June 1, 2010

Mr. Gary L. Clark
Project Manager
AREVA Federal Services, LLC
1102 Broadway Plaza, Suite 300
Tacoma, WA 98402-3526

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9305 FOR THE MODEL NO. TRUPACT-III PACKAGE

Dear Mr. Clark:

As requested by your application dated June 30, 2007, with supplements dated January 26, 2010, and May 28, 2010, enclosed is Certificate of Compliance No. 9305, Revision No. 0, for the Model No. TRUPACT-III package. The staff's Safety Evaluation Report is also enclosed.

AREVA Federal Services, LLC (AREVA) is registered as user of the package under the general license provisions of 10 CFR 71.17. This approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Chris Staab of my staff at (301) 492-3321.

Sincerely,

/RA/
Eric Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9305
TAC No. L24403

Enclosures:
1. Certificate of Compliance No. 9305, Rev. No. 0
2. Safety Evaluation Report

cc w/encls.: R. Boyle, Department of Transportation
J. Shuler, Department of Energy

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SAFETY EVALUATION REPORT

Model No. TRUPACT-III Package
Docket No. 71-9305
Certificate of Compliance No. 9305
Revision 0

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Safety Evaluation Report
Model No. TRUPACT-III Package
Docket No. 71-9305
Certificate of Compliance No. 9305
Revision 0

SUMMARY

By application dated June 30, 2007 with supplements dated January 26, 2010, and May 28, 2010, AREVA Federal Services, LLC (AREVA) applied to the U.S. Nuclear Regulatory Commission for a Certificate of Compliance (CoC) for the TRUPACT-III package.

The package will be used to ship transuranic waste for the U.S. Department of Energy (DOE) to the Waste Isolation Pilot Project (WIPP) in New Mexico or to other designated facilities. The package is authorized by the certificate for use under the general license provisions of 10 CFR 71.17. Transport by air of fissile material is not authorized. The certificate will expire on June 30, 2015.

The staff has concluded the package meets the requirements of 10 CFR Part 71 by using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

REFERENCES

AREVA Federal Services LLC, application dated June 30, 2007, as supplemented on January 26, 2010, and May 28, 2010.

1.0 GENERAL INFORMATION

1.1 Packaging

TRUPACT-III is a shipping container for transporting transuranic waste in a Standard Large Box 2 (SLB2) primarily by highway trucks. The packaging body is a rectangular box with an external width of 2,500 mm (98.4 inches), external height of 2,650 mm (104.3 inches), and an external length of 4,288 mm (168.8 inches). The internal cavity dimensions are 1,840 mm (72.4 inches) wide, 2,000 mm (78.7 inches) tall, and 2,790 mm (109.8 inches) long.

The TRUPACT-III packaging is comprised of the containment structural assembly (CSA) made from 8-mm inner and outer stainless steel plates with 4-mm thick V-shaped stiffeners in between. A debris shield receptacle is located all around the open end of the CSA inner cavity. The receptacle is a 26-mm x 38-mm cross section bar with a 15-mm wide by 20-mm deep groove cut along its length. The 109 - 120-mm polyurethane foam, 10-mm thick puncture resistant stainless steel plate, 60-mm balsa wood layer, and the 6-mm stainless steel skin form the integral energy-absorbing overpack structure. A 409-mm deep octagonal recess in the bottom end with 6-mm thick stainless steel plate, a 60-mm thick balsa wood layer, a 15-mm thick puncture-resistant stainless steel plate, and a 120-mm thick foam layer protect the bottom end of the packaging during drops or punctures.

A rectangular closure lid made from 4-mm thick V-shaped stiffeners sandwiched between an inner and an outer 12-mm thick stainless steel plates is attached to the packaging body by 44

socket head cap screws and contains two elastomer O-ring face seals. A sampling/vent port with O-ring seals are recessed into the closure lid. The inner stainless steel plates of the closure lid and the body along with the inner elastomer O-ring seal, the sampling/vent port insert, and the sampling/vent port inner O-ring seal form the single containment boundary.

An overpack cover is designed to protect the closure lid. The outer face of the overpack cover contains an octagon recess 393 mm deep. The cover structure consists of a 6-mm thick stainless steel cover plate encasing a 60-mm thick layer of balsa wood, a 15-mm thick puncture resistant stainless steel plate, a 120-mm thick layer of polyurethane foam, and a 6-mm thick inner stainless steel cover plate. The edges of the overpack cover consist of an inner 6-mm stainless steel plate, a 42-mm thick layer of calcium silicate insulation, a 16-mm thick puncture-resistant stainless steel plate, a 380-mm thickness of 0.48 kg/dm^3 polyurethane foam, a 6-mm thick puncture-resistant stainless steel plate, a 140-mm thick layer of 0.16 kg/dm^3 polyurethane foam, and an 8-mm thick external stainless steel plate.

The approximate dimensions and weights of the package are as follows:

Overall package outside dimensions	
Width	2,500 mm (98.4 inches)
Length	4,288 mm (168.8 inches)
Height	2,650 mm (104.3 inches)
Maximum content weight	5,210 kg (11,486 lbs)
Maximum package weight (Including contents)	25,000 kg (55,116 lbs)

1.2 Drawings

This packaging is constructed in accordance with AREVA Federal Services LLC Drawing Nos. 51199-SAR, Rev. 2, sheets 1 through 21.

1.3 Contents

The application requests one SLB2 container as the TRUPACT-III content. The SLB2 is a specialized steel container with a top-loading and a bottom-loading option that can accommodate 4 x 4 x 7 and 5 x 5 x 8 boxes as well as other smaller containers loaded with transuranic wastes. The SLB2 has a body, lid, and elastomeric gasket seals. A payload loading system, such as a roller floor and a loading pallet, are used as part of the content for facilitating easy operation.

1.3.1 Type and Form of Material

Dewatered, solid or solidified transuranic contaminated materials and wastes, any particle size, large objects, and bulky objects are directly loaded into an SLB2 to be placed in a TRUPACT-III packaging.

1.3.2 Maximum Quantity of Material per Package

The TRUPACT-III packaging is designed to transport contact-handled transuranic (CH-TRU) waste and other authorized payloads that do not exceed 10^5 A_2 quantities. No more than 325 grams of Pu-239 fissile gram equivalent (FGE) is generally allowed per TRUPACT-III package.

Per the TRUPACT-III TRAMPAC, Revision 2, the FGE limit per TRUPACT-III package may be increased if the payload is documented to contain Pu-240. A TRUPACT-III payload shall not contain greater than 1 percent by weight beryllium and/or beryllium oxide nor machine compacted waste. Only one SLB2 may be loaded in a TRUPACT-III package at a time. The maximum decay heat per package not to exceed 80 watts

1.4 Criticality Safety Index 0.0

Based on the statements and representations in the application, as supplemented, the staff concludes that AREVA has described the overall design of the TRUPACT-III in sufficient detail to provide an adequate basis for its evaluation against 10 CFR Part 71.

2.0 STRUCTURAL AND MATERIALS EVALUATION

The Model TRUPACT-III package is designed for transporting contact-handled transuranic (CH-TRU) waste confined within a single steel standard large box (SLB2) container. The object of the review is to verify that the structural performance of the Type B(U)F-96 package meets the requirements of 10 CFR Part 71, including those under the tests and conditions for normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

2.1 Structural Design

2.1.1 Description of Structural Design

The TRUPACT-III transportation package is made of three principal structural components: a body, a closure lid, and an overpack cover.

Body: The TRUPACT-III packaging body is a stainless steel weldment of 140-mm thick, double-wall composite construction. The 8-mm thick inner and outer stainless steel plates are joined by interior V-stiffener assemblies made of 4-mm thick stainless steel sheets. The 2,500-mm wide, 2,650-mm high, and 4,288 mm-long rectangular box body, with one end closed and the other open to receive the closure lid and overpack cover, is comprised of the containment structural assembly (CSA) and its integral energy-absorbing overpack. Section 1.2.1.1 of the application describes the body components, including their primary structural design features.

The inner sheets on four sides and the closed end of the CSA form part of the containment boundary of the packaging. At the open end, the wall sections are welded to a flange weldment made of the 140-mm wide by 145-mm high composite box-beam with threaded bolting bosses passing through the flange that are welded to both the front and rear plates.

To facilitate emplacement of the 1,752-mm wide, 1,854-mm high, and 2,743-mm long SLB2 payload container, stainless guide bars are installed on the side and top walls of the packaging inner cavity measured 1,840-mm wide by 2,000-mm high and 2,790-mm long. To limit the axial free space available relative to the SLB2 container movement, plates made of hard plastic material are attached to the inner surface of the stainless steel guide bars on the closed-end wall such that an axial space of no more than 28 mm is maintained.

As displayed in Sheet 4, Drawing 51199-SAR of Appendix 1.3.1 to the application, a debris shield receptacle, which is cut from the 27 mm x 39 mm stainless steel bar stock with a 15-mm wide by approximately 20-mm deep grove, is welded around the front perimeter of the CSA

inner cavity near the opening. This permits engagement of the receptacle with the silicone foam insert attached to the closure lid lip for preventing debris in the packaging cavity from reaching the containment O-ring seal.

The overpack, which is integral to and fully envelops the CSA body, is designed to provide energy absorption, puncture resistance, and thermal insulation for the package containment boundary. Its construction consists primarily of layered balsa wood and polyurethane foam, each of varied thickness, density, and applicable grain or rise direction, sandwiched between stainless steel plates for different parts of the CSA body to provide desired level of protection. Drawing 51199-SAR, Sheets 1 through 21, provides design details of the overpack and its installation interfaces with the CSA body, including those for the octagonal recess at the body closed end, the CSA flange faces that envelop the sides of the overpack cover, and features of the puncture-resistant packaging components.

Closure Lid: The 148-mm thick closure lid, which measures 2,108-mm wide and 2,280-mm high, has a similar stainless steel weldment construction to that of the CSA body wall section, except for the 12-mm thick inner and outer steel plates connected by V-stiffeners. The box-beam around the outside of the lid mates with the CSA body flange. The lid is attached to the body flange weldment by forty-four M36 x 205 mm bolts made from the American Society for Testing and Materials (ASTM) A320 L43 alloy steel. Section 1.2.1.2 of the application presents closure lid details, including the 20-mm thick shear lip with a10-mm bearing width, which runs on all four sides of the lid and engages the CSA opening.

Overpack Cover: The 2,108-mm wide, 2,650-mm high, and 870-mm thick overpack cover features a design similar to that of the overpack structure at the closed end of the CSA. When installed, it fits between the cheeks on the body and completely envelops the closure lid and the CSA body flange to provide energy absorption and puncture-resistance protection for the closure lid. Using ten M-36 x 60 mm ASTM A320 Grade L43 bolts, the overpack cover is attached to the threaded bosses welded into the CSA overpack structure. Section 1.2.1.3 of the application provides design details of the overpack cover, including, layered balsa wood, puncture-resistance stainless steel plates, polyurethane foam, calcium silicate thermal insulations protected by steel plates, and a 393-mm deep, large octagonal recess. As noted also in the application, on the inside surface, short, 3-1/2-inch diameter cylindrical depressions, are located around the perimeter to provide receptacles for the heads of the 44 closure lid bolts.

2.1.2 Design Criteria

Section 2.1.2 of the application notes that proof of performance for the TRUPACT-III packaging is achieved by a combination of analytical and empirical evaluations. The acceptance criteria for analytical assessments, which involve stress allowables, are in accordance with Regulatory Guide 7.6, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” and the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NB and Appendix F for the containment structure. The acceptance criterion for empirical assessments is a demonstration that containment boundary remains leaktight following the imposed loading conditions. The acceptance criteria for non-containment structures, such as CSA body and overpack cover configured primarily for energy dissipation, are that package deformations obtained from certification drop testing must be such that deformed-geometry assumptions used in subsequent thermal and criticality evaluations remain bounding. As delineated in Sections 2.7.1 and 2.7.3 of the application, these criteria include not to result in separation of the overpack cover from the package, excessive deformation in the

containment sealing area, and excessive compression, damage, or exposure of polyurethane foam and calcium silicate insulation after a HAC free-drop test of the package. Other performance criteria for miscellaneous structural failure modes, such as those for brittle fracture, fatigue, and buckling, are presented in Sections 2.1.2.2.

2.1.3 Fabrication and Examination

Section 2.3 of the application describes the fabrication and examination processes and applicable codes and standards for the packaging body, the closure lid, and the overpack cover. This includes the CSA containment boundary fabricated by joining the inner wall sections and the body flange weldment with full penetration welds, for which, in addition to visual examination, radiographic inspection is performed on those welds in accordance with ASME Code, Section III, Division 1, Subsection NB, Article NB-5000, and Section V, Article 2. By making reference to Section 8.1.5 of the application, the applicant also commits to examining and testing key structural component materials, such as polyurethane foam and balsa wood of the overpack structure and overpack cover.

The staff reviewed the package structural design and concluded that it is adequately described. The design criteria and structural evaluation approaches, including empirical evaluations to demonstrate package performance, are consistent with NUREG-1609, “Standard Review Plan for Transportation Package for Radioactive Material,” acceptance criteria and are, therefore, acceptable.

2.2 Weights and Centers of Gravity

The maximum weight of the package, including a maximum payload weight of 5,210 kg is 25,000 kg. Table 2.1-2 of the application summarizes weights of individual parts of the package. Section 2.1.3 recognizes packaging design symmetry and notes that the package center of gravity is located 168 mm towards the closure end from the longitudinal geometric center, based on an overall package length of 4,288 mm.

2.3 Materials Evaluation

The TRUPACT-III rectangular design is constructed of the body, closure lid and overpack cover assemblies which collectively make up the transportation packaging as discussed in Section 1.2.1 of the application. The closure lid when bolted to the body form the containment structural assembly (CSA) which contains and supports the containment boundary consisting of the following:

- the inner duplex stainless steel plates (four sides and a closed end),
- the closure lid inner duplex stainless steel plate,
- the inner O-ring (butyl) seal (flange of closure lid),
- the vent port (aluminum-bronze) insert (closure lid),
- the vent port insert inner O-ring (butyl) seal.

Section 2.2 of the application discusses the TRUPACT-III packaging materials. Structural components are primarily manufactured from duplex stainless steel (unified numbering system (UNS) S31803 or grade 2205). Various other secondary component materials are covered such as American Society of Testing Materials (ASTM) (A276/A479, Type 304/304L) austenitic stainless steel guide pins, (A320, Type L43) nickel-chromium-molybdenum steel fasteners,

(B150, UNS C63200) aluminum-bronze vent/test port insert, (Rainier Rubber R0405-70) butyl rubber seals, (GenPore, 1 micron) polyethylene filter, (closed cell) silicone foam debris shield insert, (calcium silicate) thermal insulation, energy absorbing polyurethane foam and balsa wood for puncture resistance.

The TRUPACT-III packaging is designed to transport payloads confined within a steel standard large box 2 (SLB2). Payloads consist of contact-handled transuranic waste and other authorized payloads ($\leq 10^5$ A_2 quantities).

Specifications and temperature dependent mechanical properties, including yield strength, tensile strength, allowable strength, modulus of elasticity, and coefficient of thermal expansion conform to ASME Code, Section II, Part D or Code Case N-635-1 and are presented in Tables 2.2-1 through 2.2-8 of the application. Section 2.2.1 of the application provides temperatures, density and Poisson's ratio values used for duplex stainless steel. The staff reviewed the materials selected and determined that they are acceptable.

2.3.1 Chemical or Galvanic Reactions

Section 2.2.2 of the application discusses reactions due to chemical, galvanic or other reactions. As stated above the CSA is fabricated of duplex stainless steel, grade 2205. This grade is known to exhibit very good general corrosion resistance, in many environments, including localized, pitting, crevice and chloride stress corrosion cracking resistance. The polyurethane is rigid, closed-cell, non-water absorbent foam, free of halogens and chlorides. The applicant considered the possibility for chloride induced corrosion of the important-to-safety (ITS) duplex stainless steel components and, as a result, specifies in Section 8.1.5.1.2.1.1 that the physical characteristic for leachable chlorides shall be tested once for each specific foam formulation.

The alloy steel closure bolts are cadmium-plated to federal specification QQ-P-416E for cathodic protection. The various helium fill, test and sample/vent fittings are aluminum-bronze, a copper alloy, offering good mechanical properties and corrosion resistance. Balsa wood does not react with the stainless steel or foam and non-reactive plastic threaded plugs are used to prevent moisture from entering these cavities. As noted in Section 8.2.5.2 of the application, containment boundary O-ring seals and the debris shield silicone foam insert are replaced within the one year period prior to a shipment or if damaged and this new O-ring seal will be leakage rate tested.

The SLB2 is constructed of a steel body and lid with an elastomeric gasket. The SLB2 may be loaded directly with waste or accept packaging of various existing sized containers. The SLB2 employs external square tubing used as bumpers aligning with applicable payload cavity guide bars. The approved payload for the TRUPACT-III transportation packaging is limited to materials in the final waste form that are inert, in an inert form or have been rendered inert. In addition, payloads may consist of solid form plutonium exceeding 0.74 Tbq or 20 curies of activity.

The staff concludes that, during normal conditions of transportation, the CSA internals will not be subject to continuous or frequent exposure to moisture or that any water intrusion is not likely to occur in great quantities. The number of and galvanic potential between the different metals used in fabrication is low. Therefore, the conditions required to create the possibility for galvanic corrosion is small. Further, visual inspections to be performed of the TRUPACT-III

payload cavity at various timed intervals provide reasonable assurance against any significant corrosion occurring unnoticed.

2.3.2 Brittle Fracture

Section 2.1.2.2.1 of the application discusses material brittle fracture concerns. To comply with 10 CFR Part 71.71(b), the prototypical packaging was performance tested at minimum service temperature of -29ºC (-20ºF) to assure that no brittle fracture of TRUPACT-III components occurs. No observable differences in test results (e.g., drop test results) were noted for the low temperature test versus the normal ambient temperature test. Therefore, low temperature has no effect on the TRUPACT-III packaging material performance.

2.3.3 Materials and Material Testing

Section 8.1 of the application discusses acceptance and maintenance testing. The metallic materials of construction (body, closure lid and overpack cover assemblies) are procured and fabricated to consensus industry standards. The various CSA components are fabricated from American Society Testing Materials (ASTM) standard materials. Welding is performed in accordance with American Society of Mechanical Engineers (ASME) Code, and inspected in accordance with the ASME Code and the American Welding Society (AWS) D1.6 Welding Code.

As discussed in Section 3.2.2 and Table 3.4-1 of the application the applicant has stated that duplex steels, such as the Alloy UNS S31803, may experience a transition from ductile-to-brittle fracture if exposed to temperatures in excess of 300 °C (572 °F) for extended periods of time. Weld material and processes have been selected in accordance with the American Society of Mechanical Engineers (ASME) Code to provide as good or better material properties, including corrosion resistance. In addition, an upper temperature limit of 316 °C (600 °F) has been placed on the use of the Alloy UNS S31803 stainless steel. This temperature point represents the maximum temperature listed for the material in the ASME Code Case N-635-1. The 316 °C limit is also conservatively used for the short-term limit under hypothetical accident conditions (HAC) conditions for all UNS S31803 duplex stainless steel, Type 304/304L austenitic stainless steel and ASTM A320 L43 nickel-chromium-molybdenum steels. A short-term limit of 1,370 °C is applied for the outer plates of the package.

The staff concludes that welding processes that controls the interpass temperature is required in order to obtain sound welds and no pre- or post-heat treatments are required. Both solidification and hydrogen cracking can be a consequence when welding duplex stainless steels. Material properties can be considerably affected by welding due to formation of detrimental metallurgical phases. In addition, high alloy content renders them susceptible to the creation of inter-metallic phases from extended exposure to high temperatures. Welding procedures must be suitably specified and controlled to ensure deposited metal will deliver a properly balanced duplex structure. The welding processes, filler materials and heat limits imposed by the applicant in accordance with ASME code case and standards are acceptable.

2.3.4 Conclusion

The staff finds that the TRUPACT-III transportation package meets the regulatory requirements for preventing or mitigating galvanic or chemical reactions, is unaffected by cold temperatures,

and is constructed with materials and processes in accordance with acceptable industry codes and standards.

2.4 General Standards for All Packages (10 CFR 71.43)

2.4.1 Minimum Package Size

The minimum dimension of the TRUPACT-III package is 2,500 mm, which is the package width. This is greater than 10 cm and meets the minimum package size requirement of 10 CFR 71.43(a).

2.4.2 Tamper-Proof Feature

Tamper-indicating seals are installed through two of the access tubes for the overpack cover. As noted in Section 2.4.2 of the application, a lock wire device is used between two tie points. Failure of the tamper-indicating devices provides evidence of possible unauthorized access. Thus, the requirement of 10 CFR 71.43(b) is satisfied.

2.4.3 Positive Closure

The application notes that the package cannot be opened inadvertently. The overpack cover, which is secured with 10 M36 x 60 mm screws, fully conceals the closure lid and the vent port. The closure lid is secured with 44 M36 closure bolts. Thus, the requirements of 10 CFR 71.43(c) for positive closure are satisfied.

2.5 Lifting and Tie-Down Standards for All Packages (10 CFR 71.45)

2.5.1 Lifting Devices

The TRUPACT-III package is lifted by the four upper International Organization for Standardization (ISO) fittings located at each corner of the body. Section 2.5.1 of the application evaluates lifting margins of safety (MS), considering three times the total package weight of 25,000 kg supported only by two diagonally opposed ISO fittings. Three failure modes evaluated are: (1) shear tearout of the ISO twist lock in the top ISO fitting plate, (2) shear failure of the welds attaching the top ISO fitting plate, and (3) bending failure in the lifting arm structures. The smallest margin of safety, as related to weld shear tearout failure of the top plate on the ISO fitting, is determined to be 1.54. This demonstrates the structural capability of the lifting device. It also suggests that, under excessive load condition, failure of the weld, which is the most vulnerable in the load path, will not affect other capabilities of the package body. Thus, the 10 CFR 71.45(a) requirements for lifting devices are satisfied.

2.5.2 Tie-Down Devices

Section 2.5.2 of the application states that the package is secured to its conveyance by tie-rods which connect to a frame installed over the top of the package and horizontal restraint is provided by structural pockets on the conveyance in the vicinity of the four lower ISO fittings. The TRUPACT III package has no integral tie-down devices that are part of the package. Therefore, the staff agrees with the applicant’s assessment that no analysis of tie-down devices is required for satisfying the requirements of 10 CFR 71.45(b).

2.6 Normal Conditions of Transport (10 CFR 71.71)

2.6.1 Heat

Considering direct sunlight and 38°C still air, Section 3 of the application determines the maximum normal operating pressure (MNOP) of 172 kPa gauge and maximum CSA outer structural sheet temperature of 57.6°C for the TRUPACT-III package. On the basis of a reduced external pressure of 25 kPa absolute, the resulting net internal pressure of 248 kPa (273 - 25 = 248 kPa) together with a bounding uniform temperature of 71 °C are used for structural analysis of the packaging systems and components.

Section 2.6.1.2 of the application notes the only potential for differential thermal expansion (DTE) between the closure lid bolts, composed of ASTM A320, Grade L43, alloy steel, and the material clamped by the bolts, composed of Unified Numbering System (UNS) S31803 stainless steel. For the bolts installed and pre-tensioned at a temperature of 21 °C, the increased bolt preload due to DTE effect is determined to be 1.5%, which is negligibly small compared to a bolt tensile stress margin of safety of 0.42.

Section 2.6.1.3 uses classical hand calculations to evaluate stresses in the CSA walls. As conservative estimate, all global wall bending along their span and lateral local bending between the V-stiffeners from pressure loading are considered, and individually calculated stresses are arithmetically added for comparison with the ASME Code Section III, Subsection NB, stress intensity limits. Table 2.6-2 lists stress results with a minimum margin of safety of 0.36 for the 71 °C, at-temperature membrane stress intensity limit of 207 MPa in the side wall inner and outer plates. The minimum shear stress margin of safety is calculated to be 1.07 for the outer sheet plug welds with a stress intensity limit of 124.2 MPa.

The fillet welds attaching the V-stiffeners to the containment sheets are classified as welded attachments, per ASME Code, Paragraph NB-3123.2. A fatigue analysis is performed of the fillet welds by applying a loading range for the full internal pressure differential of P = 248 kPa to the full internal vacuum and normal ambient external pressure of 101 kPa. The resulting allowable operating cycle is conservatively calculated to be 2E+5 cycles, which far exceeds a service life of 35 years with 50 shipments per year for the TRUPACT-III package.

The staff reviewed the analysis results and concludes that the heat condition will not degrade structural performance of the package. The staff also agrees that effects associated with differential thermal expansion of the various packaging components are negligible. Thus, the requirements of 10 CFR 71.71(c)(1) are satisfied.

2.6.2 Cold

Considering zero insulation and zero decay heat, Section 2.6.2 of the application evaluates the package for the cold condition, at -40°C, and determines that the structural performance of the package is not adversely affected. For DTE effects, the applicant calculates a preload reduction in the lid closure bolt from 222.2 kN to 216.1 kN. This reduction by 2.7% is negligible and the reduced bolt preload is more than adequate to compress the elastomeric O-ring seals. On this basis, the staff agrees with the applicant's conclusion that the requirements of 10 CFR 71.71(c)(2) are satisfied.

2.6.3 Reduced External Pressure

Section 2.6.3 of the application notes the ability of the CSA to independently withstand a maximum MNOP of 172 kPa gauge internal pressure at the reduced external pressure of 25 kPa. Thus, the staff agrees with the applicant's conclusion that the effect of a reduced external pressure of 25kPa on the TRUPACT-III package is negligible. This satisfies the requirements of 10 CFR 71.71(c)(3).

2.6.4 Increased External Pressure

Section 2.6.4 of the application notes the negligible compressive stress effect of an increased external pressure of 140 kPa absolute (39 kPa gauge) for the package. To evaluate the containment boundary buckling capability, which is prevailing, reference is made to Section 2.12.4, "HAC Immersion Buckling Evaluation," for which a buckling factor of safety of 4.41 is calculated for an external pressure of 150 kPa gauge. This translates to a safety factor of 16.96 (4.41 x 150/39 = 16.96) for the increased external pressure of 39 kPa gauge. The negligible stresses in the CSA body and large buckling safety factors for the CSA containment walls demonstrate the structural adequacy of the package for satisfying the requirements of 10 CFR 71.71(c)(4).

2.6.5 Vibration

Section 2.6.5 of the application evaluates effects of vibration on the fatigue performance of the TRUPACT-III package. This is accomplished by comparing the applicable alternating stresses with the corresponding endurance limits for the key packaging components.

Considering a dynamic load factor of 2 for the package lifting, the applicant determines the alternating shear stress amplitude of 66 MPa in the upper lifting arm attachment weld. This provides a MS of 0.75 against the endurance limit of 115.2 MPa (MS = 115.2/66 - 1 = 0.75). For the bottom containment wall subject to an ANSI N14.23 vertical vibratory acceleration of 2.0 g, the endurance limit margins of safety are calculated to be 0.86 and 2.95 for the primary membrane-plus-bending stress intensity of the wall and the associated plug welds, respectively. This satisfies the vibration requirements of 10 CFR 71.71(c)(5).

2.6.6 Water Spray

The materials of construction of the package are not affected by the water spray test. The staff agrees that the water spray test of 10 CFR 71.71(c)(6) has negligible effects on the TRUPACT-III package.

2.6.7 Free Drop

A 0.3-m free-drop test was performed during the full-scale certification testing of the certification test unit 1 (CTU-1), which, per Section 2.12.3 of Appendix 2.12 to the application, resulted in negligible visible damage to the test unit. A NCT free-drop height of 0.3 m for packages weighing more than 15,000 kg represents a potential energy at impact of only 3.3% of a HAC 9-m free drop. Since the structural performance of the TRUPACT-III was demonstrated by testing to be acceptable, as reviewed in Section 2.7.1of the safety evaluation report, the staff has reasonable assurance to conclude that the 0.3-m free-drop testing meets the intent of the 10 CFR 71.71(c)(7) requirements.

2.6.8 Corner Drop

The package weighs in excess of 100 kg and this test does not apply in accordance with 10 CFR 71.71(c)(8).

2.6.9 Compression

The package weighs in excess of 5,000 kg and this test does not apply in accordance with 10 CFR 71.71(c)(9)

2.6.10 Penetration

Section 2.6.10 of the application notes that the TRUPACT-III package is designed to minimize the consequences associated with the much more limiting case of a one-meter drop of the entire package onto a puncture bar. Thus, the staff agrees with the applicant's conclusion that the penetration test is of negligible consequence. This satisfies the intent of the 10CFR71.71(c)(10) requirements.

2.7 Hypothetical Accident Conditions (10 CFR71.73)

The applicant demonstrated structural performance compliance with the requirements by a combination of test and analysis. The thermal and immersion cases were evaluated by analysis. Two full-scale certification test units, CTU-1 and CTU-2, were used for all test demonstrations.

2.7.1 30-foot Free Drop

Section 2.12.1 of Appendix 2.12 to the application presents results of the engineering tests performed on two half-scale specimens each of a prototypical representation of the TN-Gemini and TRUPACT-III packages. These results are considered in Section 2.7.1.1of the application for determining the worst-case free drop orientations for which maximum damage is expected. As noted in the application, the criteria used for this determination included considerations of rupture of containment boundary, buckling of the CSA, excessive deformation in the containment sealing area, separation of the closure lid from the body and of the overpack cover from the package, and excessive compression, damage, or exposure of overpack insulation materials. Sections 2.7.1.1.1 and 2.7.1.1.2 present evaluations of 12 end-drop and 9 side-drop configurations, respectively, which resulted in selecting four 9-m drop orientations for testing the ETU-1, in addition to a 0.3-m, lid-down, NCT free drop.

Certification Tests on CTU-1: Section 2.12.3 of Appendix 2.12 to the application presents test conduct and test results for the CTU-1, which was an essentially prototypical representation, in full scale, of the TRUPACT-III packaging. Section 2.12.3.3 evaluates the differences between the CTU-1, as tested, and a regular production unit, and determines that the CTU-1 was in full compliance with the TRUPACT-III design drawings of Appendix 1.3 to the application. It also notes exceptions, however, in two major design details: (1) The closure lid bolt washers made from ASTM A564, Grade 630, conditions H1025 (17-4 PH) material for the CTU-2 and product units were significantly stronger than the CTU-1 washers made from Type 304 stainless steel, and (2) The debris shield assembly used in the CTU-2 and production units was not present in the CTU-1. To simulate the maximum TRUPACT-III payload of 5,210 kg, a large quantity of

square-ended, two-inch and four-inch diameters aluminum bars and other brass and aluminum scrap items weighing 6,746 kg was loaded loosely in the CSA cavity. To account for initial loading condition effects on the containment boundary, the CSA cavity was pressurized at ambient temperature to a MNOP of 172 kPa for the drop testing.

Table 2.7-1 of the application summarizes test details, including test temperatures, for the four sequential 9-m free drops, which followed the 0.3-m, lid down, NCT drop, for the package lid down, side-flat, side-edge, and C.G.-over-corner orientations. To demonstrate containment boundary leakage rate performance, Section 2.7.1.4 notes the two-step process of (1) applying a vacuum to the annulus between the containment O-ring and test O-ring seals on the closure lid after each drop, and (2) performing a helium leakage rate testing on the entire containment boundary subsequent to the complete series of free drop and puncture tests. The section also notes that the vacuum application was not attempted to the side-edge drop and the applied vacuum could not be adequately maintained for the subsequent C.G.-over-Corner drop. However, at the conclusion of all certification drop testing, the helium leakage rate testing demonstrated that the containment metallic boundary and vent port insert O-ring seal remained leaktight per the American National Standards Institute (ANSI) N-14.5, “Radioactive Materials - Leakage Tests on Packages for Shipment,” criteria.

Sections 2.7.1.4.1 through 2.7.1.4.5 of the application summarize packaging structural performance of the package for the four free drops. In addition to individual crush footprint and crush distance, measured as indentation of the crushable material in the direction of impact, other damages determined to have insignificant effects on the package include cracks incurred in the welds of the overpack cover, small gaps between the cheek and overpack cover edge, and some deformation and outward bending of the body top and bottom outer shell sheets. Since the side-edge and C.G.-over-corner free drops were performed at ambient temperatures, Section 2.7.1.5 performs an analysis to extrapolate the measured crush deformations for the damage that would have incurred for maximum NCT temperatures. The analysis uses reduced crush strengths of foam materials at higher temperature and establishes crush deformations that need to be considered for the packaging HAC thermal test evaluations by analysis.

Certification Tests on CTU-2: To complement the CTU-1 testing series, which had failed in the closure lid O-ring seal leakage rate test for the C.G.-over-corner drop, the applicant introduced a closure lid debris shield assembly to the second prototypical certification test unit, CTU-2, to demonstrate performance of the package for meeting the HAC drop test requirements. As provided in Section 2.12.5 of Appendix 2.12 to the application, given that the presence of debris in the sealing nip had been determined to be the cause for failing the closure lid O-ring vacuum test, the debris shield was designed for preventing debris from reaching the containment O-ring seal.

Section 2.12.6 of Appendix 2.12 to the application presents test conduct and test results for the CTU-2, a prototypical representation, in full scale, of the TRUPACT-III packaging. Similar to those for CTU-1, Section 2.12.3.3 evaluates the differences between the CTU-2, as tested, and a regular production packaging unit and notes that fabrication non-conformances were minor in nature and did not have a significant effect on the performance of the CTU-2 during testing. The test payload included a prototypical roller floor, pallet, and SLB2 loaded with a quantity of square-ended, two-inch and four-inch diameters aluminum bars and other brass and aluminum scrap items for a gross weight of 25,154 kg. Approximately one quart of debris composed of crushed concrete and fine grinding grits was also poured into the CSA cavity to simulate potential debris collection next to the closure lid. To account for initial condition effects on the

containment boundary, the CSA cavity was pressurized at a temperature of -4°C to 170 kPa, which exceeded the design pressure of 172 kPa corresponding to an ambient temperature of 21 °C.

Section 2.7.1.4.5 of the application observes that, for the single C.G.-over-corner 9-m free drop performed at a material temperature of -33.6°C, the impact footprint for the CSA body was comparably smaller than that of the CTU-1 testing, which is consistent with the at-temperature performance for the foam material. Tables 2.12.6-4 and 2.12.6-5 of Appendix 2.12 to the application list the overpack cover gap measurements and closure lid bolt residual torques, respectively, with acceptable results. The application also states that no significant weld seam failures or exposed foam was noted. In evaluating leak tightness of the containment boundary per ANSI N14.5, the application notes: (1) After the test, a vacuum was applied to the annulus between the two O-rings in the closure lid and the lowest vacuum achieved was below 200 millitorr, indicating a good seal, and (2) after two puncture tests subsequent to the C.G.-over-corner drop, a helium leakage rate test was performed. The leakage rate tests of the CSA containment boundary and the closure lid containment and vent seals all met the leaktight criteria of ANSI N14.5.

On the basis of the above review, the staff concludes that the tests performed on the CTU-1 and CTU-2, in aggregate, demonstrate adequate performance of the TRUPACT-III package for meeting the requirements of 10 CFR 71.73(c)(1).

2.7.2 Crush

Since the package weighs more than 500 kg (1,100 lbs) the dynamic crush test of 10 CFR 71.73(c)(2) does not apply.

2.7.3 Puncture

Section 2.7.3.1 of the application considers the puncture drops performed on the ½-scale specimens, as reviewed in Section 2.7.1 of the safety evaluation above, in the engineering testing for determining the worst-case free-drop orientations for which maximum damage is expected. As noted in the application, the criteria used for this determination included considerations of rupture of containment boundary, excessive deformation in the containment sealing area, separation of the overpack cover from the package, and excessive compression, damage, or exposure of overpack insulation materials, such as polyurethane foam or calcium silicate insulation. A total of 9 puncture orientations were evaluated, which resulted in selecting four testing configurations of dropping the CTU-1 onto the puncture bar in the areas of: (1) prior damage from the side-flat drop, (2) overpack cover, (3) prior damage from the C.G.-over-corner drop, and (4) prior damage from the side-edge drop. For the complementary testing, the CTU-2 was first dropped onto the puncture bar in the area of prior damage from the 9-m C.G.-over-corner drop and then in the region outside a puncture-resistant structure.

Section 2.7.3.2 of the application notes that the primary means of puncture resistance is afforded by the use of puncture-resistance plates embedded in the overpack materials all over the TRUPACT-III packaging. For the three plate types made of Alloy UNS S31803 stainless steel, material tests have been performed at cold temperatures according to ASTM E604 to demonstrate that they are ductile in nature. Therefore, the staff agrees with the applicant's assessment that the puncture resistance of the TRUPACT-III, as demonstrated in prevailing ambient temperatures, is not significantly affected by temperature.

Table 2.7-2 of the application summarizes test details, including orientations of the puncture bar axis with respect to drop surface and purposes of testing, to demonstrate specific puncture-resistance capability of the packaging for the four drops on CTU-1 and the two drops on CTU-2. Sections 2.7.3.3.1 through 2.7.3.3.6 present test conduct and structural performance for the six puncture drops. In addition to penetrations through the CSA outer skin and puncture-resistant plate, local damages, including minor weld cracks and deformations of the thermal shield, if any, were also noted. As reported in Section 2.7.3.3 for the two CTU-2 puncture drops, they exposed no significant amounts of foam or caused significant weld tears, and the containment boundary remained leaktight after all testing was completed.

On the basis of the above review, the staff concludes that the puncture drops performed on the CTU-1 and CTU-2, in aggregate, demonstrate adequate performance of the TRUPACT-III package for meeting the requirements of 10 CFR 71.73(c)(3).

2.7.4 Thermal

See Section 3.0 of the safety evaluation report for the package thermal performance.

2.7.5 Immersion – Fissile Material

The criticality evaluation assumes optimum hydrogenous moderation of the contents. This conservatively addresses effects and consequences of the package water in-leakage for meeting the requirements of 10 CFR 71.73(c)(5).

2.7.6 Immersion - All Packages

Section 2.7.6 of the application analyzes the effects of a 150 kPa gauge pressure applied to the outside of the CSA. The applicant notes and the staff agrees that the stress results are bounded by the analysis performed in Section 2.6.1.3 for an internal gauge pressure of 172 kPa. Section 2.12.4 of Appendix 2.12 to the application calculates a governing stress of 88.7 MPa in the most critical sidewall of the package subject to an external gauge pressure of 150 kPa, assuming also an internal pressure of zero gauge. For the allowable inelastic buckling load of 391 MPa, this corresponds to the factor of safety of 4.41 (391/88.7 = 4.41). Therefore, demonstration of stress and buckling performance of the CSA body meets the immersion requirements of 10 CFR Part 71.73(c)(6).

2.7.7 Deep Water Immersion Test

The TRUPACT-III package does not transport payloads with an activity greater than 10^5 A_2. Hence, the deep water immersion test requirement of 10 CFR 71.61 does not apply.

2.7.8 Summary of Damage

Using two prototypical specimens, CTU-1 and CTU-2, of the TRUPACT-III production unit, the applicant has demonstrated that the HAC testing sequence does not result in any significant package damage and the testing acceptance criteria as established in Section 2.1.2 of the application, “Design Criteria,” are satisfied. Section 2.7.8 summarizes damages incurred to the two certification test units for various structural performance attributes, including primarily: (1) through the post-test leakage rate testing of the CTU-2 containment metallic boundary, closure

lid O-ring seals, and vent port insert O-ring seal, the TRUPACT-III is demonstrated to be capable of withstanding a worst-case 9-m free drop and puncture testing sequence and continuing to remain leaktight, (2) the overpack cover is securely retained on both CTU-1 and CTU-2, and (3) damages incurred on the thermal insulation and polyurethane foam are consistent with the assumptions used for analyzing the thermal fire event. Hence, the staff agrees with the applicant's conclusion that the TRUPACT-III package satisfies all of the requirements of 10 CFR71.73.

2.8 Conclusion

On the basis of the review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

3.0 THERMAL EVALUATION

The TRUPACT-III transportation package payload consists of contact-handled transuranic waste limited to 80 watts of decay heat. The package external dimensions are rectilinear; approximately 4.3 meters long by 2.5 meters wide by 2.7 meters high. The thickness of the package varies from a maximum of 0.75 meters on the ends to approximately 0.33 meters on the sides. The packaging wall material, from outside to inside, consists of 6 mm thick stainless steel plate, 60 mm thick balsa wood, 10 mm thick puncture resistant stainless steel plate, 109 mm thick (minimum) light density foam, 8 mm thick structural stainless steel plate, 4 mm thick stainless steel stiffeners which maintain a 124 mm gap from the 8 mm thick stainless steel containment plate The inner wall of the containment structure assembly (CSA) serves as the containment boundary for the package and its bolted lid is sealed with butyl elastomer o-rings which need to be protected from accident extreme temperatures. The end cross sections have a similar configuration except the sheet steels bounding the stiffeners are thicker, and the foam is slightly thicker. The bolted flat closure lid is protected by an energy absorbing overpack. The payloads for all TRUPACT-III transportation packages are contained within a steel box called the Standard Large Box 2 (SLB2).

3.1 Description of the Thermal Design

The heat transfer types used in the design of the TRUPACT-III include conduction and radiation within the packaging, and convection and radiation external to the package. The CSA is insulated from thermal temperature swings during normal and accident conditions by the balsa wood and polyurethane foam. However, the corners of the CSA are structurally supported with 6 mm thick stainless steel that provide a direct heat transfer path from the outside of the package to the internal containment sheet. The bolted closure lid for the CSA is thermally protected by the overpack cover assembly which contains similar configurations of stainless steel encased balsa wood and foam.

The thermal loading of 80 watts of decay heat is applied to the inner surface of the CSA via a hypothetical waste box that is dimensionally smaller than the SLB2 to conservatively provide a lower bound for the credible volumetric heat loading and credible non-uniform distribution of decay heat. The hypothetical waste box is centered within the CSA to maximize the payload temperature and therefore provide the highest pressurization. Shifting the hypothetical waste box to the lid end would cause the seal temperature to increase, but the effect would be minor due to the presence of bumpers on the SLB2 which maintain an air space. The maximum

temperature of the SLB2 during NCT hot conditions is 144.1 °F (62.3 °C) which is below the seal NCT limit. The payload decay heat is assumed to be distributed equally within the hypothetical waste box. This assumption is justified because as stated above, the hypothetical waste box is dimensionally smaller than the SLB2 to conservatively provide a credible non-uniform distribution of decay heat, and the thermal conductivity of the SLB2 volume is that of air which creates a bounding peak payload temperature that is below the seal NCT limit.

Closures for the containment test port and vent port are made with O-rings composed of butyl rubber. Impact and thermal protection of these seals is provided by the overpack cover assembly. To provide additional thermal protection in the area of the containment seals, a 42 mm thick layer of calcium silicate insulation is used, which is held in place and protected by a 16 mm thick stainless steel plate. Also, the extension arms of the overpack cover assembly include a 30 mm layer of calcium silicate insulation protected by 16 mm thick stainless steel plate.

Table 3.1 - Summary of Maximum Package Temperatures (from Table 3.1.1 of SAR)

Component / Location	Temperature °F (°C)			
	NCT Hot	HAC	Maximum Allowable	
			NCT	HAC
Bounding Waste Box Payload				
- Maximum	324.0 (162.2)	350.6 (177)	446.0 (230)	446.0 (230)
- Bulk Avg.	194.7 (90.4)	224.6 (107)	446.0 (230)	446.0 (230)
Standard Large Box (SLB2) Payload				
- Maximum sidewall	144.1 (62.3)	192.2 (89)	446.0 (230)	446.0 (230)
- Bulk Avg. of total volume	145.4 (63.0)	181.4 (83)	446.0 (230)	446.0 (230)
Containment O-ring Seal	126.7 (52.6)	203.0 (95)	224.6 (107)	399.2 (204)
Sampling/Vent Port O-ring Seal	124.2 (51.2)	176.0 (80)	224.6 (107)	399.2 (204)
Debris Shield	126.7 (52.6)	203.0 (95)	248.0 (120)	--
Containment Structure Assembly (CSA) Containment Sheet	132.1 (55.6)	431.6 (222)	600.8 (316)	600.8 (316)
Foam				
- Package Body, Peak	153.1 (67.3)	1263.2 (684)	500.0 (260)	--
- Package Body, Avg	125.4 (51.9)	204.8 (96)	149.0 (65)	--
- Package Corner, Peak	180.3 (82.4)	1466.6 (797)	500.0 (260)	--
- Package Corner, Avg.	126.1 (52.3)	372.2 (189)	149.0 (65)	--
- Package Cheek, Peak	171.1 (77.3)	1472 (800)	500.0 (260)	--
- Package Cheek, Avg.	121.5 (49.7)	703.4 (373)	149.0 (65)	--
- Overpack Cover Outer Area, Peak	182.5 (83.6)	1457.6 (792)	500.0 (260)	--
- Overpack Cover Outer Area, Avg.	126.3 (52.4)	336.2 (169)	149.0 (65)	--
- Overpack Cover Recess Area, Peak	137.5 (58.6)	1283.0 (695)	500.0 (260)	--
- Overpack Cover Recess Area, Avg.	122.9 (50.5)	210.2 (99)	149.0 (65)	--
Balsa Wood				
- Package Body, Peak	187.2 (86.2)	1459.4 (793)	212.0 (100)	--
- Package Body, Avg.	131.5 (55.3)	851.0 (455)	149.0 (65)	--
- Overpack Cover, Peak	152.4 (66.9)	1443.2 (784)	212.0 (100)	--
- Overpack Cover, Avg.	124.3 (51.3)	840.2 (449)	149.0 (65)	--

Table 3.2 - Summary of Package Maximum Pressures (from Table 3.1.2 of SAR)

Condition	CSA Cavity Temperature °F (°C)	Pressure kPa gauge (psig)
NCT Hot	138.2 (59)	172 (25)
HAC	307.4 (153)	249.3 (36.2)

3.2 Material Properties

The material properties for the stainless steels related to the thermal evaluation are taken from the ASME Code. The thermal properties for the alloy steel closure bolts are likewise taken from the ASME Code.

In lieu of precise modeling of the geometry for the CSA sidewall, CSA lid, the box beam structure at the end of the CSA structure and around the perimeter of the closure lid; the components are modeled using effective thermal properties resulting in simulated homogeneous solids. The staff reviewed the methodology for calculating the effective thermal properties for the CSA sidewall and lid structures, presented in Appendices 3.5.2.4 and 3.5.2.5 and found them to be acceptable.

The thermal properties for the foam, balsa and calcium silicate insulation are assumed to be constant with temperature for the NCT. During the HAC fire, the staff noticed the calcium silicate maximum temperature exceeded the material temperature range provided in the SAR, but this peak temperature occurs on the outside of the calcium silicate and one would not expect to see any effect on the underlying maximum seal temperature.

Under NCT the thermal properties for the four densities of foam used for TRUPACT-III remain essentially constant and were taken from the manufacturer's on-line data. The thermal properties for the foam under HAC are described in Appendix 3.5.4 of the SAR and are summarized below:

- The General Plastics LAST-A-FOAM FR-3700 (i.e., foam) has been used in numerous transportation packages for its shock absorption and thermal insulation capabilities

- Upon exposure to fire temperatures, the foam decomposes into a char that swells and tends to fill voids or gaps created by the free drop or puncture. At the same time the resultant char layer protects the underlying undamaged foam from further direct exposure to the fire temperature

- The thermal decomposition of the foam from the fire is an endothermic process, resulting in the foam absorbing a significant amount heat, which is then expelled from the package as a high temperature gas. The gases generated by the decomposition process are combustible and will burn while exposed to flame.

- The foam is self extinguishing and will not support a flame once the external fire is removed. However, some of the gases could remain trapped within the charred layer of foam and support a limited amount of combustion until the gas is depleted.

The thermal conductivity of balsa wood is taken from the SCALE computer code database which gives a value for cross grain as 0.05 W/m-K. The Wood Handbook lists a maximum ratio of 2.8 for across grain vs. cross grain properties and also noted that the variation in values could be 20%. For NCT the applicant conservatively used approximately a 20% reduction in the SCALE value for thermal conductivity in both the “With-grain” and “Cross-grain” values. The staff agreed with this approach because the foam and balsa wood will act to insulate the payload heat load and increase internal temperatures. However, the insolation heat input would be impeded by the lower balsa wood thermal conductivity, but would not adversely affect the internal temperatures because of the foam insulation. For HAC, the balsa conductivity was increased by a factor of 2.8 and 20% to increase the heat input into the package. When the balsa wood is fully exposed due to puncture damage, the wood is assumed to be gone at the start of the HAC fire, therefore exposing the underlying structure to the HAC fire environment.

The staff reviewed the thermal radiative properties of absorptivity and emissivity used for the packaging materials and found them to be consistent with the regulatory guidance.

3.3 Thermal Evaluation for Normal Conditions of Transport

The thermal model of the TRUPACT-III was developed using the Thermal Desktop and SINDA computer programs. The configuration of the model is symmetrical about the package’s axial axis and 180° symmetry about the package vertical axis, resulting in one quarter of the package volume being modeled. Further, the model assumes that the package is in its normal horizontal orientation. The model captures the thermally sensitive seal region. The model consists of over 11,000 solid elements and 9,000 planar elements with approximately 14,700 thermal nodes. One boundary node is used to represent the ambient environment for convection purposes and a second boundary node is used to represent the ambient temperature for radiation heat transfer. An effective emissivity of 1.0 is assumed for the fire. To account for the lack of contact between component interfaces with either foam, balsa wood, or calcium silicate an air gap of 0.5 mm to 1 mm thickness is modeled and only conduction is modeled for conservatism (i.e., radiation ignored). As stated earlier in Section 3.1 of this SER the SLB2 is represented by a hypothetical bounding waste box of smaller volume with the heat load evenly distributed within its volume, and centered within the package. The SLB2 can be rolled into the package via a roller floor pallet or slid into the package onto a floor pallet structure. The pallet structure is simulated in the model by two 4.75 mm aluminum sheets separated by a 66.7 mm airspace. The vent port temperature was calculated from a set of lid nodes where the actual vent port would be located on the lid as well as at a symmetrical lid location to provide a representation of the potential vent port temperature.

3.3.1 Heat and Cold

As seen from the analysis results for maximum NCT temperatures in SAR Table 3.3.1, reducing the heat load from the maximum of 80 watts to 20 watts has a minimal effect on package temperatures. Therefore, the maximum package NCT temperatures are dependent primarily upon the ambient temperatures. The staff notes that the use of air gaps between component interfaces with either foam, balsa wood, or calcium silicate, results in inhibiting the transfer of heat into the package from the ambient. To address this, the applicant performed a sensitivity study assuming no air gaps between component interfaces and the resulting peak temperatures decreased but by less than 1°C.

As for the minimum NCT temperature requirement of -40 °F (-40 °C), all TRUPACT-III components have a minimum service allowable temperature below this value. Specifically, the butyl rubber O-rings used for the containment seals and sampling/vent port have a minimum service allowable temperature of -65.2 °F (-54 °C). The applicant demonstrated by analysis that the maximum accessible external surface temperature is 107.6 °F (42°C) without insolation which is below the regulatory limit in 10 CFR 71.43(g) of 122 °F (50 °C) required for packages under nonexclusive use. This package will be transported under exclusive use where the regulatory limit in 10 CFR 71.43(g) is 185 °F (85 °C). Because of the margin between the calculated maximum accessible external surface temperature and the exclusive use limit, the relatively low maximum decay heat of the package, and the overall size of the package, the staff determined that it is not necessary to perform a temperature survey during the final preparation for transport of the loaded package.

3.3.2 Maximum Normal Operating Pressure (MNOP)

The applicant declares that the MNOP over the maximum shipping period is limited to 172 kPa gauge (25 psig) by design. Justification for the MNOP is provided in Section 5.4 “Compliance with Design Pressure and Total Gas Generation Limits” of the TRUPACT-III, Authorized Methods for Payloads Control (TRAMPAC) Rev.1. Its value is based on consideration of the amount of air initially in the TRUPACT-III cavity, the amount of gas generated in the waste in the payload containers, the expansion of the gases due to their temperature under NCT operating conditions, and the amount of water vapor in the package. It should be noted that use of operational controls to limit the package’s pressure is contrary to ASME Code practice of either ensuring that the vessel is designed to the maximum achievable pressure or using a relief device to limit the maximum pressure. However, these containers are not built in accordance with full compliance with the ASME code.

3.4 Thermal Evaluation of Hypothetical Accident Conditions

The thermal performance of the TRUPACT-III package under HAC is evaluated using a computer analysis rather than actual fire testing. The condition of the package was based on the full scale drop testing of the certified test unit which includes damage resulting from the 30 foot drop followed by the puncture bar drops. The damaged package configuration to be analyzed included the oblique free drop on the side-edge of the package (i.e., Test LD5), followed by a puncture bar impact just aft of the cheek to body joint. Justification of these drop test selections is that the oblique 30 foot drop on the side edge of the package will produce the most significant damage over the greatest surface area compared to any of the other free drop scenarios and the puncture bar impact location will produce the greatest damage compared to the other puncture bar impacts and places that damage close to the closure seals. Additional description of drop and puncture damage dimensions is provided in Appendices 3.5.2.6 and 3.5.3 of the SAR. The applicant stated a longer puncture bar would not produce more damage. Based on the video record, the package does not receive any support from the ground before the energy of the puncture has been absorbed. As the package rolled off the bar, the bar bends, reaching the limit of damage to the package. A longer bar would have bent sooner yielding less damage than a shorter bar. The applicant also stated that a puncture closer to the containment seals would not have produced additional damage because the overpack wall structures are stiffer in the region of the seals and the bar would not have passed through the package center of gravity.

The packages initial conditions prior to the fire were based on the NCT hot condition which includes insolation effects which is beyond what the regulations require and is an added conservatism.

The HAC thermal model consisted of making the following changes to the NCT thermal model:

- Simulated the worst case damage to the package resulting from a 30 foot oblique side edge drop and a puncture just aft of the cheek to body joint (area of seals).

- Changed the conductivity of the balsa wood to a value in the high end.

- Increased emissivity of external surfaces to 0.9.

- The thermal properties of solid wood rather than charred wood are used for the balsa wood protected by the outer skin (i.e. no damage) and are conservative since the thermal conductivity of solid wood is greater than charred wood. Any balsa wood that is fully exposed due to the puncture damage is assumed to be gone at the start of the HAC fire.

- Assumed direct contact between the layered components of the package side wall (i.e. no gaps).

- Replaced the adiabatic boundary condition for the package bottom with radiative and convective heat transfer.

- Applied forced convention heat transfer coefficients during the fire and still air convection coefficients post fire.

- An 1475 °F (800 °C) ambient temperature is assumed during the fire along with an emissivity of 1.0. Post fire the ambient temperature is set at 100.4 °F (38 °C), with an emissivity of 1.0 and insolation added.

As a result of the analysis performed, the applicant demonstrated that all long-term material temperature limits were not exceeded except for the CSA structural sheet. The CSA structural sheet in the area of the puncture bar drop reached a local maximum temperature of 1272.2 °F (689 °C) which lasts less than one hour. Localized full embrittlement would not occur unless the CSA structural sheet was exposed for approximately 1 hour at 1337 °F (725 °C). The containment sheet is at a much reduced temperature of 431.6 °F (222 °C), and as such the containment will continue to perform its function post HAC fire. The applicant performed further thermal analysis to show how the CSA stiffeners act to restrict heat flow into the containment sheet under the transient high heat flux conditions that exist for the portion of the CSA surface exposed by the puncture bar attack.

The maximum pressure within the CSA as a result of the HAC fire is determined by using the MNOP pressure at the initiation of the fire and applying the ideal gas law for a void volume fire temperature of 307.4 °F (153 °C). This results in a maximum fire pressure increase of 77.3 kPa or a maximum pressure of 249.3 kPa gauge (36.2 psig) for the CSA which is structurally evaluated in Section 2.7.4 of the SAR. Operational controls are used to limit the amount for flammable gas buildup within the package by limitations on the payload. It should be noted that use of operational controls to limit the package's pressure is contrary to ASME Code practice of

either ensuring that the vessel is designed to the maximum achievable pressure or using a relief device to limit the maximum pressure. However, these containers are not built in accordance with full compliance with the ASME code.

3.5 Conclusion

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 package meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

4.1 Description of Containment System

4.1.1 TRUPACT-III Package

The containment system of the TRUPACT-III package consists of the inner surfaces of the containment structural assembly (CSA), the inner sheet of the closure lid, and the innermost O-ring seal. The single containment boundary penetration is a stainless steel vent port with a mating inner butyl O-ring seal. The containment system is constructed primarily of Alloy UNS S31803 duplex stainless steel, with the elastomer butyl rubber containment O-rings meeting the acceptance tests described in SAR 8.1.5.3. The main containment O-ring seal and the vent port O-ring seal are designed to demonstrate “leaktight” sealing integrity as defined in ANSI N14.5, “Radioactive Materials – Leakage Tests on Packages for Shipment.”

With the potential that the debris, generated by HAC free drop and puncture tests, can intrude on the containment boundary through the closure joint and the O-ring seal due to transient separation of the closure joint, the elastomer non-response, the pressure difference across the containment seal, and the sliding motions, the applicant modified the package design by (1) including a debris shield with the silicone foam insert to prevent the debris from reaching the main closure lid containment O-ring seal, and (2) adding a porous polyurethane filter to reduce the debris particles and act as a pathway for the leakage rate test. The debris shield design with the silicon foam insert and the porous polyurethane filter provides an equivalent pathway for the helium leakage rate test to verify that the closure joint remains leaktight. The staff reviewed SAR Figure 1.1-7 and Drawing 51199-4 for the configuration of the debris shield and accepted that the filter can acts as a pathway to ensure that the helium can reach the containment O-ring seal for the helium leakage rate testing at the closure lid O-ring seal, as well as can prevent a pressure build-up across the silicon foam insert that might promote movement of the debris past the insert.

All containment boundary welds are full penetration and have been radiographed to confirm the structural and containment integrity. The fabrication leakage rate testing of the entire containment boundary is performed to demonstrate a leakage rate not greater than 1.0×10^{-7} ref-cm^3/sec, as described in SAR 8.1.4.

The closure lid of the TRUPACT-III package is secured by (44) M36 x 4 socket head cap screws tightened to a torque of 1,600 ± 120 N-m. The overpack cover is installed over the closure lid, and is secured with (10) M36 x 4 socket head cap screws tightened to a torque of 1,600 ± 120 N-m. Installation of the overpack cover prevents the closure lid and vent port from being inadvertently opened.

4.1.2 TRUPACT-III TRAMPAC Payload Control

The contents of the TRUPACT-III package consist of transuranic waste from U.S. Department of Energy (DOE) facilities and its national laboratories, inside of an SLB2 payload container. This waste material has the potential to generate flammable gases while staying inside the package. The TRUPACT-III Authorized Methods for Payload Control (TRAMPAC) is the governing document for the characterization and loading of the transuranic waste into the TRUPACT-III package. Conformance with the requirements in this document ensures that any combustible gases generated in the package during the time the package is sealed during transport do not exceed 5% (by volume) of the free gas volume in any confined region of the package.

The applicant specified in Section 5.3 of TRUPACT-III TRAMPAC that the containers that have been stored in an unvented condition shall be aspirated for the specific length of time to ensure equilibration of any gases that may have accumulated in the closed container. The staff agreed that the aspiration requirement is applicable only to the containers that have been stored in an unvented condition, and the aspiration time shall be determined using the methodology outlined in Appendix 3.7 of the CH-TRU Payload Appendices.

4.2 General Consideration

4.2.1 Type A Fissile Packages

TRUPACT-III package is a reusable shipping package designed to protect greater than Type A quantities of radioactive material from both NCT and HAC as required by 10 CFR 71.

4.2.2 Type B Packages

The TRUPACT-III transportation package is a Type B(U)F-96 package, with Criticality Safety Index (CSI) of zero (0.0).

4.2.3 Combustible-Gas Generation

Hydrogen Gas Generation:

For any package containing water and/or organic substances that could radiolytically generate combustible gases, the hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume of the innermost layer of confinement if present at standard temperature of 32 ^{o}F and pressure of 14.7 psia (STP). The applicant recognized that the primary mechanism for potential hydrogen generation in TRU waste is radiolysis and evaluated the hydrogen generation based on the waste type, the waste material type (gas generation potential), the gas resistance (type of payload container and type and maximum number of confinement layers used), and the shipping period (a 10-day period for controlled shipment and a 60-day period for non-controlled shipment).

The applicant stated that the evaluation of compliance with flammable (gas/VOC) limits is performed under either the analytical category or the test category. The TRUPACT-III TRAMPAC requires all SLB2 to be screened for a total flammable VOC head space concentration of less than or equal to 500 parts per million (ppm) for compliance evaluation under the analytical category, or greater than 500 ppm under the test category, as outlined in CH-TRU Payload Appendices.

The staff recognized that while the predominant flammable gas in TRUPACT-III is hydrogen, the presence of methane and flammable volatile organic compounds (VOCs) must be limited along with hydrogen to ensure the absence of flammable (gas/VOC) mixture in the TRU waste payloads. The staff also accepted the methods of compliance and verification that if the

payload container meets the analytical decay heat limit, the compliance with the flammable (gas/VOC) limits is ensured.

Maximum Normal Operating Pressure (MNOP) Limit:

The applicant calculated the pressure increase in TRUPACT-III, based on three sources: 1) the pressure increase generated by the radiolysis and the subsequent thermal expansion, 2) the pressure increase by the thermal expansion of the initial gas, and 3) the pressure increase from water vapor. The staff reviewed the methodology and the bounding calculations, described in TRUPACT-III TRAMPAC Section 5.4 and Table 5.4.2, for waste types I, II, and III under the corresponding decay heat limits of 80 watts (type I), 80 watts (type II), and 20 watts (type III), and ensured that the gas generation rate limits and the maximum pressures for the waste types I, II, and III, in a TRUPACT-III package, are below the allowable limits and are in compliance with 10 CFR 71.43(d).

The staff also concluded, through the confirmatory analysis (Table 1), that the waste material types I and II are bounded, in the pressure increase, by the waste material type III, because of its higher activation energy and effective G value in the radiolysis.

Table 4.1 – TRUPACT-III Pressure Increase of 60-day Duration

Pressure Increase	Waste Material Type I.1	Waste Material Type II.1	Waste Material Type III.1
Applicant's calculations	22.65 psig	20.84 psig	25.00 psig
Staff's confirmatory calculations	22.67 psig	20.86 psig	25.04 psig

4.3 Containment under Normal Conditions of Transport

Under the normal conditions of transport specified in 10 CFR Part 71.71, the applicant evaluated the package for thermal performance in SAR 3.3, and for structural performance in SAR 2.6. The package is also subject to full scale structural testing, as described in SAR 2.12.3. The applicant demonstrated, through the structural and the thermal tests, that the seal region of the package will remain within the acceptable temperatures of 107°C for the seal materials and the containment boundary will not significantly deform under the testing requirements of §71.71. Therefore, the package will remain leaktight under normal conditions of transport.

The maximum normal operating pressure (MNOP) of the TRUPACT-III package is 25 psig. The pressure developed in the package is a function of the initial quantity of gas in the containment vessel, the quantity of gas generated by radiolysis of the contents, and the quantity of water vapor, which may exist in the package, during normal conditions of transport. The applicant calculated the total amount of gas, which can be generated by radiolysis for the package in Section 5.4 of the TRUPACT-III TRAMPAC. This section also determines the maximum pressures of the package, containing waste material types I, II, and III, during the 60-day shipping period. Based on the structural evaluation in Section 2.0 of the SAR, the MNOP of 172 kPa (25 psig) will not reduce the containment effectiveness of the TRUPACT-III package.

4.4 Containment under Hypothetical Accident Conditions

Under the hypothetical accident conditions specified in §71.73, the applicant evaluated the package for the thermal performance in SAR 3.4, and for the structural performance in SAR 2.7. The package was also subject to full scale structural testing with the added debris shield design, as described in SAR 2.12.3. The primary success criterion was that, subsequent to all free drop and puncture tests, the CTU containment boundary, including the closure lid and vent port seals, is verified to be leaktight per ANSI N14.5.

The staff verified that the temperatures, the pressures and the physical conditions are consistent with those determined in Structural and Thermal Evaluation sections of the application. The staff confirmed that the temperatures of the O-ring seals at closure lid and the vent port are below the allowable temperature limits under HAC, in compliance with 10 CFR 71.73.

4.5 Leakage Rate Tests for Type B Package

Post-test helium leakage rate testing on TRUPACT-III with debris shield:

As discussed in SAR 2.12.5.2, the post-test helium leakage rate testing of the closure lid containment O-ring seal, performed in the original TRUPACT-III (without debris shield), failed due to contamination of the sealing nip. The contamination was present in the form of small debris particles, which were generated by the numerous collisions of the aluminum round bars which made up the simulated payload in the testing.

Therefore, the applicant modified the design by adding a debris shield to the package, and performed a supplemental certification test using a new full-scale package which includes the debris shield and using the worst-case free drop and puncture orientation, as specified in SAR 2.7.1.4.5 and 2.7.8, to confirm the ability of the modified TRUPACT–III (with debris shield) to remain leak tight in the absence of the debris on the containment seal. In the testing, the applicant applied a vacuum to the annulus between the two O-rings in the closure lid and achieved the lowest vacuum below 200 millitorr or 0.00026 atm, indicating a good seal for the TRUPACT-III with debris shield. Then after the subsequent drop and puncture tests, the applicant performed the post-test helium leakage rate testing and demonstrated, in SAR 2.12.6.8.1, the leakage rates of 1.7×10^{-9} Pa-m^3/s, He ($\approx 7.6 \times 10^{-9}$ ref-cm^3/s) for the metallic containment boundary, zero leakage for both the vent port containment O-ring seal, and the closure lid containment O-ring seal, where zero means no detectable leakage rate in the range tested (10^{-9} Pa-m^3/s, He).

After reviewing the material properties and the post-test leakage test conditions of the TRUPACT-III package (with the debris shield) and discussing with the structural reviewer and the material reviewer, the staff concluded that:

- both elastomeric O-ring and silicon foam insert at the closure lid are organic in nature and non-corrosive to the stainless steel containment boundary of the package,
- both silicon foam insert and polyethylene filter, as part of the debris shield, are made of the inert materials which will not contribute to corrosion and will not affect the containment if any corrosion occurs,
- the containment boundary of the new design is not affected by both drop and puncture tests, and
- the debris shield in the package successfully prevents the contamination of the containment closure lid O-ring seal.

The staff further confirmed, through assurance of the conclusions above and demonstration of

the post-test leakage rate testing specified in SAR 2.12.5, that the containment metallic boundary, the closure lid O-ring seal, and the vent port insert O-ring seal remained leaktight after drop and puncture tests on TRUPACT-III (with debris shield), and met the leaktight criteria of 1.0 x 10^{-7} ref-cm^3/s, in accordance with ANSI N14.5.

4.6 Conclusion and Evaluation Findings

Based on the containment evaluation of TRUPACT-III transportation package, the staff concluded that the containment design of TRUPACT-III package has been adequately described, and evaluated and that the package design satisfies the containment requirements of 10 CFR Part 71 under NCT and HAC.

The staff has reviewed the description of the containment system and has reasonable assurance that the information provided satisfies the containment requirements of 10 CFR Part 71,

The staff has reviewed and evaluated the package under NCT and has reasonable assurance that there shall be no release or dispersal of radioactive contents under the tests, specified in 10 CFR 71.71,

The staff has reviewed and evaluated the package under HAC and has reasonable assurance that there shall be no release or dispersal of radioactive contents under the tests, specified in 10 CFR 71.73,

The staff has reviewed the post-test helium leakage rate testing on TRUPACT-III with debris shield, and confirmed that the containment boundary remained leaktight after all certification testing on TRUPACT-III (with debris shield), and met the leaktight criteria of 1.0 x 10^{-7} ref-cm^3/s, in accordance with ANSI N14.5.

The staff has reviewed the methodology and the calculations of hydrogen generation, and has reasonable assurance that there will be no flammable gas (hydrogen) greater than 5% in concentration, in compliance with 10 CFR 71.43(d),

5.0 SHIELDING EVALUATION

The objective of the review is to verify that the shielding of the TRUPACT-III package provides adequate protection against direct radiation from its contents and that the package design meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

5.1 Shielding Design Features

In order meet the dose rate limits established by 10 CFR 71.47 for NCT and HAC the TRUPACT-III packaging relies on limiting the dose rate of the payload container in lieu of using supplemental shielding within the package, and relies on the additional dose rate attenuation from the structural design of the package to ensure that the dose rate requirements are met. The TRUPACT-III package is not designed to provide any significant gamma or neutron shielding. The package consists of five concentric stainless steel sheets that provide an overall composite thickness of 36 mm. A minimum of 109 mm of polyurethane foam and 60 mm of balsa wood occupy the remaining spaces between the containment structural assembly and outer sheet.

5.2 Shielding Evaluation

Since the TRUPACT-III is not designed to provide any significant gamma or neutron shielding, each contact-handled transuranic (CH-TRU) waste payload container is limited such that the external radiation field, both gamma and neutron, is less than 2 mSv/hr at the surface of the payload container. This dose rate limit is for any payload in the container prior to adding any other shielding materials to the payload container for ALARA dose reduction purposes during non-transport handling operations and is required to be performed on the payload container prior to loading into a TRUPACT-III package by the TRUPACT-III TRU Waste Authorized Methods for Payload Control (TRUPACT-III TRAMPAC).

Prior to transport the TRUPACT-III package is surveyed again on the conveyance for both gamma and neutron radiation to demonstrate compliance with the limits of 10 CFR 71.47. Since the TRUPACT-III package is not significantly deformed under NCT, the package will meet the dose rate limits for NCT if the measurements demonstrate compliance with 10 CFR 71.47. The shielding Transport Index (TI) is determined by measuring the dose rate at a distance of one meter from the package surface under the requirements of 49 CFR 173.403.

Shielding materials are not part of the TRUPACT-III package and none are permitted in the payload containers to meet the dose rate limits of 10 CFR 71.47 for NCT. Therefore, any shielding provided by the stainless steel shell walls and polyurethane foam of the packaging is not needed to meet the higher dose rate limits of the HAC. This ensures that the dose rate limit of 10 mSv/hr at a distance of one meter from the package surface under the requirements of 10 CFR 71.51(a)(2) are met.

If during the HAC the payload material is released into the TRUPACT-III package cavity, the dose rate limit of 10 mSv/hr at a distance of one meter from the package surface will always be met since each CH-TRU waste payload container must have a dose rate of less than 2 mSv/hr on contact prior to the addition of any ALARA dose reduction shielding for non-transport handling operations prior to being loaded into the package. Since shielding is not allowed within the package, any release of contents from the payload container during a HAC event will not increase the dose rate significantly or cause it to exceed the dose rate limit for HAC.

5.3 Conclusion and Evaluation Findings

The staff reviewed the description of the package design features related to shielding, and since TRUPACT-III design does not provide any gamma or neutron shielding, nor allows any shielding material to be placed into the payload to meet dose rate limits, found them acceptable. The methods used are consistent with accepted industry practices and standards. The staff reviewed the maximum dose rates for normal conditions of transport and hypothetical accident conditions. The subsequent measurement of the dose rates prior to shipment to ensure that the measured values are below the regulatory limits in 10 CFR 71.47 and 71.51 prior to shipment and that the TRUPACT-III package will remain below these limits under both NCT and HAC.

Based on its 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 package design and contents satisfy the shielding and dose limits in 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The staff reviewed changes to the criticality analysis for the TRUPACT-III package as well as the capability of the package to provide adequate protection against any inadvertent criticality from the payload contents.

6.1 Criticality Design Criteria and Features

The primary feature important for criticality control of the TRUPACT-III package is presence and location of the stainless steel containment vessel sheets and adjoining concentric sheet and plate structures to retain the fissile material under normal and hypothetical accident conditions. Packages in arrays are not limited and assumed infinite.

6.1.1 Criticality Design Features

The TRUPACT-III was evaluated for four different ^{240}Pu loadings, 0, 5, 15, and 25 grams respectively. Since ^{240}Pu behaves neutronically as a poison, the fissile gram equivalent limit increases with increasing ^{240}Pu mass.

The staff evaluated the TRUPACT-III criticality design features and found them acceptable. The applicant's analysis provides reasonable assurance that the criticality safety design of the package meets the regulatory requirements of 10 CFR Part 71.

6.2 Fissile Material Contents

6.2.1 General

The TRUPACT-III packaging is designed to transport contact handled transuranic (CH-TRU) waste and other authorized payloads that do not exceed 10^5 A_2 quantities, and may contain waste contaminated with plutonium fissile materials containing less than or equal to 1% by weight quantities of special reflector materials. The payload of each package is contained within a Standard Large Box 2 (SLB2), with each package containing one SLB2. The contents of the package may be manually compacted by hand. Machine compaction is not allowed.

The composition of the fissile material in the TRUPACT-III consists primarily of ^{239}Pu. Using ANSI/ANS-8.1, the quantities of all fissile isotopes other than ^{239}Pu that are present in the CH-TRU waste material and other authorized payloads are converted to a fissile gram equivalent (FGE) of the most restrictive isotopes for criticality evaluations. The mass limit allowed in each container is limited to 325 FGE ^{239}Pu with no ^{240}Pu content, up to 380 FGE with 25 grams of ^{240}Pu.

Credit is not taken for any parasitic neutron absorption in the CH-TRU waste materials, other authorized payloads, dunnage, or package contents except for any ^{240}Pu that may be present, where credit is taken for the neutron absorption. The waste may contain plastic materials such as anti-contamination clothing, plastic bags, and other plastic refuse. Since the waste is hand packed the volume fraction of potential polyethylene was experimentally determined to be ~13%, so an assumption of 25% by volume was conservatively used.

6.2.2 Special Reflectors

Additional restrictions are placed on the quantity of special reflectors that can be present in the materials placed in the TRUPACT-III package. Any materials that could provide better than the assumed 25% polyethylene/75% water mix is limited to a maximum of 1% by mass. These special reflectors are limited to beryllium and beryllium oxides. Carbon, deuterium, magnesium oxide, and depleted uranium are also special reflectors, but these special reflectors are not subject to the 1% by mass restriction for the reasons summarized in the following paragraphs.

Carbon – Carbon is present as a constituent in CH-TRU waste but not in forms that can reconfigure as a reflector. For example: (1) Carbon may be present as graphite molds or crucibles. In these forms the carbon will be chemically and irreversibly bound to the plutonium or other fissile material and cannot be separated. (2) Carbon may be present in filter media as spent or activated carbon. The plutonium or other fissile material would then be attached to the carbon filter media and would not be easily separated. (3) Granular activated carbon (GAC) pads may also be present in an enclosed bag for the purpose of absorbing volatile organic compounds. Once the GAC pad is placed inside the payload container, there is no method for the carbon to fully surround the fissile material and reconfigure as a reflector. (4) Carbon may also be present in alloys, which are by definition chemically and/or mechanically bound. In summary, there is no identified mechanism that could cause the carbon in CH-TRU waste to be separated from the fissile material and to be reconfigured as a reflector.

Deuterium – The presence of liquid waste in the payload containers, except for residual amounts, is prohibited. As specified by the TRUPACT–III TRAMPAC, the total volume of residual liquid in a payload container shall be less than 1% (volume) of the payload container. This limitation on the authorized contents is such that deuterium will not be present in concentrations of greater than 1% by weight.

Magnesium Oxide – Magnesium oxides used in temperature control applications may be present in solid inorganic waste forms such as glass, metal, and pyrochemical salts. If present, magnesium oxide will be bound to the fissile material and would not be easily separated. Magnesium oxide used for neutralization in solidified material cannot be separated out as it is chemically reacted in the waste generation process. There is no identified mechanism that could cause the magnesium oxide in CH-TRU waste to be reconfigured as a reflector.

Depleted Uranium – Depleted uranium may be present in CH-TRU waste, but it will be chemically and/or mechanically bound to the plutonium or physically inseparable because the densities of uranium and plutonium are similar. Separation by mechanical means or by leaching is extremely difficult and is considered highly unlikely in CH-TRU waste. Depleted uranium in CH-TRU waste will, therefore, not be separated from the fissile material and reconfigured as a reflector.

6.3 General Considerations

6.3.1 Model Configuration

Due to the nature of the packaged waste in the TRUPACT-III package, any fissile material would likely be distributed throughout the waste volume. However, under accident conditions water in-leakage may cause the fissile material to migrate within the package. Due to the unknown geometric configuration of the fissile material, the applicant conservatively chose to

model the fissile material in a spherical lump, which is bounding for any configuration of the material.

The applicant performed a parametric study of the H/X ratio for the four possible configurations of the $^{239}Pu/^{240}Pu$ material and determined the most reactive radius of the sphere for each. MCNP was used by the applicant to model various scenarios and parametric studies to determine the most reactive configuration for both single packages and arrays under NCT and HAC.

The SAR contains a detailed description of the models used to develop the MCNP code calculations that included all relevant materials and dimensions. Certain materials were replaced with either void or moderator to determine the maximum reactivity of all analyzed scenarios and in all cases conservative assumptions were made.

For NCT, 12 inches of water reflection was used for the single package, and the foam density was varied to maximize the hydrogen density. The calcium silicate used in the closure lid end overpack was assumed to be foam as well for conservatism.

Under HAC, crush damage was evaluated and conservatively assumed to crush all sides of the package, conserving the space between all packages in the array and increasing reactivity. All foam and balsa materials were replaced with water of variable density.

The staff evaluated the criticality models and found them acceptable. The material compositions and densities used were appropriate and provide reasonable assurance that the TRUPACT-III was adequately modeled.

6.3.2 Material Properties

The materials used in the TRUPACT-III package include plutonium, water, stainless steel plates, balsa wood, and polyurethane foam of several different densities as described in Section 6.3.2 of the SAR.

Although the closure lid end overpack contains calcium silicate, this was replaced with foam to increase the hydrogen density to maximize reactivity.

6.3.3 Computer Codes and Cross-Section Libraries

The applicant used MCNP5 v1.30 for the criticality analysis utilizing various cross section sets, including ENDF/B-VII, -VI, and -V based on their applicability to the materials used in the calculations. All cases were run with 1000 neutrons per generation for 510 generations. The SCALE 6 computer software package was used by staff for all confirmatory and validation calculations using the CSAS25 sequence and both the 238 energy group ENDF/B-V nuclear data and the V6-238 library.

6.3.4 Demonstration of Maximum Reactivity

The applicant moderated and internally reflected the package with a mixture of 25% polyethylene, 74% water, and 1% beryllium by volume which is more reactive than using 100% water. For the HAC array, the analysis demonstrated that reducing internal reflection reduces the reactivity at the cost of increasing neutronic interaction between packages. Therefore, the

most reactive condition was simulated by infinitely reflecting the most reactive single package geometry.

Full in-leakage of water was modeled in both the NCT and HAC cases. For the NCT cases, the foam and balsa are modeled explicitly. In the HAC cases these materials are replaced with variable density water, and the effects of crushing the package are assumed to occur on all six sides of the package. This crush assumption has the effect of reducing the distance between the modeled fissile spheres in adjacent packages.

For the HAC array cases, various combinations of fissile sphere locations and reflector densities are used to maximize the reactivity. During their analysis the applicant determined that the most reactive case is a fully-reflected fissile sphere at the center of the cavity. Since the cavity in the TRUPACT-III is relatively large, the fissile material in each package is isolated from adjacent packages and there is no difference between the most reactive single package and array cases.

Staff performed confirmatory analyses on the most reactive configurations described by the applicant. The SCALE6 computer software package was used as an alternate independent code. Significant parameters were varied to ensure maximum reactivity peaks were adequately captured and in all instances staff calculations agreed closely with those performed by the applicant.

6.4 Single Package Evaluation

6.4.1 Configuration

6.4.1.1 NCT Single Package Configuration

The bounding model is the model described in section 6.3.1 of the SAR where all relevant design features of the TRUPACT-III are modeled. The package is externally reflected with 12 inches of water and assumed to be internally flooded with water that fills the CSA annulus as well as the cavity. Within the cavity the internal reflector and moderator is modeled as a mixture of 25% polyethylene, 74% water, and 1% beryllium by volume.

The fissile material is modeled as a sphere at the center of the cavity, varying both the H/X ratio to adjust the radius of the fissile sphere. The four different FGE loadings described in 6.1.1 above were modeled.

6.4.1.2 HAC Single Package Configuration

The bounding model is same model described above with all of the foam and balsa components replaced with water and all sides of the package crushed one inch. The package is externally reflected with 12 inches of water and assumed to be internally flooded with water that fills the CSA annulus as well as the cavity. Within the cavity the internal reflector and moderator is modeled as a mixture of 25% polyethylene, 74% water, and 1% beryllium by volume.

The fissile material is modeled as a sphere at the center of the cavity, varying both the H/X ratio to adjust the radius of the fissile sphere as was done in the NCT case for all four different FGE loadings. The maximum reactivity was the same as that found for the NCT case which indicates

that the package is so well reflected that essentially no neutrons are interactive with the package boundary.

6.4.2 Results

The maximum $k_{eff}+2\sigma$ was found to be 0.93354 for both the NCT and HAC cases. This is under the upper subcritical limit of 0.9392 applicable to this case and demonstrates that a single package is subcritical under NCT and HAC.

6.5 Evaluation of Package Arrays under NCT

6.5.1 Configuration

Since the HAC array analysis demonstrates that the most reactive array configuration is with full density internal reflector and the fissile sphere in the center of the cavity, this assumption is also valid for the slightly larger (i.e., not crushed) NCT case. The NCT single package was infinitely reflected on all sides and a series of cases run for each of the four FGE limits of interest over a range of H/X ratios.

6.5.2 Results

The maximum $k_{eff}+2\sigma$ was again found to be 0.93354 due to the high degree of internal reflection in the cavity. This is under the upper subcritical limit of 0.9392 applicable to this case and demonstrates that an infinite array is subcritical under NCT.

6.6 Evaluation of Package Arrays under HAC

6.6.1 Configuration

Using the bounding single package HAC model the maximum reactivity was found for a wide variety of scenarios with package arrays. The baseline model assumes an infinite array of packages and all foam and balsa are replaced with variable density water. Since neutronic communication between packages is minimized when the package internal reflector is a maximum density, studies were performed to see the effects of reducing the internal reflector, which should allow more neutrons to interact between packages. Reactivity could also be impacted by the relative position of the modeled fissile sphere within the cavity since placing spheres adjacent to each other would tend to increase package to package interactions.

Nine separate computational series were performed for the 325 FGE case, which was found to be the single package most reactive configuration. These studies looked at varying internal reflector density and relative fissile sphere position. The most reactive configuration found for each series was then modeled using the 340, 360 and 380 FGE fissile material configurations to ensure that they were bounded by the analysis as described in section 6.6.1 of the SAR.

6.6.2 Results

The studies performed by the applicant indicated that by removing the external water reflector to maximize interaction between packages had very little effect on the multiplication factors and behaved as a single fissile sphere surrounded by a large reflector. By removing the internal

reflector the interaction between packages was maximized, but resulted in considerably lower k_{eff}s.

This study was repeated by placing the spheres near the corner of the TRUPACT-III package so that in an array eight fissile spheres were placed in close proximity to each other. The reactivity of this configuration tended to decrease due to the parasitic absorption in the steel components of the package.

The study was again repeated by varying the density of the hydrogenous material with the sphere back in the center of the cavity. The reactivity again went down as the density of the hydrogenous material went down, which demonstrated that full internal reflection rather than increased package to package interactions maximizes the reactivity of the TRUPACT-III package.

Lastly, the most reactive configuration was modeled using all four FGE loadouts and the maximum $k_{eff}+2\sigma$ was found to be 0.93354 for the FGE of 340 grams ^{239}Pu with 5 grams of ^{240}Pu. This is under the upper subcritical limit of 0.9392 applicable to this case and demonstrates that an infinite array is subcritical under HAC.

6.7 Fissile Material Packages for Air Transport

Air transport for the TRUPACT-III was not sought by the applicant and is not authorized.

6.8 Benchmark Evaluations

Staff reviewed the benchmark evaluations and bias determination performed by the applicant and found them to be applicable for each identified case. The upper safety limit (USL) and bias were determined using USLSTATS for three trending parameters. These parameters were the H/X ratio, the 240Pu/239Pu ratio, and the energy of the average neutron lethargy causing fission (EALF).

6.9 Burnup Credit

Burnup credit is not used in the analysis of the TRUPACT-III package.

6.10 Conclusions and Evaluation Findings

6.10.1 Section 6 of the SAR, sufficiently describes the packaging design in sufficient detail to allow evaluation of their effectiveness for criticality safety and is in compliance with 10 CFR Part 71.

6.10.2 The fissile material contents are described in sufficient detail to provide a basis for the criticality evaluation of the TRUPACT-III.

6.10.3 The staff has reviewed the criticality description and evaluation of the package and concludes that it addresses the criticality safety requirements of 10 CFR Part 71.

6.10.4 The staff has reviewed the criticality evaluation of a single package and concludes that it is subcritical under the most reactive credible conditions.

6.10.5 The staff has reviewed the criticality evaluation of the most reactive array of 5N packages and concludes that it is subcritical under normal conditions of transport.

6.10.6 The staff has reviewed the criticality evaluation of the most reactive array of 2N packages and concludes that it is subcritical under hypothetical accident conditions, including those conditions applicable under air transport.

6.10.7 The staff has reviewed the benchmark evaluation of the calculations and concludes that they are sufficient to determine an appropriate bias and uncertainties for the criticality evaluation of the package.

6.11 References

- U.S. Code of Federal Regulations, PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL, Title 10, Part 71.

- U.S. Nuclear Regulatory Commission, Standard Review Plan for Transportation Packages for Radioactive Material, NUREG-1609, January 2000.

7.0 PACKAGE OPERATIONS EVALUATION

The objective of this review is to verify that the operating controls and procedures meet the requirements of 10 CFR Part 71 and that the operating procedures are adequate to assure the package will be operated in a manner consistent with it's evaluation for approval. The staff reviewed the TRUPACT-III transport package operating procedures to ensure that the transportation package will be operated in accordance with 10 CFR Part 71, and to ensure the package loading, preparation for package shipment, and the package unloading procedures, are done in accordance with regulatory requirements.

7.1 Package Loading

The applicant stated in SAR 7.1 that the leakage rate testing of the main containment O-ring seal and the vent port O-ring seal shall be performed based on the criteria: (a) the maintenance/periodic leakage rate test will be performed, if the main containment O-ring seal or the vent port O-ring seal is replaced, or the corresponding sealing surface(s) were repaired, and (b) the preshipment leakage rate test will be performed, if there are no changes to the main containment O-ring seal or the vent port O-ring seal, and no repairs are made to the corresponding sealing surface(s).

7.2 Package Unloading

The applicant provides adequate procedures for unloading a payload from the TRUPACT-III packaging in section 7.2 of the SAR. Procedures are provided for removing the packaging from the trailer, removing the overpack cover and closure lid, and unloading the payload from the package.

7.3 Preparation of Empty Package for Transport

The applicant provides adequate procedures for preparing for transport an unloaded package, including procedures to load and secure the package onto a transport trailer if not already done.

7.4 Preshipment Leakage Rate Test

The applicant described in SAR 7.4 that the O-ring seals in the lid and the vent port are designed to facilitate the preshipment leakage rate testing according to the guidelines in Section A.5.2 of ANSI N14.5, *Gas Pressure Rise*, and demonstrated that the package shall have no detectable leakage to a sensitivity of 1 x 10^{-3} ref-cm^3/sec for the preshipment leakage rate test, per Section of 7.6 of ANSI N14.5.

7.5 Conclusion and Evaluation Findings

Based on review of the statements and modifications in the TRUPACT-III package application and TRUPACT-III TRAMPAC payload control, the staff concludes that the package operations meet the containment requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its containment evaluation for approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM EVALUATION

The staff reviewed the TRUPACT-III package to ensure that the package will be tested and maintained in accordance with 10 CFR Part 71, and to ensure that the welding examinations, the fabrication leakage rate tests and the maintenance/periodic leakage rate tests are done in accordance with ANSI N14.5 and the regulatory requirements.

8.1 Acceptance Tests

Section 8.1 of the application specifies review, inspection, and testing of the package. The acceptance tests and inspections considered critical to the safe operation of the TRUPACT-III package are requirements in the CoC.

8.1.1 Visual Inspections and Measurements

Visual inspection requirements are provided which verify the packaging has been fabricated and assembled in accordance with drawings and other requirements specified in the SAR. Dimensions and tolerances specified on the drawings are confirmed by measurement.

8.1.2 Weld Inspections

The applicant will identify and record the locations, types, and sizes of all welds to ensure compliance with the drawings in SAR Appendix 1.3.1, Packaging General Arrangement Drawings. The applicant will visually examine all welds in TRUPACT-III packaging and will inspect the containment boundary welds by radiographic examination (RT). All welds will be liquid penetrant examined, with exception of seal and specific non-structural welds.

8.1.3 Structural and Pressure Tests

The applicant will perform the pressure test on the CSA up to 150% of the MNOP to verify the containment integrity, per the requirements of 10 CFR 71.85(b). The MNOP of the TRUPACT-III package is equal to 172 kPa (25 psig); thus, the CSA will be pressure tested to at least 258 kPa (37.5 psig).

8.1.4 Leakage Tests

The fabrication leakage rate testing of the containment structural assembly is performed according to the guidelines of ANSI N14.5, Section A.5.3, *Gas Filled Envelope – Gas Detector*,

as described in SAR 8.1.4.2. The O-ring seals in the closure lid and the vent port are designed to facilitate the fabrication helium leakage rate testing according to the guidelines of ANSI N14.5, Section A.5.4, *Evacuated Envelope – Gas Detector*. The helium leakage rate tests on the containment structure, the main containment O-ring seal and the vent port O-ring seal are described in SAR 8.1.4.2, 8.1.4.3 and 8.1.4.4, respectively, for the fabrication leakage rate test. For the fabrication leakage rate test, the package shall have a leakage rate of not greater than 1.0×10^{-7} ref-cm^3/sec, demonstrated to a sensitivity of 5.0×10^{-8} ref-cm^3/sec.

8.1.5 Component Tests

Appropriate requirements and acceptance criteria for installation, inspection, and testing of the rigid, closed-cell, polyurethane foam used within the TRUPACT-III packaging is provided. A thermal conductivity test using a heat flow meter and a specific heat test using a differential scanning calorimeter will be conducted to ensure thermal requirements are not exceeded. Appropriate balsa wood inspection requirements are provided to ensure no gross defects and knots exist. Appropriate Butyl Rubber O-ring acceptance tests are provided.

8.1.6 Thermal Tests

Based on the information provided by the applicant, the staff has determined that a thermal test of the TRUPACT-III package is not required because there are significantly large thermal margins for all components as demonstrated in the thermal evaluation, and the package design does not appear to contain unique design features that could be sensitive to fabrication errors.

8.2 Maintenance Tests

The applicant provides adequate maintenance tests for the TRUPACT-III package. The maintenance/periodic helium leakage rate tests on the main containment O-ring seal and the vent port O-ring seal are described in SAR 8.2.2.2 and 8.2.2.3, respectively.

8.2.1 Structural and Pressure Tests

Adequate containment vessel pressure testing and interior cavity surface inspection requirements are provided.

8.2.2 Leakage Tests

The maintenance/periodic helium leakage rate tests on the main containment O-ring seal and the vent port O-ring seal are described in SAR 8.2.2.2 and 8.2.2.3, respectively. The applicant will perform the maintenance helium leakage rate test per Section 7.4 of ANSI N14.5, and the periodic helium leakage rate test per Section 7.5 of ANSI N14.5, to demonstrate a leakage rate of 1×10^{-7} ref-cm^3/s, on both main containment O–ring seal and vent port insert O-ring seal.

8.3 Evaluation Findings

Based on review of the statements and modifications in the TRUPACT-III package application, the staff concludes that the acceptance tests for the packaging meet the containment requirements of 10 CFR Part 71 and that the maintenance program is adequate to assure packaging containment performance during its service life.

CONDITIONS

The following are conditions in CoC No. 9305, Revision No. 0:

- The package is for transport of the CH–TRU materials and other authorized payloads that are limited in form to solid or solidified material. Materials must be restricted to prohibit explosives, corrosives, nonradioactive pyrophorics, and pressurized containers. Within a payload container, radioactive pyrophorics must not exceed 1 percent by weight, and residual liquid volumes greater than 1 percent are prohibited.
- Limits for physical, nuclear, chemical, and gas generation properties shall be as defined in the TRUPACT-III TRAMPAC, Revision 2.
- Hydrogen must be limited to a molar quantity that would be no more than 5% by the volume of the innermost layer of confinement during transport.
- Each payload shipping container must be assigned to a shipping category in accordance with TRUPACT-III TRAMPAC, Revision 2, Section 5.0.
- The gas generated in the payload and released into the cavity shall be controlled to maintain the pressure within the containment vessel below the acceptable Maximum Normal Operating Pressure of 25 psig.
- Venting and aspiration are required to the TRUPACT-III containers stored in an unvented condition prior to transport, to ensure equilibration of gases that may have accumulated in the closed container in accordance with TRUPACT-III TRAMPAC, Revision 2, Section 5.3.
- The package shall be prepared for shipment, operated, tested, and maintained in accordance with Chapter 7 and Chapter 8 of the SAR.
- The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.
- Transport by air of fissile material is not authorized.
- The certificate expires on June 30, 2015.

CONCLUSION

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the Model No. TRUPACT-III package meets the requirements of 10 CFR Part 71.

NRC staff evaluated the TRUPACT-III package and documented the security assessment review separately, as it contains sensitive information that cannot be made publicly available. The security assessment should be reviewed prior to approval of any amendment to this application.

Issued with Certificate of Compliance No. 9305, Revision No. 0,
on June 1, 2010.