free drop analysis in the HAC as in the NCT. It includes deriving the crushing force from the impact limiter's reaction forces during the impact and then applying this force as a load condition to the finite element analysis.

The applicant performed structural analyses of the cask body in calculation RT-200 NTE 2004, using various individual loadings and combining the stress result following RG 7.8. The summary of load combinations is listed in table 2.7-1 and table 2.7-2 in the application.

2.6.1 Free Drop

The package was analyzed under 9 m (30 ft) end drop, side drop, corner drop (CG over top corner), and oblique drop conditions (also known as slap down drop) onto an unyielding surface. Following Newton's 2^{nd} law, the impact limiters utilized the numerical integration approach for evaluation of all drop conditions. The impact limiter deformations, crush force, velocity, and dissipated energy are calculated and presented in the calculation for all drop conditions and the entire impact duration. This information is also fed into finite element analysis for the cask evaluation using ANSYS.

Figures 2.7-1 through 2.7-28 in the application show the stress intensity contour plot result of different structural components under HAC. The stress intensity levels for components at all seventeen (17) locations were tabulated in appendix tables 2.12-7 through 2.12-10 in the SAR. Similar to NCT, these tables documented safety margins for the primary membrane stress (Pm), primary membrane plus primary bending stress (Pm+Pb), and the primary plus secondary stress (Pm+Pb+Q) in accordance with the criteria presented in RG 7.6.

Using the finite element analysis for the free drops, the applicant conducted the lead slump evaluations for each of the drop configurations. The numerical analyses show that a maximum lead slump occurs under the HAC end drop case and shown in figure 2.7-29 in the application. The applicant stated that this has been conservatively considered in the shielding study in section 5.3.1 in the application.

The staff reviewed the analysis results and verified that the most critically stressed component, among the seventeen locations, is at location “08” for HAC end drop, at location “10” for HAC side drop, at location “07” for HAC corner drop, and at location “07” for HAC oblique drop. The safety margins are all larger than zero. Based on these findings, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.73(c)(1).

2.6.2 Crush

The dynamic crush is only required when the specimen has a mass not greater than 500 kg (1,100 lb), an overall density not greater than 1,000 kg/m^3 (62.43lb/ft^3) based on external dimension, and radioactive contents greater than 1,000 A_2 not as special form radioactive material. As such, the Model RT-200 package, with a weight of more than 500 kg and an overall density greater than 1,000 kg/m^3, the regulatory requirements of 10 CFR 71.73(c)(2) do not apply.

2.6.3 Puncture

The applicant evaluated the package for puncture drop by using the classical elastic analysis and finite element analysis methods. The calculation package, RT-200 NTE 2004, Rev. B, details the evaluation of the regulatory puncture drop and the hypothetical drop test. The applicant considered two scenarios: (i) a puncture drop on the lid, and (ii) a puncture drop on the sidewall.

2.6.3.1 Cask Lid Puncture

For the analysis of the puncture drop on the lid, the applicant used the ANSYS finite element code with adjusted boundary condition tailored for lid puncture case to remove the statical instability. A dynamic flow stress of 350 MPa (51 ksi) is used to simulate the impact of the pin puncture effect in the puncture analysis.

The bolt preload is included in the initial condition along with hot and cold thermal condition. The results of the analysis were provided in table 2.12-11 in the SAR. Similar to NCT, this table documented safety margins for the primary membrane stress (Pm), primary membrane plus primary bending stress (Pm+Pb), and the primary plus secondary stress (Pm+Pb+Q) in accordance with the criteria presented in RG 7.6.

The staff reviewed the cask lid puncture analysis results in the SAR and found that the margins of safety are positive when compared to the stress intensity for each category. Based on these findings, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.73(c)(3).

2.6.3.2 Cask Side Puncture

The applicant determined that the maximum deformation occurs during a postulated puncture event when the packaging strikes the puncture probe approximately mid-span on the packaging outer shell. In the analysis, the applicant considered the package to be a closed cylinder subjected to a concentrated load at mid-span. The applicant manually calculated the minimum required outer shell thickness using Nelm's Equation per ORNL-NSIC-68, titled "Cask Designers Guide," dated February 1970. The results show that the outer shell is sufficient to resist the puncture considering the thickness of the package shell.

The cask sidewall bending is evaluated using the same approach of applying a dynamic flow stress of 350 MPa (51 ksi). The resulting factor of safety is 14.5.

The lead deformation during side puncture is investigated by the energy method. The stiffness of the outer shell, middle lead layer, and the inner shell are calculated to derive the potential energy of the entire composite section. The lead deformation is derived from the ratio of the effective stiffness of the entire shell and lead stiffness. The entire lead deformation is conservatively assumed to be permanent. This deformation is less than the lead deformation derived for HAC drop as discussed in section 2.7.1.5 of the application.

The staff reviewed the cask side puncture evaluation method and found that the puncture would yield a maximum impact when the puncture probe strikes at the middle of the packaging outer shell. The result of the analysis shows that the stress due to the puncture is much less than the ASME stress criteria listed in section 2.1.4 of this SER. Based on the analysis results, the staff determines that the packaging meets the regulatory requirements of 10 CFR 71.73(c)(3).

2.6.4 Thermal

The regulatory requirements of 10 CFR 71.73(c)(4) require exposure of the package with an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes. The applicant performed an evaluation for the thermal expansion of the bolts and evaluation for the packaging body under pressures associated with the fire accident that produces a surrounding environment of 800°C (1475°F) for a period of 30 minutes.

The applicant used the same 3D (180° axisymmetric) finite element model and 2D model as the models used for the NCT and HAC loading conditions. Different loading conditions and analysis steps are summarized in section 2.7.4.1 to section 2.7.4.3. The analysis results and staff evaluation are provided in section 2.7.4.4.

2.6.4.1 Summary of Pressure and Temperatures

The applicant used the ANSYS finite element computer code to analyze the package components temperatures under varying conditions. Table 3.1-1 and table 3.1-2 of chapter 3 of the application presented the maximum NCT and HAC temperatures for each component of the cask. Table 3.1-4 summarized the maximum NCT and HAC pressures.

2.6.4.2 Differential Thermal Expansion

The applicant performed an evaluation for the dissimilar material of the packaging and on the closure bolts for thermal expansion under the fire accident condition. The resulting stress from differential thermal expansion are combined with other loads the cask is subjected to per table 2.7-2 and RG 7.8. The bolting evaluation and the effects of thermal expansion on the closure bolts are presented in calculation RT-200 NTE 2005.

2.6.4.3 Stress Calculation

The thermal induced bolt stresses are included in the bolt stress evaluation which was presented in calculation RT-200 NTE 2005. This calculation evaluated both prying and non-prying effects for the bolt evaluations. A finite element (FE) analysis is performed using the FE models to simulate the bolt and lid behavior of the closure lid and the cover plate. The finite element analysis results and manual calculation results are used to obtain the final stress results per NUREG/CR-6007. The applicant compared the calculated bolt stresses with the allowable stresses from section 2.1.2.2 of the SAR, based on the recommendations of NUREG/CR-6007. The comparison shows that the calculated stresses are less than the allowables.

The thermal induced cask stresses are included in the cask evaluation under NCT and HAC conditions.

2.6.4.4 Analysis Stress Results

Based on the verifications and review of the calculation method and the loading calculation, the staff found that the applicant’s calculations adequately address all applicable loading cases for closure lid and cover plate bolts defined in NUREG/CR-6007. The staff reviewed the results of the analysis and determined that the bolts continue to provide a tight seal to ensure that the containment is maintained. Therefore, the staff concluded that the package satisfies the requirements in 10 CFR 71.43(c).

Figures 2.7-35 through 2.7-40 in the SAR show the stress intensity contour plot results of different structural components under HAC fire pressure condition. The staff reviewed the results of the accident pressure safety margins in table 2.12-12 of the SAR. Similar to NCT, this table documented safety margins for the primary membrane stress (Pm), primary membrane plus primary bending stress (Pm+Pb), and the primary plus secondary stress (Pm+Pb+Q) in accordance with the criteria presented in RG 7.6. The staff found that the margins of safety are positive when compared to the stress intensity for each category. The minimum margin of safety was found to be 2.8 for the primary plus secondary stress intensity (Pm+Pb+Q).

Based on these findings the staff verified the applicant's calculations method, input and result and found that the calculated margins of safety are larger than 1.0 thus satisfy the ASME design criteria listed in section 2.1.4 of this SER. Therefore, the staff concludes that the packaging meets the regulatory test requirements of 10 CFR 71.73(c)(4).

2.6.5 Immersion – Fissile Material

The HAC immersion test for fissile materials is not applicable, as the package does not have any fissile material subject to the requirements of 10 CFR 71.55.

2.6.6 Immersion – All Packages

The regulatory requirements of 10 CFR 71.73(c)(6) are required for all packages. Based on the review of the results of the evaluations provided in chapter 2 of the SAR, the staff determines that the stress intensity values at critical components during impact analysis impose a much larger external pressure to the packaging than the immersion pressure of 150 kPa (21.7 lbf/in) as listed in 10 CFR 71.73(c)(6). Therefore, the package meets the regulatory requirements of 10 CFR 71.73(c)(6).

2.6.7 Deep Water Immersion Test

The Model RT-200 package does not contain irradiated fuel or contents containing more than 3,000 A_2. Thus, the deep water immersion test per 10 CFR 71.61, required for type B packages containing more than 10^5 A_2 is not applicable to the Model RT-200 package.

2.6.8 Summary of Analysis

The staff reviewed the analysis pertaining to the HAC condition in sections 2.7.1 through 2.7.7 of the application and the resulting contour plots and tables. The staff found that the resulting safety margins for the stress evaluations in all tables satisfy the ASME design criteria listed in section 2.1.4 of this SER. The staff also found in contour plots that a 9-meter drop or a 1-meter pin puncture accident may introduce a local deformation due to combinations of applicable HAC loading conditions, but the ability of the package to maintain the containment boundary remain.

Based on these findings, the staff determines that the assessed damages are acceptable, and that the package can safely withstand the HAC free drop, puncture, and fire test performed in sequence. The staff concludes that the package meets the regulatory requirements of 10 CFR 71.73.

2.7 Accident Conditions for Air Transport of Plutonium, for Fissile Material Packages for Air Transport, Special Form, Fuel Rods

These sections are not applicable.

2.8 Evaluation Findings

On reviewing the information provided in the application, the staff concludes that the Model RT-200 package is adequately described and evaluated to demonstrate that its structural design is adequate and capable of meeting the regulatory safety performance required by 10 CFR Part 71.

Based on the review of this application, the staff concludes with findings:

F2-1 The staff has reviewed the package structural design description and concludes that the contents of the application satisfy the requirements of 10 CFR 71.31(a)(1) and (a)(2) as well as 10 CFR 71.33(a) and (b).

F2-2 The staff has reviewed the structural codes and standards used in package design and finds that they are acceptable and therefore satisfy the requirements of 10 CFR 71.31(c).

F2-3 The staff has reviewed the lifting and tie-down systems for the package and concludes that they satisfy the standards of 10 CFR 71.45(a) for lifting and 10 CFR 71.45(b) for tie-down.

F2-4 The staff has reviewed the package description and finds that the package satisfies the requirements of 10 CFR 71.43(a) for minimum size.

F2-5 The staff reviewed the package closure description and finds that the package satisfies the requirements of 10 CFR 71.43(b) for a tamper-indicating feature.

F2-6 The staff reviewed the package closure system and the applicant's analysis for normal and accident pressure conditions and concludes that the containment system is securely closed by a positive fastening device and cannot be opened unintentionally or by a pressure that may arise within the package and therefore satisfies the requirements of 10 CFR 71.43(c) for positive closure.

F2-9 The staff reviewed the structural performance of the packaging under the normal conditions of transport required by 10 CFR 71.71 and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(1) for a Type B package and 10 CFR 71.55(d)(2) for a fissile material package.

F2-10 The staff reviewed the structural performance of the packaging under the hypothetical accident conditions required by 10 CFR 71.73 and concludes that the packaging has adequate structural integrity to satisfy the subcriticality, containment, and shielding requirements of 10 CFR 71.51(a)(2) for a Type B package and 10 CFR 71.55(e) for a fissile material package.

3.0 THERMAL EVALUATION

The objective of this review was to verify that the thermal performance of the Model RT-200 package has been adequately evaluated for the tests specified under both normal conditions of transport (NCT) and hypothetical accident conditions (HAC) and that the package design satisfies the thermal requirements of 10 CFR Part 71.

3.1 Description of Thermal Design

Section 1.2 of the application mentioned that the cylindrical body of the package is constructed of inner stainless-steel plate shell and outer stainless-steel shell with the annular space between the shells filled (i.e., poured) with lead. Table 1.3-3 of the application provided the lead thickness and has properties as defined in table 3.5-1, table 3.5-3, table 2.12-1, and table 2.12-2 (e.g., ASTM B-29) in the application. The lid and rear of the package consist of stainless-steel forgings. The lid is attached to the cask body's stainless-steel front forging flange with thirty (30) M42 hex bolts. An impact limiter is fastened to each package end. The impact limiter is fabricated as a stainless-steel casing filled with polyurethane foam. Sections 3.1, 1.2.1.1, and 8.1.5.1 of the application indicated that the impact limiter provides protection for the package during NCT and HAC tests, including acting as an insulated barrier for the lid's O-rings and portion of the lead during the 30-minute HAC fire. Similarly, section 1.2.1.12 and section 3.1 of the application indicate that a low thermal conductivity (i.e., insulation) ceramic fiber with its stainless-steel covering acts as a thermal shield over the package's radial surface, thereby insulating the radial lead. Finally, section 8.1.5.4 of the application indicated the package has discrete thermoplastic material plugs that melt at high temperatures (e.g., during the HAC fire) and allow pyrolysis gases that are produced during high temperature decomposition to be vented. The plugs are batch tested to verify the plug's melting temperature.

The application mentioned two types of contents that are transported in the Model RT-200 package. Section 1.2.2.1 and section 1.2.2.1.3 of the application provided details of the content consisting of disposable inserts, boxes, and three storage containers loaded with solid irradiated materials and contaminated non-fuel-bearing materials; there is no gas or liquid content. Section 1.2.2.2 of the application provided details of the content consisting of irradiated and contaminated solid components that are mainly metallic. Section 1.2.2.2.10 of the application specifically stated that material that presents other risks than those related to radioactive features is prohibited as content, such as explosives, non-radioactive pyrophoric materials, corrosives, pyrophoric radionuclides and materials that may auto-ignite or undergo phase transformation at temperatures less than 140°C. Sections 1.2.2.1, 1.2.2.1.9, and 1.2.2.2.9 of the application noted that the Model RT-200 package is limited to a decay heat of 1200 W. Section 3.1 of the application stated that the thermal criteria of the Model RT-200 package include maintaining the lead shielding in the package body below the melting point and maintaining the O-ring seals below their maximum operating temperature.

3.2 Material Properties and Component Specifications

Section 3.2.1 and appendix 3.5.2 of the application, section 5.4 of the thermal calculation document (RT-200 NTE 3002, Rev. C), and material thermal properties document (RT-200 NTE 3001, Rev. C) discussed the Model RT-200 package's thermal-related material properties, including thermal conductivity, density, specific heat, and emissivity. For example, table 3.5-1 in appendix 3.5.2 of the application listed temperature-independent properties, which included stainless-steel density and emissivity values at NCT, HAC fire, and post-fire as well as the lead having a constant density value. Table 3.5-2 of the application listed the thermal conductivity, thermal diffusivity, and specific heat of stainless-steel as a function of temperature. Table 3.5-3 and table 3.5-4 of the application provided the lead's thermal conductivity and specific heat values and the ceramic paper's thermal conductivity and specific heat, respectively. Finally, table 3.5-5 of the application provided the thermal conductivity, specific heat, and density temperature-dependent values for air. Staff notes that the large temperature margin of the lead and O-ring from their allowable temperatures would indicate those important-to-safety components would function even if there were slight variations in actual thermal properties.

Section 3.2.1 of the application indicated that some of the above-mentioned thermal properties were modified for NCT and HAC analyses. For example, the reported ceramic paper thermal conductivity value was divided by a factor of 1.5 during the NCT analyses, which would reduce heat transfer out of the package, to account for tolerances in the ceramic paper's dimensions. Likewise, the ceramic fiber paper's thermal conductivity was multiplied by a factor of 1.5 during the fire HAC, which would reduce the thermal protection aspect of the insulation paper. Similarly for the fire HAC, which takes place after the HAC drop and impact tests and potential reduction of air gaps, the air thermal conductance of the gaps between the lead and the outer shell and between the impact limiters and the cask body was multiplied by a factor of 10 to increase the heat transfer from the fire into the cask components.

Sections 3.2.2 and 1.3.3 of the application (including drawings RT-200 PC 001 Rev. D) provided technical specifications of the Model RT-200 components that are important to the package's thermal performance. Specifications also included the operation temperature limits of the package components' maximum NCT and HAC allowable service temperatures, such as those provided in table 3.1-1, table 3.1-2, and table 3.2-1 of the application. Additional O-ring seal specifications and properties were also provided in appendix 4.6.3 of the application. Section 5.5 of the thermal calculation document stated that all package materials can be used at low temperatures of -40°C and table 3.2-1 noted that the minimum allowable O-ring temperature was -45°C. Likewise, table 3.2-1 in the application noted the lead and polymer foam had a maximum allowable temperature of 327°C and approximately 1000°C, respectively. Section 5.5 of the thermal calculation document stated that the stainless-steel and ceramic paper had allowable temperatures between -40°C to 800°C.

3.3 General Considerations

Section 4.5 of the application discussed the potential for hydrogen generation within the package due to radiolysis of water associated with content loading. The calculations and inputs indicated that the content and operations, including allowable transport time, would result in a hydrogen concentration from radiolysis to be below 5% vol. As noted in sections 4.5.3 and 7.5 of the application, the radiolysis calculation was based on using a safety factor of 2 when determining the maximum shipping period to reach hydrogen concentration of 5% vol. Section 1.2.2.1.6 of the application noted that the shipment period begins when the package is prepared and sealed. Additional discussion about the radiolysis calculation and there being less than 5% volume concentration of hydrogen is provided in chapter 4 of the SER.

3.4 Thermal Evaluation under Normal Conditions of Transport

3.4.1 Model Description

As noted in section 3.3.1.2 of the application and section 6.1 of the thermal calculation document (RT-200 NTE 3002, Rev. C), the NCT thermal model was generated using the ANSYS finite element code (Release 21.2) and is maintained under a quality assurance program. The thermal analysis considered a two-dimensional axisymmetric model of the cask and its major components, including the inner shell, outer shell, lead shielding between the inner and outer shells, ceramic paper insulation and its stainless-steel casing around the outer shell, and the front and rear foam impact limiters; the geometry of the model was provided in figure 3.5-1 through figure 3.5-4 in appendix 3.5.3 of the application. Thermal properties associated with the thermal model, including emissivity values were discussed in section 3.2 and appendix 3.5.2 of the application as well as section 6.3.3 and table 8 of the thermal calculation document. As discussed in section 6.3.3 and table 8 of the thermal calculation document, an absorptivity value of approximately 0.5 was applied to the package's external stainless-steel surfaces when considering the thermal input from NCT.

According to section 3.3.1.2 of the application, the thermal analyses considered the following thermal modes: conduction in the package's materials, convection and radiation heat transfer modes to the ambient, and conduction and radiation heat transfer modes through the internal air gaps. Figure 3.5-4 of the application as well as figure 4 and section 6.3.1 of the thermal calculation document provided air gap dimensions between the impact limiters and the cask body, between the lid and cask body, between the lead and the outer shell, and between other lead parts. According to the thermal calculation document, gaps were modeled using ANSYS contact elements and their corresponding conductance values. Similarly, the radiation heat transfer between the gap's two surfaces considered an equivalent emissivity based on the simplification of parallel planes of the gap boundaries. Section 6.3.3 of the thermal calculation document provided the average convection heat transfer coefficient for the external package during NCT. The response to RAI-Th-2 (ML24304A911) and section 7.1.3 of the application noted the use of a barrier (e.g., rain cover) that allows natural ventilation would not affect thermal performance.

Sections 3.3.1.1 and 3.3.1.2 of the application discussed the analyzed thermal cases and model boundary conditions. The 1200 W content was modeled by applying an equivalent thermal flux to the internal surfaces of the cask. The staff finds that this is an acceptable assumption because the content is comprised of metal components with allowable temperatures that far exceed the internal package temperatures. The NCT "(1) Heat" analysis consisted of a 14.5-day transient calculation based on a 38°C ambient temperature; a constant 400 W/m^2 insolation value was applied to the package's external surface for a 12-hour period, followed by no insolation for 12 hours. The staff finds that the 400 W/m^2 value is appropriate for the cylindrical package surface (i.e., curved surface) and it is slightly conservative relative to the 10 CFR 71.71(c) insolation requirement of 400 g cal/cm^2 for 12 hours (i.e., approximately 388 W/m^2).

The NCT “(0) Shade” case was a steady-state analysis assuming 38°C ambient temperature without insolation. According to section 3.3.1 of the application, the maximum package outer surface temperature for a 1200 W decay heat was 50.3°C and was below the 85°C exclusive use temperature requirement of 10 CFR 71.43(g).

Finally, the “(2) Cold” case assumed the package with no decay heat experienced ambient conditions of -40°C with no insolation such that package components would be at -40°C. As mentioned above, section 5.5 of the thermal calculation document stated that all package materials can be used at -40°C.

The staff reviewed the assumptions, boundary conditions, and parameters used in the thermal model as well as the temperature margins of package components with allowable values. Based on the staff’s review, the staff finds that the applicant’s thermal evaluation under NCT is acceptable and meets the requirements of 10 CFR 71.71.

3.4.2 Temperature Results

Section 3.1.3 of the application provided a summary of the NCT temperatures from the thermal model discussed above. The results of the transient thermal analysis with 12-hour insolation/12 hour no insolation boundary condition over 14.5 days were presented in section 3.3.1.3 and figure 3.3-1 of the application. It was shown that the maximum temperature of the package’s structural parts and impact limiter was approximately 70°C. Figure 3.3-1 of the application indicated that the maximum O-ring and lead temperatures were much less than their allowable values.

As noted previously, section 3.3.1.3 of the application indicated that the steady-state NCT “(0) Shade” case at 38°C ambient temperature without insolation indicated a maximum outer surface temperature that had approximately a 30°C margin below the 85°C exclusive use requirement of 10 CFR 71.43(g).

3.4.3 Maximum Normal Operating Pressure (MNOP)

Section 3.3.2 of the application and section 6 of the pressure calculation document (RT-200 NTE 3003, Rev. C) described the calculation of maximum normal operating pressure (MNOP). The contributions to the package pressure included the effect of higher temperature during NCT compared to ambient conditions (i.e., the ideal gas law), the effect due to water vapor within the package cavity, and the effect of hydrogen and oxygen gases generated during the radiolysis process.

Section 3.3.2 of the application noted that an interior gas temperature of 80°C was assumed for pressure calculations, which bounds the calculated cavity surface temperature listed in table 3.1-1 of the application. The pressure due to the increased package temperature (80°C) during NCT was calculated as 121.61 kPa (absolute) and the pressure due to the presence of water vapor was conservatively based on the water vapor pressure at 80°C (47.39 kPa, absolute). The pressure due to the radiolysis process was calculated as 13.71 kPa (absolute) and was based on assuming a hydrogen partial pressure that was 5% of the total pressure and its corresponding oxygen partial pressure within the package due to the presence of air, water vapor, hydrogen, and oxygen. The sum of these pressure components was calculated to be

182.71 kPa (absolute). Section 3.3.2.6 of the application stated that the MNOP was conservatively chosen as 98.675 kPa (gauge), which is equal to 200 kPa (absolute). This pressure and the component temperatures presented in table 3.3-1 of the application were used in the structural analyses, as noted in section 2.6.1.1 of the application.

The staff reviewed the pressure calculation and finds it acceptable that the 200 kPa (absolute) MNOP is conservatively set higher than the calculated pressure of 182.71 kPa (absolute).

3.4.4 Maximum Thermal Stress

Section 3.1.2 of the application stated that the content's decay heat did not produce significant temperature gradients through the cask body. Nonetheless, section 2.6.7.2.4.1 of the application indicated that the stress distribution from hot and cold normal transport conditions was calculated using a mechanical model based on input NCT temperature distributions from the thermal model discussed in section 3 of the application. The resulting thermal loads were combined with other structural loads that were then used as input to the structural calculations. An additional discussion of structural loads is provided in chapter 2 of this SER.

3.5 Thermal Evaluation under Hypothetical Accident Conditions

3.5.1 Model Description

Section 3.4.1 of the application stated that the axisymmetric HAC finite element thermal model was identical to the NCT model except for changes that simulate damage due to the HAC drop test and puncture test. The thermal model simulated the damage from the drop test by reducing the impact limiter thickness to 30 mm and simulated the puncture test by removing a circular portion of impact limiter foam, thus more readily exposing that portion of the package to the fire's thermal input. This is a conservative feature applied for the entire transient because the application noted the circular portion would be filled in by adjacent intumescent foam at some point during the fire. Section 3.2.1 of the application indicated the thermal conductance associated with the air gaps between the lead and the outer shell and between the impact limiters and the cask body was multiplied by a factor of 10 to increase the heat transfer from the fire to the cask components (i.e., the effect was to reduce the gap sizes). Similarly, section 3.2.1 of the application indicated the ceramic fiber paper's thermal conductivity was multiplied by a factor of 1.5 during the fire HAC, which would tend to reduce the thermal protection aspect of the insulation paper. To account for additional local puncture damage, the outer package's stainless-steel layer and ceramic paper within a 150 mm wide circular band around the entire package circumference was removed. This is a conservative assumption for the axisymmetric model because the actual damage would occur in the local puncture location, rather than a portion of the package's entire circumference.

The thermal calculation document (RT-200 NTE 3002, Rev. C) and section 3.4 of the application provided the HAC fire model conditions. Section 3.4.2 of the application stated that the model's initial temperature condition was based on the peak temperatures from the thermal analysis solution for NCT at 38°C ambient temperature with insolation (i.e., hot NCT). The HAC transient analysis consisted of modeling the convection and radiation heat transfer effects of the 30 minute 800°C fire followed by a seven-day cool-down period at 38°C ambient temperature with insolation. The thermal request for additional information (RAI) responses (ML24304A911) indicated that a radiative energy equation (e.g., Stefan-Boltzmann relation) was used during NCT, the 30-minute fire, and after the fire with varying surface emissivity values. For example, the response to RAI-Th-3 noted the emissivity and absorptivity of the package external surface was 0.8 during the 30-minute fire and multi-day cool-down period due to the potential presence of soot. A 10 W/m^2-K convection heat transfer coefficient was applied to the external package surface during the engulfing HAC fire, based on reference data in International Atomic Energy Agency (IAEA) Specific Safety Guide (SSG-26) "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material" (2018 edition).

The staff notes that the response to RAI-Th-3 included thermal parameters (e.g., emissivity, absorptivity) and results of an analysis that showed the temperature of the center of the outer cask surface during the NCT transient period of the package with 1200 W decay heat, the 30-minute fire, and the post-fire period. It was noted that both the emissivity and absorptivity of the surface during the post-fire period was set to a 0.8 value. The results showed similar cask surface temperature during NCT and after post-HAC fire cooldown, indicating that results were somewhat insensitive to surface condition. Although complete conditions were not explicitly provided, staff notes that the large temperature margin of the lead and O-ring from their allowable temperatures (e.g., margin of approximately 75°C for the O-ring) would indicate those important-to-safety components would function even if there were slight variations with surface condition values.

The staff reviewed the assumptions, boundary conditions, and parameters used for the HAC thermal analysis as well as the temperature margins of package components with allowable values. Based on the staff's review, the staff finds acceptable the applicant's HAC thermal evaluation, thus meeting the thermal requirements of 10 CFR 71.73.

3.5.2 Maximum Temperatures

The maximum temperatures of package components during the HAC fire transient were presented in section 3.4.3.1 of the application and the transient temperatures during the fire and cool-down phases were provided in figure 3.4-1 of the application, which showed peak temperatures occurring within approximately a few hours into the transient. The temperatures of critical components, such as for lead, lid O-ring, drain and vent port cover lid O-ring, and package cavity, were provided in section 3.4.3.1. It was noted that the lead temperature was much less than its 327°C melting point and the O-ring temperatures were well below the 150°C maximum allowable normal operation temperature.

3.5.3 Maximum Pressure

Section 3.4.3.2 of the application and pressure calculation document (RT-200 NTE 3003, Rev. C) indicated that the calculations for the pressure within the Model RT-200 package from the fire HAC considered the effects of higher internal package pressures of the sealed air within the package, water vapor pressure, and the hydrogen and oxygen gases generated by radiolysis. Section 3.4.3.2.1 of the application stated that the pressure calculations were based on a temperature greater than the reported HAC fire cask cavity temperature in section 3.4.3.1 of the application.

The HAC pressure increased in value from the NCT pressure due to the higher HAC temperature within the package and was calculated in section 3.4.3.2.2 of the application to be 145.8 kPa (absolute). Similarly, the pressure contribution from water vapor at 150°C was 475.8 kPa (absolute). Finally, the pressure contribution from the formation of hydrogen and oxygen due to the radiolysis of water was calculated as 50.4 kPa (absolute).

The sum of these individual pressure contributions resulted in a fire HAC package internal pressure of 672 kPa, which was conservatively approximated as 700 kPa (absolute) and used in structural and containment calculations. This was confirmed, for example, in section 2.7.4.3.2 of the application, which stated that 700 kPa (absolute) pressure was the boundary condition for structurally evaluating the package's containment boundary. Finally, the staff notes section 2.7.4.4 of the application stated that the margins of safety of the structural components were positive for the HAC fire accident.

3.5.4 Maximum Thermal Stresses

Section 3.4.4 of the application stated that the stresses produced by the HAC fire temperature gradients in the cask body were provided in section 2.7.4 of the application, which mentioned that thermal stresses resulting from differential thermal expansion between dissimilar materials were calculated from a two-dimensional model described in section 2.6.7.2 of the application. These loads were considered in the HAC load combinations provided in table 2.7-2 of the application. Section 2.7.4.4 of the application reported positive margins of safety when comparing a component's stress intensity and allowable stress (including bolts and inner shell boundary weld). Additional structural discussion is provided in chapter 2 of this SER.

3.6 Evaluation Findings

The staff reviewed the package description, material properties, component specifications, and the methods used in the thermal evaluation and has reasonable assurance that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71. The staff reviewed the accessible surface temperatures of the package as it will be prepared for shipment and has reasonable assurance that the temperatures satisfy 10 CFR 71.43(g) for packages transported by exclusive-use vehicle. The staff reviewed the package design, construction, and package preparations for shipment and has reasonable assurance that the package material and component temperatures will not extend beyond the specified allowable limits during NCT, consistent with the tests specified in 10 CFR 71.71. The staff also has reasonable assurance 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.

Based on review of the statements and representations in the application, the staff concludes that the thermal design has been adequately described and evaluated, and that the thermal performance of the Model RT-200 package meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

The objective of the containment review is to verify that the Model RT-200 package containment design is adequately described and satisfies the containment requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions to transport activated and irradiated metallic hardware as well as control rod blades, nuclear instrumentation, and other reactor hardware.

4.1 Description of the Containment System

The Model RT-200 package is designed and prepared for shipment to assure no loss or dispersal of contents as demonstrated to a sensitivity of 10^{-6} A_2 per hour under NCT, in compliance with 10 CFR 71.51(a)(1), and no escape of Krypton-85 exceeding 10 A_2 in one week and no escape of radioactive material exceeding a total of A_2 in one week under HAC, in compliance with 10 CFR 71.51(a)(2). The applicant stated, in section 2.3.1, “Fabrication,” of the application, that the Model RT-200 packaging is designed as a category II container, and the fabrication and procurement of the containment components is based on ASME B&PV code, Section III, Subsection NCD - Class 3.

The applicant stated, in section 2.4.3, “Positive Closure,” of the application, that the Model RT-200 does not rely on any valve or pressure relief device to meet the containment requirements. The quick disconnect valves on the vent and drain ports are protected by the cover plates which protect the valve from unauthorized operation and provide a sealed enclosure to retain any leakage from the device in accordance with 10 CFR 71.43(e).

The applicant presented classification of the containment system component, in section 1.3.3, “RT-200 Bill of Materials,” of the application according to importance to safety within transportation packaging and assigned the confinement system components as Category A due to critical to safe operation.

The staff referred to NUREG/CR-6407, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” and confirmed that the confinement system components are assigned as Category A because the failure of a containment component could cause loss of primary containment leading to release of radioactive material.

4.1.1 Containment Boundary

The applicant described in section 4.1.1, “Containment System,” of the application that the containment system of the package consists of the containment vessel (the inner shell, the rear forging plate, and the front forging flange), together with the cask lid, the vent and drain port cover plates, the associated inner elastomer O-ring seals installed on the cask lid, and vent and drain port cover plates, and the associated containment welds, as shown in figure 4.6-1 of the application.

4.1.2 Weld, Seals, and Closure

The applicant described the containment welds in section 4.1.3 “Welds and Seals,” of the application and tabulated the temperature performance of the elastomers for normal/continuous operation in table 4.6.3-1 of the application. The applicant stated, in section 4.1.3 of the application, that radiation resistance of the elastomer O-ring is up to 5×10^8 rads while retaining reasonable flexibility and strength, hardness, and very good compression set resistance.

The applicant stated, in section 4.1.4, “Closure,” of the application, that the lid is attached to the cask body by the bolts, with two elastomer O-rings retained in machined grooves at the lid perimeter. The groove dimensions prevent over-compression of the O-rings by the closure bolt preload forces and hypothetical accident impact forces. The applicant provided the main characteristics of the O-ring grooves in table 4.1.4-1 of the application.

The staff finds that the description of the containment system, described in section 4.1, “Description of the Containment System,” of the application, is consistent with the details shown in the license drawings provided in section 1.3.4, “RT-200 Design Drawings,” of the application.

The staff also accepts the description of the containment penetration, welds, seals, and closure for the Model RT-200 package.

4.2 Containment Under Normal Conditions of Transport (NCT)

The applicant stated, in section 4.2, "Containment Under Normal Conditions of Transport," of the application, that (1) the package cavity maximum pressure is below the maximum normal operating pressure (MNOP) of 200 kPa (absolute), as shown in table 3.1-3 of the application and (2) the maximum temperatures of the containment boundary components, including lid, inner shell, and O-ring seals at lid, vent port and drain port, do not exceed the corresponding NCT limits, as shown in table 3.1-1 of the application.

The staff reviewed the NCT thermal evaluation described in section 3.3 of the application and confirmed that the maximum temperatures of the package containment boundary components are below their allowable limits and the maximum package cavity pressure is below the MNOP of 200 kPa (absolute) for effectiveness of the containment system under NCT, in compliance with 10 CFR 71.71 and 71.51(a)(1).

4.3 Containment Under Hypothetical Accident Conditions (HAC)

The applicant stated, in section 4.3, "Containment Under Hypothetical Accident Conditions," of the application, that (1) the package maximum HAC pressure, shown in section 3.4.3 of the application, is below the bounding pressure of 700 kPa (absolute), as shown in table 3.1-3 of the application, and (2) the maximum temperatures of the containment boundary components, including lid, inner shell and O-ring seals at lid, vent port and drain port, do not exceed the corresponding limits under HAC, as shown in table 3.1-2 of the application.

The staff referred to the thermal and structural evaluations described in the application and confirmed that the maximum temperatures of the package containment boundary components are below their allowable limits and the maximum package cavity pressure is below the design pressure of 700 kPa (absolute) for effectiveness of the containment system under HAC, in compliance with 10 CFR 71.71 and 71.51(a)(2).

4.4 Leakage Rate Tests

The applicant stated, in chapter 4, "Containment," of the application that (1) Model RT-200 package is designed to be a leak tight containment, per ANSI N14.5-2022, under NCT and HAC and therefore the leakage rate criterion is 1×10^{-7} ref-cm^3/sec for NCT and HAC, and (2) the package is tested to a sensitivity of at least 1.0×10^{-3} ref-cm^3/sec for the pre-shipment leakage rate test and a leak-tight criterion of 1×10^{-7} ref-cm^3/sec for fabrication, maintenance, and periodic leakage rate tests, in accordance with ANSI N14.5. The applicant described the leakage tests of the Model RT-200 package in table 4.4-1 of the application.

The applicant stated, in section 4.4, "Leakage Rate Tests for Type B Packages," of the application that (1) the fabrication, maintenance, and periodic leakage tests may be performed using helium as the test gas, with acceptance criterion of the equivalent reference leakage rate for helium gas and (2) the pre-shipment leakage tests may be performed using air as the test gas, with acceptance criterion of the equivalent reference leakage rate for air. The applicant presented the procedures for determining the equivalent reference leakage rates for helium gas and air in section 4.4 of the application.

The staff confirmed that (1) Model RT-200 package is designed and tested to meet leak tight containment criterion for fabrication, periodic and maintenance leakage rate tests and that there will be no leakage at a sensitivity of less than $1x10^{-3}$ ref-cm^3/sec, and (2) that the calculation for determining the equivalent reference leakage rates for helium and air is acceptable in accordance with ANSI N14.5.

4.5 Hydrogen Gas Generation

The applicant stated, in section 4.5, “Hydrogen Gas Generation,” of the application, that the residual water from wet loading may accumulate in the containment vessel and generate hydrogen by radiolysis and is limited to be less than 5 vol% hydrogen concentration, in accordance with the criterion defined in NUREG-2216. The applicant referred to NUREG/CR-6673, “Hydrogen Generation in TRU Waste Transportation Packages,” (ML003723404) for hydrogen gas generation by radiolysis.

The applicant discussed the effective G values (G_{H2}) and the shipping period, in section 4.5 of the application, for hydrogen gas generation. The applicant presented examples of hydrogen gas generation calculation in section 4.6.6 of the application: (a) Realistic calculation assuming alpha decay energy fraction of 0.01 (G_{H2} = 1.6) and beta/gamma decay energy fraction of 0.99 (G_{H2} = 0.45), and (b) bounding calculation assuming alpha decay energy fraction of 1.0 (G_{H2} = 1.6).

According to NUREG/CR-6673, in many instances detailed information concerning the radionuclides and their concentrations in a waste material may be unavailable, and determination of separate decay fractions (alpha, beta, gamma) may not be possible. For most waste types and waste configurations, a conservative approach is to assume alpha decay energy fraction of 1.0 (G_{H2} = 1.6). Therefore, in a Model RT-200 package shipment with separate decay fractions undetermined, the users need to evaluate maximum allowable shipping time based on alpha decay energy fraction of 1.0 (G_{H2} = 1.6) to increase safety margin.

The staff confirmed that the applicant’s bounding calculations using alpha decay energy of 1.0 (G_{H2} = 1.6) to evaluate the gas generation by radiolysis and the required shipping period are consistent with the analytical methodologies and the general guidelines described in NUREG/CR-6673. This will limit the hydrogen generation to less than 5 vol% in the package throughout the shipment, in accordance with NUREG-2216 and in compliance with 10 CFR 71.43(d).

4.6 Evaluation of Findings

Based on the review of this application, the staff concludes with findings:

F4-1 The package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71, the package satisfies the containment requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1) for NCT.

F4-2 The package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.73, the package satisfies the containment requirements of 10 CFR 71.51(a)(2) for HAC.

F4-3 The package is designed to be leak tight under NCT and HAC. This degree of containment is achieved by demonstration of a leakage rate less than or equal to 1×10^{-7} ref-cm^3/s of air.

F4-4 The package does not rely on any valve or pressure relief device to meet the containment requirements. The quick disconnect valves on the vent and drain ports are protected by the cover plates which protect the valve from unauthorized operation and provide a sealed enclosure to retain any leakage from the device in accordance with 10 CFR 71.43(e).

F4-5 Hydrogen and other flammable gases should make up less than 5 percent by volume (5 vol%) of the total gas inventory, or lower if warranted by the flammable gas, within any confined volume of the package, consistent with the requirements of NUREG-2216 and NUREG/CR-6673, and in compliance with 10 CFR 71.43(d).

Based on review of the statements and representations in the application, the staff concludes that the package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71.

5.0 SHIELDING EVALUATION

The objective of this evaluation is to verify that the design of the Model RT-200 package meets the external radiation requirements of 10 CFR Part 71.

5.1 Description of Shielding Design

5.1.1 Shielding Design Features

The Model RT-200 package is a right circular cylinder whose inner cavity and overall dimensions are listed in table 1.3-2 of the application. The gamma shielding of the Model RT-200 cask is composed of thicknesses of stainless-steel and lead as detailed in table 1.3-3 of the application. In particular, the shielding design covers the inner shell, the outer shell, the lead between the inner and outer shell, the thermal shield plate, the rear forging, and the lid. Under transport conditions, the top and bottom impact limiters provide additional gamma shielding after the inner steel casing. The shielding evaluations assume that the Model RT-200 is transported on a truck trailer that is 2,430 mm wide and whose length enables it to be tied down, in the center of the package, further than 2 meters from the end of the package.

According to the applicant, for Content No. 1, the dedicated basket shores the disposable insert in place and prevents it from shifting during transportation.

5.1.2 Summary Tables of Maximum External Radiation Levels

The limiting external radiation levels for Content No. 1 are shown in table 5.1-1 of the application. The cask operator must follow the procedures outlined in chapter 7, “Package Operations,” of the application to ensure these limits are respected.

The calculated results for the maximum radiation levels for Content No. 2 are shown in table 5.1-2 of the application. This package is allowed for exclusive use of shipment using an open (flat-bed) transport vehicle under NCT and HAC for the worst-case loading of radionuclides. These results represent the maximum dose rates for the worst-case allowable for contents as presented in section 5.4.4 of the application.

5.2 Source Specifications

5.2.1 Gamma Source

Content No. 1 of the Model RT-200 cask consists of 3 storage containers (SCs), described in section 1.2.2.1 of the application. The maximum total activity of Content No. 1 (including 3 SCs) is limited to 30,000 Ci (1.11×10^{15} Bq) and 3,000 A_2. The principal gamma emitter nuclide within the SC's content is Co-60. Co-60 overwhelmingly participates in the maximum radiation levels around a SC with a contribution greater than 99%. The quantity of radioactive material within the Model RT-200 for Content No. 1 is limited by the maximum amount of radioactive material that corresponds to the external radiation standards as defined in 10 CFR 71.47. The cask operator must follow the procedures outlined in chapter 7 of the application to ensure personnel safety and regulatory compliance.

Content No. 2 of the Model RT-200 cask consists of miscellaneous solid irradiated and contaminated non-fuel-bearing hardware in secondary containers as described in section 1.2.2.2 of the application, with a Co-60 equivalent specific activity ≤ 0.37 TBq/kg (≈ 10 Ci/kg) and a maximum payload of 8,400 kg, that is essentially uniformly distributed. The maximum total activity is limited to 30,000 Ci (1.11×10^{15} Bq) and 3,000 A_2. The applicant states that the specific activity shall ensure that the most activated portion of any single waste item is less than the specific activity limit (specific activity ≤ 0.37 TBq/kg (≈ 10 Ci/kg)). According to the applicant, for better attenuation properties of the source material and packaging components, the source material needs to be either stainless-steel or a material that provides equivalent or superior gamma shielding than stainless-steel.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The applicant performed shielding analyses using the MCNP computer code. The applicant modeled the package under NCT and HAC conditions, as prescribed in 10 CFR 71.71 and 71.73 respectively.

The quantity of radioactive material within the Model RT-200 for Content No. 1 is limited by the maximum amount of radioactive material that corresponds to the external radiation standards as defined in 10 CFR 71.47. The cask operator must follow the procedures outlined in chapter 7 of the application to ensure compliance with these limits.

A MCNP model was developed to represent Content No. 2 in a right circular cylinder of stainless-steel. The associated source term consists of Co-60.

Both shielding models, NCT and HAC, considered the photon source uniformly distributed throughout the inner cavity.

For the NCT model, the applicant states that adjustments and simplifications were made according to the main assumptions and to the main principles. The main adjustments and simplifications that are considered for the MCNP® model are described in section 5.3.1.2 of the application.

For HAC model, the applicant states that puncture test cannot result in a decrease of the thicknesses of the package shielding layers since:

- Impact limiter contribution is neglected; their potential damages do not affect the NCT findings in terms of dose rates level; outer shell of the packaging body is not perforated;

and its potential local bump (see section 2.7.3.2.3 of the application) does not affect the NCT findings in terms of dose rates level.

- For the same reason, the impact limiter damage that would result from either the HAC fire test or the 9 m drop test does not affect the NCT findings in terms of dose rate levels.
- A 9-meter axial drop test on the rear end of the package could result in an axial slump in the lead shielding layer of the body. In such a case, an annular gap would be generated under the front or rear forging of the package body and is modeled in the HAC model.

The staff examined the sketches in the application to evaluate the applicant's shielding models. The staff also verified that the dimensions and materials properties of the contents, radioactive sources in the contents, and the packaging components used in the shielding models were consistent with those specified in the package drawings and contents descriptions presented in the "General Information" section of the application.

5.3.2 Material Properties

The standard material compositions used within the MCNP model are listed in table 5.5-4 in the appendix 5.5.7 of the application. These compositions are used for all materials within the model, but as detailed below, densities are adjusted. The MCNP model of the Model RT-200 cask relies on the nominal geometry according to drawing data. The effect of potential tolerances on the part dimensions is considered to reduce their material densities. In appendix 5.5.7, table 5.5-5 of the application sums up this information and figure 5.5-7 illustrates it.

5.4 Shielding Evaluation

5.4.1 Methods

The staff evaluated the use of the MCNP6.2 to perform the shielding evaluation of the Model RT-200. According to the applicant, the MCNP code used the ENDF/B-VI Release 8 Photo-atomic Data gamma cross-section library, and MCPLIB84 in the transport computations. The staff found it acceptable to use the MCNP code since MCNP is a Monte Carlo transport code that offers a full three-dimensional combinatorial geometry modeling capability. This type of modeling means that no gross approximations are required to represent the Model RT-200 cask in the shielding analysis.

5.4.2 Code Input and Output Data

The MCNP code calculates a photon flux (particles/s/cm^2) at a particular tally or detector location given the source magnitude. These values are converted into doses by use of flux-to-dose (Flux-to-dose conversion factors from ANSI/ANS 6.1.1, 1977 version) response functions. This conversion is done internally in the MCNP code by associating dose response functions to each tally in the input file. The gamma flux-to-dose and neutron flux-to-dose response functions used in these calculations are listed, respectively, in table 5.5-2 and table 5.5-3 of the application.

5.4.3 External Radiation Levels

The applicant uses tally types 2 and 4 within MCNP to calculate the dose rates.

For Content No. 2, the applicant performed calculations by normalizing the source. To find a suitable dose rate limitation on Content No. 2, a 5% error due to uncertainties was taken.

For Content No. 1, the applicant limited the maximum dose rates around the Model RT-200 by the maximum external radiation standards as defined in 10 CFR 71.47 and summarized in table 5.1-1.

For HAC, the applicant demonstrated that if the dose rates do not exceed the regulatory limits for NCT, the regulatory limit for HAC will not be exceeded. This analysis was based on Content No. 2 shielding evaluation.

In terms of neutrons and secondary gammas, the NCT results are shown in table 5.4-2 and table 5.4-3 of the application.

The staff found the neutron limit for incidental radionuclide contamination that generates neutrons acceptable.

For the shielding evaluation uncertainties, the staff found that to obtain accurate results from the shielding analysis of transport casks are important to ensure that loading limits yield doses that do not exceed the regulatory limits for external radiation levels.

For the lead slump, calculations were performed for each of the free drop configurations. A 9-meter axial drop test on the rear end of the package could result in an axial slump in the lead shielding layer of the body. The numerical analyses show provides a maximum lead slump in the HAC End Drop case. The latter value is considerably inferior to the value considered in the shielding analyses in chapter 5 of the application.

5.5 Evaluation Findings

The staff reviewed the description of the package design features related to shielding and the source terms, and the method and instructions for determining the contents. The staff also reviewed the shielding analyses, the assumptions and approximations used in the analyses as presented in the shielding safety analysis, the results of the analysis as presented in the application, and the maximum dose rates for NCT and HAC to determine that the reported values were below the regulatory limits in 10 CFR 71.47 and 71.51 for an exclusive use package.

Based on the review of the statements and representations provided in the application, the staff has reasonable assurance that the shielding evaluation is consistent with the appropriate codes and standards for shielding analyses and NRC guidance, and that the shielding design of the Model RT-200 package, with the content’s limits as determined from the instructions for determining allowable content, meets the regulatory requirements of 10 CFR Part 71 with the following conditions: (1) There shall be no neutron emitting nuclides, except for trace amounts of fissile materials in excess of quantities exempted from classification as fissile material per 10 CFR 71.15; (2) The weight of water must be excluded when determining the Ci/g of content limits; and (3) For Content No. 1 only, the source distribution must not shift during NCT.

6.0 CRITICALITY EVALUATION

The Model RT-200 package is not designed to transport fissile materials subject to the requirements of 10 CFR 71.55 or 71.59. No criticality safety evaluation is necessary.

7.0 MATERIALS EVALUATION

The staff evaluated the materials performance of the Model RT-200 package to ensure it meets the requirements of 10 CFR Part 71. The Model RT-200 cask is designed to transport solid irradiated and contaminated non-fuel-bearing materials and hardware. The contents of the Model RT-200 cask are limited such that it is identified as a Category II package IAW with Table 1 of Regulatory Guide 7.11.

7.1 Materials of Construction

As described in section 1.2.1.1 of the application and the license drawings, the Model RT-200 cask is comprised of a cylindrical cask body, front forging, bottom forging, vent and drain port cover plate assemblies, lid assembly, and front and rear cylindrical impact limiters.

The cask body is comprised of a stainless-steel inner and outer shell with lead shielding in between the two shells. The outer shell is covered by a ceramic fiber paper insulation layer that is encased by a stainless-steel cover and four welded stainless-steel tie-down trunnions.

The front forging and bottom forging are fabricated from stainless-steel, and each contains a port for venting and draining respectively. The front forging also contains two stainless-steel lifting trunnions, and they are attached with thirteen (13) stainless-steel M42 bolts.

The vent and drain cover plate assemblies are each comprised of a stainless-steel cover plate, internal EPDM O-ring, external EPDM O-ring, leak test port assembly, and six (6) stainless-steel M16 bolts. The leak test port assembly is comprised of a stainless-steel control plug and an EPDM O-ring.

The lid assembly is comprised of a stainless-steel lid, internal EPDM O-ring, external EPDM O-ring, leak test port assembly, and thirty (30) stainless-steel M42 bolts. The leak test port assembly is comprised of a stainless-steel control plug and EPDM O-ring.

The front and rear impact limiters are comprised of stainless-steel casings filled with foam. The impact limiters are attached to each end of the cask with eight (8) stainless-steel M42 bolts, secured in pairs with four (4) stainless-steel bolt securing plates and four (4) stainless-steel M16 securing plate bolts. An EPDM strip is placed on this bolting surface and is secured via four (4) M6 bolts. The impact limiter foam is a polyurethane foam.

The impact limiters are lifted by a stainless-steel belt and two (2) stainless-steel lifting ears. The belt is attached to each impact limiter via two (2) stainless-steel belt guides and one (1) stainless-steel M20 bolt. The belt guides are each attached by two (2) stainless-steel M16 shoulder bolts.

Each impact limiter has 2 stainless-steel feet attached via eight (8) stainless-steel M16 bolts.

Each impact limiter is equipped with a polyethylene fusible plug to vent gases from impact limiter decomposition during the hypothetical fire accident.

Content No. 1 makes use of a stainless-steel disposable insert and stainless-steel basket.

Per the above discussion, the staff finds that the applicant's description of the materials of construction is acceptable.

7.2 Drawings

The applicant provided drawings in Appendix 1.3 of the application to incorporate the Model RT-200 cask. The drawings include a parts list that provides the materials of construction and codes/standards for each. Welds are identified on separate drawings in section 1.3.7 of the application. The staff notes that the level of detail in the drawings is consistent with the guidance in NUREG-2216. The staff reviewed the drawing contents with respect to the guidance in NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approvals," (ML20248L098) and confirmed that the drawings provide an adequate description of the materials, fabrication, and examination requirements, and, therefore, the staff finds them acceptable.

7.3 Codes and Standards

As described in sections 2.1.4, 2.3.1, and 2.3.2 of the application, the transportation containment system is designed, fabricated, and examined in accordance with American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, Subsection NCD. The staff notes that this cited standard is consistent with NRC guidance in section 7.4.2.2 of NUREG-2216 and table 1.1 of NUREG/CR-3854, for containment components of Category II shipping containers.

As described in sections 2.1.4, 2.3.1, and 2.3.2 of the application, other systems (non-containment) are designed, fabricated, and examined in accordance with ASME B&PV Code, Section III, Subsection NF. The staff notes this cited standard is consistent with NRC guidance in section 7.4.2.2 of NUREG-2216 and table 1.1 of NUREG/CR-3854 for other safety components of Category II shipping containers.

Per the above discussion, the staff determined that the description of the codes and standards applicable to the transportation package provided by the applicant is acceptable.

7.4 Weld Design and Inspection

As described in section 8.1.2 of the application, the Model RT-200 containment welds are performed in accordance with ASME B&PV Code, Section III, Subsection NCD. The staff notes this cited code is consistent with NRC guidance in section 7.4.3 of NUREG-2216 and table 1 of NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials," for containment-related welds of Category II shipping containers.

The applicant also stated that the containment welds meet the examination criteria of ASME Code, Section III, Subsection NCD, Article NCD-5000. The staff notes this cited code is consistent with the guidance in table 2 of NUREG/CR-3019 for containment-related welds of Category II shipping containers.

As described in section 8.1.2 of the application, the Model RT-200 non-containment safety related welds are performed in accordance with ASME B&PV Code, Section III, Subsection NF. The staff notes this cited code is consistent with NRC guidance in section 7.4.3 of NUREG-2216 and table 1 of NUREG/CR-3019, “Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials,” for other safety-related welds of Category II shipping containers.

The applicant also states that non-destructive examinations are performed in accordance with the applicable ASME standard and are performed by ASNT (The American Society for Nondestructive Testing) qualified inspectors.

Per the above discussion, the staff finds the welding criteria acceptable.

7.5 Mechanical Properties

The applicant provided a description of the mechanical properties of the packaging materials in section 2.2 of the application, which includes the yield strength, ultimate strength, design stress intensity, modulus of elasticity, density, and Poisson’s ratio as specified by the ASME BPV Code, Section II, Part D for certain materials. Table 2.12-1 contains temperature-dependent material properties for cask materials and tables 2.12-2 temperature-independent material properties for cask materials.

For ASME BPV Code materials, the applicant cited the material property values included in the ASME BPV Code, Section II, Part D and provided properties as a function of temperature. For ASTM or other non-ASME materials, the applicant provided supplemental information describing the testing methods and results used to determine the mechanical properties of the materials as a function of temperature. The staff reviewed these codes and standards, data, and other technical references to verify material mechanical properties.

The staff notes that the fracture toughness testing of ASME B&PV Code, Section III, NCD-2300 is not required for this transportation package due to its containment vessel being fabricated from austenitic stainless-steel. This is consistent with the guidance in NUREG-2216, section 7.4.4.2.

As described in section 2.2.1 of the application, the applicant states that all force-deformation properties for foam are based on appropriate test conditions and temperatures. Bounding curves for the foam’s mechanical behavior are obtained by qualifying the foam using test parameters in accordance with the manufacturers design guide. The applicant provided foam densities in table 9 and minimum and maximum crush strengths in table 10 of RT-200 NTE 2001, “RT-200 Type B Cask – Technical Note, Material Mechanical Properties.” As described in section 8.1.5.1 of the application, the foam density and crush strength will be verified by independent testing to verify if the material property values provided in the Technical Note are met. Any foam that fails testing will be discarded and repoured. The staff notes that this foam was previously approved for use in the Model RT-100 package (Non-Proprietary Version RT-100 Type B Cask Safety Analysis Report, Revision 8, August 29, 2022, ML22262A267) and which underwent a 3/10 scale confirmatory drop test.

The staff reviewed the applicant's thermal analysis in chapter 3 of the application and determined that the temperature ranges for the mechanical properties provided by the applicant bound the range of the packaging component temperatures for the NCT and HAC conditions.

Per the above discussion, the staff finds the mechanical properties used in the applicant’s structural analysis acceptable.

7.6 Thermal Properties

As described in section 3.2.1 of the application and RT-200 NTE 3001, “RT-200 Type B Cask – Technical Note, Material Thermal Properties,” Rev. C (Proprietary), the applicant provided thermal properties of the materials including density, thermal conductivity, thermal diffusivity, specific heat, and thermal expansion coefficients. The applicant provided values of the thermal properties as a function of temperature obtained from the ASME BPV Code Section II Part D. The applicant provided thermal properties as a function of temperature for the lead from several technical references. The applicant provided thermal properties as a function of temperature for the ceramic paper from the manufacturer’s data sheet. The applicant provided temperature independent thermal properties for the foam impact limiter material from the manufactures design guide and data sheets. The staff reviewed these codes, standards, and technical references to verify the provided material thermal properties. The staff determined that the applicant appropriately identified the materials and components important to heat transfer and provided appropriate material compositions and thermal properties over the ranges of temperatures experienced during NCT and HAC in accordance with section 7.4.5 of NUREG-2216.

Per the above discussion, the staff finds the thermal properties used in the applicant’s thermal analysis acceptable.

7.7 Radiation Shielding

As described in section 1.2.1.4 of the application, gamma radiation shielding for the Model RT-200 cask is provided primarily by the lead between the inner and outer shell of the cask, and secondarily by the stainless-steel of the inner shell, outer shell, front forging, rear forging, and the lid of the cask. Some level of shielding is provided via the thermal shield and impact limiter structures.

Geometries of the shielding materials are described in section 5.3.1.2 of the application and the drawings in appendix 1.3 of the application. Thicknesses for these lead and stainless-steel components are provided in table 1.3-3 of the application. Dimensional tolerances are provided in sections 5.3.1 of the application. Material compositions and densities are provided in appendix 5.5.7 of the application.

Section 8.1.6 of the application describes the acceptance testing of the lead shielding. Ultrasonic testing is performed, in accordance with NUREG/CR-3854, to verify the lead satisfies its minimum thickness and has no significant voids or streaming paths. Ultrasonic testing in accordance with NUREG/CR-3854 is consistent with the guidance in section 7.6.4 of NUREG-2216.

As described in section 1.2.1.4 of the application, the Model RT-200 does not carry fissile material or neutron sources, and therefore, does not incorporate neutron shielding materials.

Per the above discussion, the staff finds the radiation shielding materials acceptable.

7.8 Criticality Control

The Model RT-200 does not carry fissile materials and therefore, does not require criticality control materials.

7.9 Corrosive Resistance

As described in section 1.2.1.1 and section 2.2.2.1.1 of the application, the Model RT-200 cask is fabricated of stainless-steel and is resistant to general corrosion. To prevent localized corrosion, external surfaces receive a finishing process, to reduce ridges and crevices, and external surfaces are passivated. As described in section 2.2.2.1.1 of the application, there is no galvanic corrosion between the stainless-steels and nickel alloy steels due to lack of electrochemical potential difference. The staff reviewed the applicant’s determination of corrosion resistance and found it consistent with the guidance in section 7.4.8 of NUREG-2216.

Based on the above discussion, the staff finds that the applicant’s identification of materials and package components where corrosion should be considered, and assessment of the effects of corrosion are acceptable.

7.10 Protective Coatings

As described in section 2.2.2.1.1 of the application, no coatings are applied to the stainless-steels or nickel alloy steels used in the Model RT-200 cask. The staff reviewed the application and licensed drawings and verified that the applicant does not credit any protective coatings in its safety analysis.

7.11 Content Reactions

As described in section 2.2.2.1 of the application, the Model RT-200 cask materials are not reactive with themselves, the contents, or the expected operating environments. No gases or corrosion byproducts are generated. No reactions are expected between the stainless-steel and nickel alloy cask components. Additionally, no reactions occur between the stainless-steel and silicone products, fluorocarbon elastomers, dry film lubricants, blended polytetrafluoroethylene, or ethylene glycol. The lead shielding material, polymer foam impact limiting material, and fiber ceramic paper thermal insulation material are enclosed in stainless-steel shells and there are no potential reactions between these materials and their stainless-steel shells. The material used for seals is made of ethylene propylene diene monomer (EPDM), which is a synthetic rubber and has a stable and non-reactive composition. No potential reactions exist with the EPDM seals.

As described in sections 1.2.2.1.6, 1.2.2.2.6, and 7.5 of the application, the Model RT-200 cask can be loaded underwater, allowing for possible generation of hydrogen and oxygen due to radiolysis of residual water. Since other hydrogenous materials are not allowable cask contents, gas generation is solely from the aforementioned radiolysis.

As described in section 4.5.3 of the application, hydrogen gas generation is calculated using acceptable methods in accordance with the requirements of NUREG/CR-6673. To ensure potentially flammable or explosive conditions will not exist, section 7.5 limits the maximum allowable decay heat and maximum allowable shipping time such that resulting shipping time is limited to half the time required to reach 5% hydrogen generation. The staff notes that these measures for detecting and the presence of hydrogen and preventing its ignition are consistent with the guidance in section 7.4.10.1 of NUREG-2216.

Based on the above discussion, the staff finds that the applicant’s assessment of no content reactions or potentially flammable/explosive conditions is acceptable.

7.12 Radiation Effects

As described in sections 1.2.1.4 and 2.2.3 of the application, the Model RT-200 does not carry fissile material or neutron sources, and therefore, the metals of the cask are only exposed to gamma radiation. Gamma radiation has no significant effect on these metals and no appreciable damage occurs to the stainless-steel and lead cask materials. The staff notes that this is consistent with the guidance in section 7.4.11 of NUREG 2216, which states that metals and alloys are generally resistant to gamma radiation. The ceramic materials that comprise the thermal shield are likewise not significantly affected by gamma radiation and no radiation damage is expected. For the EPDM seals, the potential radiation dose received prior to seal replacement is far below the $5x10^8$ rad limit for which the EPDM material retains good flexibility, strength, hardness and compression, per the laboratory data references provided in the application.

Per the above discussion, the staff finds that the applicant has appropriately considered damaging effects of radiation and provides for replacement of components susceptible to radiation damage before degradation of component performance.

7.13 Package Contents

As described in section 1.2.2 of the application, the authorized contents for the Model RT-200 cask are separated into two content types, Content No. 1 and Content No. 2.

As described in section 1.2.2.1 of the application, Content No. 1 are irradiated and/or contaminated metal hardware. This metal hardware is predominately fabricated from stainless-steel, Stellite®, or Inconel®. Residual water may be present due to underwater loading. The maximum activity is 30,000 Ci and 3000 A_2 with cobalt-60 being the primary nuclide of concern for gamma radiation. Content No. 1 has a maximum allowable fissile material quantity of 15 grams and therefore is exempt from classification as fissile material as long as the package has 200 grams of solid nonfissile material. Additional information about Content No. 1 in relation to 10 CFR 71.33(b) can be found in table 1.2-3 of the application.

Content No.1 can be loaded into a maximum of 3 storage containers, which are placed into a disposable insert. Each storage container can additionally hold one Stellite® box at the bottom of the storage container. The disposable insert is placed into a basket to provide adequate shoring of the contents during NCT and HAC.

As described in section 1.2.2.2 of the application, Content No. 2 are irradiated and/or contaminated non-fuel bearing solid hardware. This content hardware is limited to metals or metal oxides in solid form. Residual water may be present due to underwater loading. The maximum activity is 30,000 Ci and 3000 A_2 with local specific activity limited to 10 Ci/kg equivalent cobalt-60. Content No. 2 has a maximum allowable fissile quantity up to the limits of 10 CFR 71.15 such that the contents are exempt from classification as fissile material. Additional information about Content No. 2 in relation to 10 CFR 71.33(b) can be found in table 1.2-5 of the application.

Content No. 2 may be loaded into secondary containers or provided with additional shoring as necessary to prevent shifting during NCT and HAC.

The staff reviewed the applicant's description of the chemical and physical form of the package contents and found it consistent with the guidance in section 7.4.12 of NUREG-2216. Based on the above discussion, the staff finds the description of the package contents acceptable.

7.14 Bolting Material

The closure lid is secured by thirty (30) M42 fixation bolts fabricated from SA-453 Gr 660 stainless-steel. Each impact limiter is secured with eight (8) M42 bolts fabricated from SA-453 Gr 660 stainless-steel. Each vent and drain port cover plate is secured by six (6) M16 assembly bolts fabricated from SA-453 Gr 660 stainless-steel. Each lifting trunnion is secured by thirteen (13) M42 fixation bolts fabricated from SA-453 Gr 660 stainless-steel. The applicant provided material property values for the bolting material from ASME BPV Code, Section II, Part D and provided properties as a function of temperature. The staff reviewed these codes and standards to verify the material mechanical properties.

As described in section 7.5 of this SER, fracture toughness testing of ASME B&PV Code, Section III, NCD-2300 is not required for the austenitic stainless-steel used in the bolting material.

The applicant provided thermal properties for the bolting material and materials being bolted together from ASME BPV Code, Section II, Part D. The staff reviewed these codes and standards and verified similar thermal expansion coefficients for the bolting material and materials being bolted. The staff finds the similarity of coefficients of thermal expansion for interfacing materials in these connections acceptable, as materials with similar coefficients will not generate additional stresses on the connection through differential thermal expansion.

As described in section 7.9 of this SER, stainless-steels are resistant to general corrosion. Galvanic corrosion is not a concern for the bolts and bolted material due to lack of electrochemical potential difference. As described in section 7.12 of this SER, gamma radiation has no significant effect on stainless-steel and no appreciable damage occurs. Further, periodic inspections of the bolts are described in section 8.2.3.1 of the application as part of the maintenance program, which will allow for identification of damage or degradation and allow for rework or replacement prior to use. Based on the above discussions, the staff considers that the applicant has assessed the effects of corrosion, chemical reactions, and radiation effects on the bolting materials.

Per the above discussion, that staff finds the applicant’s bolting material to be acceptable.

7.15 Seals

As described in sections 2.2.1 and 2.2.2.1.8 of the application, all containment boundary seals, namely the lid, vent port, and drain port, utilize elastomer O-rings. These O-ring seals are fabricated from EPDM, which the applicant states possess excellent short-term sealing, stable composition, and has no potential reactions with cask materials, contents, or expected operating environments. The applicant notes that no significant degradation results from long-term exposure to gamma radiation from the potential dose from this package, which is far below that $5x10^8$ rads level where EPDM maintains reasonable flexibility, strength, hardness, and compression set. As described in section 8.2.3 of the application, the Model RT-200 seals undergo routine inspection and are replaced on 12-month intervals.

Pressure test ports are provided in between the two O-rings for the lid and vent/drain ports to allow for leak testing in accordance with ANSI N14.5.

The applicant provided material properties in appendix 4.6.3 of the application from manufacture data sheets, to include minimum and maximum operating temperatures, tensile strength, elongation, heat resistance, cold temperature resistance, and compression set. The staff reviewed the specified material properties and applicant's thermal analysis in chapter 3 of the application and determined that these properties are adequate for the range of temperatures and operating environments for NCT and HAC.

Based on the above discussion, the staff finds the applicant's sealing material acceptable.

7.16 Evaluation Findings

Based on the review of this application, the staff concludes with findings:

F7-1 The applicant has met the requirements of 10 CFR 71.33. The applicant described the materials used in the transportation package in sufficient details to support the staff's evaluation.

F7-2 The applicant has met the requirements of 10 CFR 71.31(c). The applicant identified the applicable codes and standards for the design, fabrication, testing, and maintenance of the package and, in the absence of codes and standards, has adequately described controls for material qualification and fabrication.

F7-3 The applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a). The applicant demonstrated effective materials performance of packaging components under normal conditions of transport and hypothetical accident conditions.

F7-4 The applicant has met the requirements of 10 CFR 71.43(d). The applicant has demonstrated that there will be no significant corrosion, chemical reactions, or radiation effects that could impair the effectiveness of the packaging.

F7-5 The applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51 (a)(1). The applicant has demonstrated that the package will be designed and constructed such that the analyzed geometric form of its contents will not be substantially altered, no loss or dispersal of the contents, and no substantial reduction in the effectiveness of the packaging under the tests for normal conditions of transport.

The staff concludes that the Model RT-200 packaging adequately considers material properties and material quality controls such that the design is in compliance with 10 CFR Part 71. This finding is reached on the basis of a review that considered the regulatory requirements, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

8.0 OPERATING PROCEDURES EVALUATION

The objective of the staff's review of the package operations is to verify that the Model RT-200 package operational controls and procedures present acceptable operating sequences, guidance, and generic procedures to ensure that the package is operated in a safe and reliable manner under NCT and HAC pursuant to the provisions of 10 CFR Part 71. The operations covered in chapter 7 of the application includes: (1) the preparation for loading a packaging, (2) the loading of the contents, (3) the preparation for shipment of a package, (4) the package unloading, and (5) the preparation for shipment of an empty packaging.

The information provided in chapter 7 of the application forms the basis of the staff conclusions in this section of the safety evaluation report.

8.1 Package Loading and Handling

The Model RT-200 application presents the generic cask loading procedures. Detail cask loading procedures must be developed by each user. Based on the information in chapter 7 of the application, as discussed below, the staff concludes that the general cask loading procedures provide an adequate basis for the development of the more detailed site-specific operations and test procedures. In addition, the staff concludes that the Model RT-200 package is compatible with wet or dry loading. The staff also concludes that the cask loading procedures presented in the application are in the proper sequence and are of sufficient detail that cask users will be able to develop detailed site-specific procedures that adequately protect the workers, public, and the environment and will protect the contents from significant damage or degradation.

8.1.1 Preparation for Loading

In section 7.1.1 of the application, the applicant describes the prerequisites required to be completed prior to loading operations. The applicant specifies that the user should consult the guidance specified in appendix 7.6.1 of the application to ensure the contents meet the CoC when shipping Content No. 1. The applicant also describes the conditions for safe handling of the Model RT-200. The applicant specified that the cask is designed to meet critical loading requirements in accordance with ANSI N14.6-1963 when lifted from the two bolted lifting trunnions at the top of the cask.

In SAR section 7.1 of the application, the applicant describes loading-related preparations, package loading sequences and inspections of the package, such as those performed to ensure the package is not damaged and that radiation and surface contamination levels are within allowable regulatory limits.

The applicant developed operating procedures for loading and unloading operations for the Model RT-200 for two different shipping configurations. Configuration No. 1 for shipment of Content No. 1 - storage container contents packaged in Disposable Insert No. 1 and Basket No. 1; and Configuration No. 2 for shipment of Content No. 2 - miscellaneous solid irradiated and contaminated non-fuel bearing hardware in secondary containers. Section 1.2.2 of the application provides detailed information about Content No. 1 and Content No. 2. The applicant stated that the maximum total activity for Content No. 1 and Content No. 2 is limited to 30,000 Ci and 3,000 A_2.

Prior to loading, the shipper shall ensure the package content meets the CoC. The applicant informs the user to follow appendix 7.6.1 of the application for non-mandatory radiation level guidelines that ensure the contents meet the dose rate requirements.

The applicant states that the conditions that a shipper must meet for safe handling of the Model RT-200 package includes: (1) follow all operating instructions/procedures outlined in the Safety Analysis Report (SAR); (2) Model RT-200 shall only be lifted by the top lifting trunnions using a qualified lifting beam or by approved rigging equipment; (3) Model RT-200 package shall not be placed in an upside-down position at any time; (4) Model RT-200 cask body shall not be handled while tied down to the transport; (5) handling of the lid, drain and vent port cover plates, cavity surfaces, bolts and O-rings as potentially contaminated, and (6) inspect all bolts, hole threads or O-rings for damage, defects, or signs of deterioration at an appropriate time throughout the operating steps. The application includes operational steps for the user to perform maintenance leakage rate testing in accordance with section 8.2.2.1 and table 8.3.2-3 of the application prior to returning the package to service following maintenance, repair (such as weld repair), or replacement of components of a containment boundary.

The applicant states that the order of removal of the impact limiters will be determined by the cask user using a method that will prevent damage, and that the impact limiters shall be removed prior to lifting the cask in accordance with section 7.1.1.1 of the application. In section 7.6.2 of the application, the applicant included a visual diagram that illustrates the main steps for cask loading.

In section 7.1.1 of the application, "Preparation for Loading," the applicant has referenced table 8.3.2-3 "RT-200 Leakage Test Types- Annual/Maintenance Tests," in sections 7.1.1.3, 7.1.1.4, 7.1.2.3, and 7.1.2.5, to provide instructions for inspection and maintenance. In SAR section 7.1.1.3, the applicant states that the drain port cover plates shall be inspected upon removal.

The operating procedure provides steps for removal of front and rear impact limiters and perform inspection for damage to limiters, bolts, rubber spacers and follow the process if damaged to replace in accordance with the bill of materials listed in chapter 1 of the application.

In sections 7.1.1.3, 7.1.1.4, 7.1.1.5, 7.1.1.7 and 7.2.2 of the application, a note instructs the user to be attentive of potential release of radioactive and/or volatile gases or material and/or that the operation should be performed under the supervision of a qualified health physics personnel and in accordance with health and safety requirements.

Section 7.1.1.7, "Cask Pre-fill with Water," of the application, provides an acceptable alternative loading sequence for fully removing the cask lid prior to submergence of the cask.

8.1.2 Loading of Contents

In section 7.1.2 of the application, the applicant provided loading procedural steps for two loading shipping configurations. Configuration No. 1 describes the configuration of the Model RT-200 to ship Content No. 1. Configuration No. 2 describes the configuration of the Model RT-200 to ship Content No. 2.

Section 7.1.2.3 of the application includes a description for installation of the cask lid. The applicant states that prior to installation of the cask lid, the sealing surfaces (on the body of the package and on the cask lid) shall be inspected and cleaned and O-rings checked for damage, head cap screws be lubricated if necessary. For the cask loaded underwater, the applicant states that use of qualified lifting beams will be engaged to the two bolted lifting trunnions and the cask removed from the water. Further, the operational procedure states that once the cask lid is accessible above water, cask bolts and washers will be hand tightened to 7 N-m ± 10 % torque; the lid positioned by aligning with the holes to ensure its proper placement, and the bolts tightened, using the “star pattern” method to ensure an evenly distributed pressure on the lid and cask body, with an initial torque of 400 N-m ± 10 % and a final torque of 800 N-m ± 10 %. A pre-shipment leak test of the primary lid O-ring is then performed as described in section 8.2.2.2 of the application.

Section 7.1.2.5 of the application provides the operational steps and conditions for replacement of the drain and vent port cover plates. The applicant stated that prior to installation, the O-rings will be inspected and cleaned and corrected for any damage, crack or conditions noted. The port cover plates will be placed on the cask body and bolts threaded into the cover plate using a “star pattern” method by installing four bolts into the cask body and tightened with an initial torque of 7 N-m ± 10 % to compress the O-rings and a final torque of 70 Nm ± 10 %. The same methodology is followed to install the front and rear impact limiters, except that the initial and final torques are different, i.e., 400 N-m ± 10 % and 800 N-m ± 10 %, respectively.

The applicant stated that prior to transportation, a contamination survey on the external surfaces of the package will be completed to confirm that non-fixed (removable) radioactive contamination is as low as reasonably achievable and is within the limits specified in 49 CFR 173.443, as required by 10 CFR 71.87. If contamination is within limits, preparation for transport may be conducted. If contamination exceeds the limits, the Model RT-200 package must be decontaminated until the contamination limits are met.

In section 7.1.3 of the application, the applicant included a step that informs the user to ensure that all the steps prior to preparation for transport have been completed. The applicant also outlines preparational steps and conditions for the transportation of the Model RT-200 package. In section 7.1.3.1, “Verification for Transport,” of the application, the applicant provided a list of actions that a shipper needs to confirm prior to shipment of a loaded package.

8.2 Package Unloading

Unloading procedures include receipt of the package and removal of the contents. Upon receipt from the carrier, the package is visually inspected to verify there are no indications of impaired physical conditions. The tamper security seal is also inspected at the top locking plate on the upper and lower impact limiters and the shipment may be rejected by the consignee if the tamper seal has been removed or tampered with in any way. Comprehensive contamination and dose rate measurements are performed to ensure the cask meets NRC requirements. If survey exceeds the limits, the shipper will immediately be notified, and the shipper collaborates with the consignee or the appropriate regulatory authority and Department of Transportation to resolve the issue. The user shall meet the safe handling conditions to ensure the Model RT-200 is lifted by the top lifting trunnions using qualified lifting beams or by approved rigging equipment, Model RT-200 shall not be placed in an upside-down position at any time, and the Model RT-200 cask body shall not be handled while tied down to the transport.

The upper and lower impact limiter will be removed first prior to the removal of the quick-disconnect valve cover plate. The cask lid will be removed in accordance with section 7.1.1.4 of the SAR. During removal of the contents, the applicant stated that care should be taken not to damage the cavity of the package or the sealing surfaces.

In table 1.3-5, “List of the bolted elements – Preload Torque,” of the application, the applicant provides a list of the bolted elements and their nominal torque with tolerances. The applicant also provided a similar list in RT-200 NTE-2006, “RT-200 Type B Cask-Technical Note, Bolt preload” Revision A (Proprietary).

8.3 Preparation of Empty Package for Transport

Section 7.3 of the application describes the operational steps for the user to follow in preparation of the empty package for transportation to ensure the cask labeling meets the requirements of the Department of Transportation as specified in 49 CFR 172.428(d) and that all the requirements of 49 CFR 172.428 have been met.

8.4 Hydrogen Buildup in Model RT-200 Transport Cask

In section 7.5 of the application, the applicant stated that the Model RT-200 is designed for a maximum decay heat of 1200 watts. The method for calculating hydrogen gas generation is described in section 7.5.1 “Hydrogen Gas Generation – Analytical Model,” of the application. The rate of hydrogen gas generation is considered when evaluating the heat load, and the method for calculating the hydrogen gas generation is described in section 4.5 of the application. In section 7.5 of the application, the applicant specifies the user of the package to ensure that the maximum hydrogen gas generation within the package remains below 5 % by volume during the shipping period. Further, the applicant stated that by following the cask draining procedure described in section 7.1.2.4, “Cask Draining,” of the application, the applicant can ensure that the residual water content is less than 10 % of the total water mass remains in the containment.

The applicant stated that the use of the equations derived in chapter 4, section 4.5.3, can be used to determine the maximum allowable decay heat limit and the maximum allowable shipping time for a limit of 5 % of hydrogen gas in the cavity free volume, provided the following conditions are met: waste consists of solid irradiated and contaminated non-fuel-bearing metallic hardware, if the package is loaded underwater and drained, no more than 10 % residual water by mass shall remain in the packaging (dewatering criterion is 10 %) and except from water, no other hydrogenous materials are loaded in the Model RT-200. Alternatively, the user can follow applicable method in accordance with NUREG/CR-6673 to determine the shipping time to reach the required hydrogen concentration of 5 %. The shipping time must be defined as half (½) the time to reach the 5 % hydrogen concentration equivalent to the lower flammability limit.

8.5 Evaluation Findings

Based on the review of the operating procedures in chapter 7 of the application the staff concludes with findings:

F8-1 The proposed special controls and precautions for transport, loading, unloading, and handling and finds that they satisfy 10 CFR 71.35(c).

F8-2 The package will be prepared, loaded, transported, received, and unloaded in a manner consistent with its design and evaluation for approval.

F8-3 The procedures for providing special instructions to the consignee are in accordance with the requirements of 10 CFR 71.89.

Based on review of the statements and representations in the application, the NRC staff finds that the combination of the engineering safety features, and operating procedures provide adequate measures and reasonable assurance for safe operation of the package in accordance with the requirements of 10 CFR Part 71.

9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM EVALUATION

The objective of this review was to verify that the acceptance tests to be conducted on the Model RT-200 package have been adequately described and meet the requirements of 10 CFR Part 71, and the maintenance program, as documented in the application, is adequate to assure the Model RT-200 packaging performance while in service.

Chapter 8 of the application identifies the inspections, acceptance tests and maintenance programs to be conducted on the Model RT-200 package.

9.1 Acceptance Tests

9.1.1 Visual Inspection and Measurements

The applicant stated, in section 8.1 of the application that, prior to the first use of the Model RT-200 package, controls shall be implemented throughout the fabrication process to ensure that the packaging conforms to the dimensions and tolerances specified on the licensing drawings. The applicant states that the packaging will be visually inspected for any adverse conditions in material or fabrication for defects that would prevent the package from being assembled or operated or tested. The applicant states that, the visual and nondestructive examinations (NDE) shall be performed by American Society for Nondestructive Testing (ASNT) qualified inspectors. Any nonconforming conditions shall be evaluated and reworked or replaced as applicable.

9.1.2 Weld Examination

The applicant stated, in section 8.1.2 of the application, “Weld Examinations,” that: (1) each containment weld on the Model RT-200 is performed in accordance with American Society for Mechanical Engineers (ASME) Code, Section III, Division I, Subsection NCD – Class 3, (2) radiographic testing, dye penetrant testing, and/or visual testing are performed on weld examinations in accordance with applicable ASME standards, and (3) the containment boundary welds are also inspected by radiographic examination. The applicant further stated that all safety-related welds other than containment welds shall be performed in accordance with ASME Code Section III, Division 1, Subsection NF, and examined by radiographic examination, dye penetrant testing and/or visual tested in accordance with applicable ASME standards. The applicant states that NDE shall be performed by ASNT qualified inspectors.

9.1.3 Structural and Pressure Tests

Section 8.1.3 of the application describes the structural testing requirements for bolted lifting trunnions.

The containment system shall be subjected to internal pressure of 150 kPa (150 % of the maximum containment normal operating pressure (MNOP)) and held for 10 minutes to verify its ability to maintain its structural integrity in accordance with 10 CFR 71.85(b). Section 3.1.4 of the application specifies the MNOP of the Model RT-200 package to be 98.675 kPa (gauge). Afterwards, the cask lid is visually inspected for leakage. After depressurization and draining, the cask cavity and seal areas are visually inspected for cracks and deformation. Any cracks or deformation are remedied, and the test and inspection are repeated.

9.1.4 Leakage Tests

In section 4.4, "Leakage Rate Tests for Type B Packages," of the application the applicant describes the leakage tests to be performed on the Model RT-200 during-fabrication, maintenance, periodic and pre-shipment as required by ANSI N14.5 and shall meet the containment requirements of 10 CFR 71.51. The applicant stated that the leakage test shall be performed on the Model RT-200 package prior to its first use. A fabrication leakage rate test of the entire containment boundary, including the containment vessel cask lid, vent and drain port cover plates, etc. shall be performed to a "leak-tight" criterion using the technique described in ANSI N14.5-2014, table A1, test A5.3, or alternative methods that conforms to ANSI N14.5 with the required sensitivity.

The applicant stated that the test method, leak test sensitivity, and test acceptance criteria for all applicable equipment to be tested for acceptance are provided in section 8.3.2, "Summary of Leak Test Requirements" and table 8.3.2-1 of the application for use during-fabrication leakage test and table 8.3.2-2 for after-fabrication leakage test.

The applicant stated that the Model RT-200 package shall be leak tested after completion of annual inspection and after maintenance or repair of the containment boundary components. This includes after replacement of containment seals (cask lid, vent port, and drain port cover plates). Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested prior to returning the cask to service. The Model RT-200 package shall be leak tested before each shipment of Type B material to verify proper integrity of the containment system. Test equipment shall be calibrated to an appropriate standard.

The leak test procedure shall meet the following conditions: (a) maintenance leakage rate testing shall be performed prior to returning the package to service following maintenance repair (such as welds repair), or replacement of component of containment boundary; (b) test shall be conducted using a helium leak detector in accordance with ANSI N14.5-2014 table A1, test A.5.3, or using an alternative method that conforms to ANSI N14.5 with required sensitivity achieved; (c) the acceptance criteria shall be in accordance with table 8.3.2-1 for during fabrication tests or table 8.3.2-2 for after fabrication tests as applicable; and (d) the cask body testing during fabrication shall be performed with a temporary cover plate to seal the containment volume. Table 8.3.2-3 specifies leak rate acceptance criteria for annual and maintenance tests of cask containment components.

In section 8.1.4 of the application the applicant stated that the containment system includes elastomeric materials and therefore permeation can be a problem when a leakage rate test procedure is being used to demonstrate that the system is leak tight. As noted in section 8.1.4 of the application, the degree of permeation is affected by seal material, seal surface area, time, and temperature. The recommendations of ANSI N14.5-2014 should be considered to eliminate permeability as a factor in leakage rate measurements. The applicant provided guidelines to determine the helium permeation rate and time for the elastomeric O-rings in section 8.1.4 of the application for users to follow.

The staff noted that, as stated in section 8.1.4 of the application, the permeation time for the elastomeric O-rings of the package can be determined either by tests or by calculations. The staff also confirmed the guideline of the factors: (system response time) < (test duration) < (helium permeation time) which ensures that the leakage tests are completed before permeation reaches a significant level.

9.1.5 Component and Materials Tests

In section 8.1.5 of the application, the applicant describes the components and materials test of the Model RT-200 packaging. The components and materials tests used for the Model RT-200 package are selected and procured to assure that there shall be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents. Further, the application states in section 8.1.5.5 of the application that all steel materials used for the Model RT-200 shells, forgings, lid, cover plates, trunnions, and bolts shall conform to the respective ASME or ISO standard selected for each component.

The applicant provided the material testing requirements for the foam used in the Model RT-200 package impact limiters. The crush strength of the foam will be verified by independent testing in accordance with the American Society for Testing and Materials (ASTM) D1621, "Standard Test Method for Compressive Properties of Rigid Cellular Plastics," using table 8.1.5-1, "Required Samples for Foam Crush Testing," for each batch to ensure the crush strength meets the values defined in table 2.12-3 of chapter 2 in the application. The applicant provided in section 8.1.5.2, table 8.1.5-3, "Critical Characteristics of Elastomer O-Rings," of the application the test value, test acceptable criteria and test method/standard for verifying the critical characteristics of elastomer O-Rings.

Section 8.1.5.3, "Ceramic Paper," table 8.1.5-4 of the application, provides the acceptance criteria and test standards for verifying the thermal conductivity property of the ceramic paper.

9.2 Maintenance Program

9.2.1 Structural and Pressure Tests

No routine or periodic pressure testing will be performed on the Model RT-200 transportation cask. The bolted lifting trunnions shall be tested annually to verify continuing compliance and following any major modification or repair in accordance with ANSI N14.6 section 7.3.1(a) requirements. Defective items are replaced or remedied and tested as appropriate. If the Model RT-200 does not comply with the specifications and verifications of the application, it is taken out of service until the corrective action(s) have been corrected. All corrective actions are reported to Robatel Technologies, LLC, the NRC and approved Model RT-200 users.

9.2.2 Leakage Tests

Leak testing of the Model RT-200 must be performed after completion of annual inspection and after maintenance or repair of the containment boundary components. This includes after replacement of containment seals. All requirements for leakage test procedures, repair and replacement, and testing personnel qualification and certification shall be in accordance with ANSI N14.5 and in accordance with NUREG-2216 provisions. The leak tests must be carried out using procedures approved by a ASNT NDT Level III qualified personnel in leakage testing and shall be performed and interpreted by a ASNT SNT–TC-1A “Personnel Qualification, and Certification in Nondestructive Testing,” Level II qualified personnel for respective leak test procedure. The test is conducted using helium leak detector in accordance with ANSI N14.5-2014 table A1 test A5.3. Test equipment shall be calibrated and traceable to an appropriate standard.

The applicant presented the test method, leak test sensitivity, and test acceptance criteria for all applicable equipment to be tested annually or after maintenance or repair in table 8.3.2-3 of the application.

The staff reviewed the Model RT-200 package to ensure that the package will be helium leakage rate tested for maintenance and periodically tested to ensure it meets the leak-tight criterion as shown in table 8.3.2-3 of the application. The staff accepts that the periodic and maintenance leakage rate test procedures should be approved by personnel with an ASNT NDT Level III certification in leak testing and should be carried out and performed and interpreted by a Level II personnel qualified in accordance with ASNT SNT-TC-1A.

9.2.2.1 Pre-Shipment Leak Test

The applicant stated that a leak test of the Model RT-200 is required before each shipment of Type B material to verify proper integrity of the containment system. The applicant stated that pre-shipment leakage rate tests are performed on the cask lid and vent and drain port cover plate assemblies as described in table 8.3.2-4 of the application. The pre-shipment leakage rate tests follow ANSI N14.5-2022 and have a leakage rate criterion such that there is no leakage detected when tested to a sensitivity of 1E-3 ref.cm^3/s

The applicant presented the test method, leak test sensitivity, and test acceptance criteria for all applicable equipment to be tested prior to each shipment in table 8.3.2-4, “RT-200 Leakage Test Types – Pre-Shipment Tests,” of the application and an equation which shows test duration required for the pre-shipment leak test.

The staff accepts the pre-shipment leak test, described in section 8.2.2.2 of the application, and confirmed that the pre-shipment leakage rate test shall be performed following table 8.3.2-4 of the application. The staff accepts that the pre-shipment leak test duration should be greater than or equal to the minimum required duration, and the test procedures shall be approved by personnel with an ASNT NDT Level III qualification in leak testing.

9.2.3 Component and Material Test

9.2.3.1 Routine Component Inspection

The applicant stated in section 8.2.3.1 of the application that maintenance during normal use is performed to ensure that the Model RT-200 package continues to meet design specifications and functions. Cleanliness of sealing surface is of the highest priority during package disassembly for maintenance and assembly. The applicant stated that seals shall be visually inspected to ensure they are within the 12-month replacement period.

9.2.3.2 Annual Component Inspection

In section 8.2.3.2 of the application, the applicant states that the inspection, tests, and maintenance are performed every twelve (12) months of cask service in accordance with the application and NRC requirements. The exterior surfaces of the cask and its components are visually inspected for damage and the results of the survey documented. All major components of the packaging (e.g., upper and lower impact limiters, fusible plugs, cask lid, vent port and drain port cover plates, vent port and drain port quick-disconnect valves, cask lid, vent port cover plate and drain port cover plate O-rings, leak test port plugs, cask body including trunnions and transport trunnions and basket) are visually inspected for defects. Cask visible exterior surface welds and interior cavity welds are visually inspected for defects. Markings are inspected for readability. The cask lid, vent port cover plate and drain cover plate bolts shall be replaced after every 500 cycles based on cask operator records.

Threaded inserts may be used to repair threaded bolts holes. At a minimum, each repaired bolt hole will be tested for proper installation by assembling the joint components where the insert is used and ensuring the bolt can be tightened to the required torque.

The staff finds that visual inspections at various timed intervals provide additional reasonable assurance against corrosion occurring unnoticed.

9.3 Evaluation Findings

The applicant described its acceptance tests and the acceptance criteria for the Model RT-200 package. The applicant also described the required maintenance program of the package.

In SAR revision 3, the applicant proposed the use of French Confederation for Non-Destructive Testing (COFREND) standard in various sections of chapter 8, Maintenance and Acceptance Test. The applicant proposed: (a) to have visual and nondestructive examinations (NDT) be performed by ASNT or COFREND by qualified and certified inspectors; (b) to have the leak test procedures be approved by ASNT or COFREND Level III leak testing qualified personnel; (c) the use of COFREND qualified personnel instead of ASNT qualified personnel is accepted for leakage testing for the Model RT-200 based on equivalence note 103622 EQN 001, Revision B (ADAMS Accession No. ML24304A910); and (d) to have leak testing of the Model RT-200 performed after completion of annual inspection and after maintenance or repair of the containment boundary components be carried out and interpreted by ASNT SNT-TC-1A or COFREND level II qualified personnel.

Based on review of the use of COFREND for qualifying and certifying NDE inspectors for the helium leak test and NDT, the staff is not drawing any conclusions on the equivalency of the ASNT NDT or COFREND Level II or III inspector qualifications as part of the licensing safety review.

The staff reviewed these descriptions and determined that two acceptance criteria were considered as important during the review of this package: (i) the minimum total gap between the lead shielding and the inner and outer shell of the cask shall meet the drawing requirements; and that (ii) the maximum radial gap between the lead shielding and the outer stainless-steel cylindrical shell of the cask body does not exceed the requirements in the drawing

Based on the statements and representations in the application, the staff has reasonable assurance that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71. Further, the CoC is conditioned to specify that each package must meet the Acceptance Tests and Maintenance Program in chapter 8 of the application.

CONDITIONS

The following conditions are included in the certificate of compliance:

- There shall be no neutron emitting nuclides, except for trace amounts of fissile materials in excess of quantities exempted from classification as fissile material per 10 CFR 71.15.
- The weight of water must be excluded when determining the Ci/g of content limits.
- For Content No. 1 only, the source distribution must not shift during NCT.
- The package must be prepared for shipment and operated in accordance with the Operating Procedures of chapter 7 of the application.
- The package must be tested and maintained in accordance with the acceptance tests and maintenance program described in chapter 8 of the application.
- The package shall be transported exclusive use only.
- No air shipment is authorized.
- Flammable gas (e.g. hydrogen) concentrations is limited to less than 5% by volume.
- Material that presents other risks than those related to its radioactive features is prohibited, including explosives, non-radioactive pyrophoric materials, and corrosives (pH less than 2 or greater than 12.5), pyrophoric radionuclides and materials that may auto-ignite or undergo phase transformation at temperatures less than 140°C, with the exception of water.

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model RT-200 package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9384, Revision No. 0, on June 13, 2025