SAFETY EVALUATION REPORT
Docket No. 71-9975
Model No. 9975 Package
Certificate of Compliance No. 9975
Revision No. 0

TABLE OF CONTENTS

SUMMARY…………………………………………………………………………………………

1.0 GENERAL INFORMATION 2

2.0 STRUCTURAL REVIEW 5

3.0 THERMAL REVIEW 15

4.0 CONTAINMENT REVIEW 19

5.0 SHIELDING REVIEW 22

6.0 CRITICALITY REVIEW 26

7.0 PACKAGE OPERATIONS 30

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM 32

9.0 CONDITIONS 33

CONCLUSION 34

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SUMMARY

By letter dated September 30, 2013, the U.S. Department of Energy (DOE) submitted an application for the Model No. 9975 package. The application was revised on April 7, 2014, and supplemented on September 16, 2014, with Revision No. 1 of Chapter 6 and of Appendix 6.1.

The Model No. 9975 package is a Category I package used to ship radioactive contents that have been stabilized and packaged in accordance with DOE Standard 3013. This Standard applies to plutonium-bearing metals and oxides containing at least 30 wt. % plutonium plus uranium. The contents are in solid form as oxides and do not generate fission gases. Liquid contents are not permitted in the Model No. 9975 package.

The contents are loaded into four, nested “leak-tight” vessels, i.e., the inner and outer DOE-STD-3013 dual containers, sealed by welding, that are placed within a leak-tight Primary Containment Vessel (PCV) itself placed within a leak-tight Secondary Containment Vessel (SCV). The containers are placed within a 35 gallon-sized drum package with a bolted-flange closure. The 3013 containers of the Model No. 9975 package are inerted with helium or nitrogen to keep the oxygen content in all void spaces less than 5% by volume at the time the container is weld-sealed. Likewise, the PCV is inerted with carbon dioxide to limit the oxygen concentration to less than 5% by volume.

The package has a calculated Criticality Safety Index (CSI) of 0.0. The package utilizes passive cooling to maintain internal temperatures below allowable limits. Packages may be shipped as non-exclusive use conveyance, since the CSI is zero, the TI does not exceed 10, and no accessible surface temperature of the package exceeds the standards of 10 CFR 71.43(g).

The package was evaluated against the regulatory standards in 10 CFR Part 71, including the general standards for all packages and the performance standards specific to fissile material packages under normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

NRC staff reviewed the application using the guidance in "Standard Review Plan for Transportation Packages for Radioactive Material" NUREG-1609, and associated Interim Staff Guidance (ISG). Based on the statements and representations in the application, and the conditions listed in the certificate of compliance, the staff concludes that the package meets the requirements of 10 CFR Part 71.

References

Safety Analysis Report (SAR) Model 9975, S-SAR-G-0001, Revision 1, dated April 7, 2014.

Supplements Chapter 6, Rev. 1, and Appendix 6.1 NCSE, Rev. 1, dated September 16, 2014.

1.0 GENERAL INFORMATION

1.1 Packaging

The PCV is a stainless steel pressure vessel designed, fabricated, and examined in accordance with Section III, Subsection NB, of the ASME Code. The PCV is fabricated from 5-inch, Schedule 40, seamless, Type 304L stainless steel (SS) pipe with a Schedule 40 Type 304L SS pipe cap at the one end. The closed PCV has an internal volume of approximately 313 cubic inches, a usable inside cavity approximately 15 inches deep with a minimum diameter of 5 inches, and weighs approximately 34 lb.

The SCV is a stainless steel pressure vessel designed, and fabricated in accordance with Section III, Subsection NB, of the ASME Code. The SCV is fabricated from 6-inch, Schedule 40, seamless, Type 304L SS pipe with a Schedule 40 Type 304L SS pipe cap at the blind end. A 5-inch, Schedule 40 Type 304L SS pipe is welded to the convex side of the cap to form a skirt to vertically support the SCV. The skirt has two slots on the bottom edge (180° apart) to engage a rectangular key to prevent vessel rotation during removal and installation of the closure. The assembled SCV has an internal volume of approximately 604 cubic inches, a usable cavity approximately 21.5 inches deep with a minimum diameter of 6 inches, and weighs approximately 56 lb.

An aluminum honeycomb spacer, contoured to fit the curved bottom of the PCV, is installed in the bottom of the PCV to provide a flat surface for the 3013 container. Aluminum honeycomb impact absorbers are used in the SCV to reduce the impact loads transmitted between the containment vessels. The impact absorbers are fabricated from 3-mil minimum thickness foil and are rated for an axial compressive strength of 1500 ± 500 psi before deformation.

The packaging assembly is shown in Figures 1.1 and 1.2 of the application and in Drawing R-R2-G-00078. Package weights and overall dimensions are summarized in Table 1.

Table 1 - Package Weights and Overall Dimensions

Nominal Drum Size (gallons)	Drum Diameter (inch)	Drum Height (inch)	Empty Weight (Max.) (lb)	Maximum Payload (lb)	Maximum Gross Weight (lb)
35	20.9	36.1	374	44.4	404

The payload weight must be limited such that the loaded package gross weight is equal to, or less than, the package Maximum Allowable Gross Weight.

An insulation assembly surrounds the shielding and is fabricated from cane or softwood fiberboard insulation manufactured in accordance with ASTM Specification C 208.

The Model No. 9975 packaging consists of a (i) containment boundary, (ii) structural shell, (iii) gamma shielding materials, and (iv) solid neutron shielding materials. The containment boundary is defined as the containment vessel body, the cone-seal plug, outer O-ring, and the leak-test port plug. The radiation shield for the packaging is a stainless steel-lined lead cylinder. The nested

PCV and SCV are loaded into the shielding body. The interior liner consists of a 7¼-inch ID 20-gauge 304L SS cylinder with a 20-gauge bottom and 24.1-inch interior height. The interior liner is used as part of the form for casting the lead shielding body. The lead is ASTM B-749 or B29 and machined, after casting, to a nominal thickness of ½-inch. The lid of the shielding body is ½-inch thick ASTM B-209 1100 aluminum

The Gland Nut is an Important to Safety (Category A) packaging component to ensure that the Leak-Test Port Plug is properly seated and sealed at the containment boundary, but the Gland Nut is not intended to provide containment if the port plug fails. All of the components of the PCV and SCV are "Important to Safety."

1.2 Contents

The 9975 package is used to ship contents of plutonium and uranium oxides, and other compounds in Type B quantities which exceed 3,000 A_2. The contents are in solid form as oxides and do not generate fission gases. Liquid contents are not permitted in the 9975 package. Small concentrations of other actinides, fission products, decay products, and neutron activation products are permitted as long as the concentrations are less than 1,000 ppm each. Assessment of these impurities may be based on process knowledge.

In addition to the radioisotope and impurity restrictions, the following loading conditions apply: (i) the atmosphere within the PCV is diluted to at least 75% CO2, (ii) the 3013 Container shall be inerted with helium or nitrogen such that oxygen content in all void spaces is no greater than 5% by volume at the time the 3013 outer container is sealed (welded closed), and (iii) the maximum radial gap between the 3013 outer container, the inner container, and convenience container(s), is no more than 0.75 inch between each nested container, as measured by the difference in diameters. This requirement for gap size is based on the evaluation of hydrogen generation from plutonium oxide.

The maximum mass of the content envelop is 5 kg. The maximum mass of the package contents is 20.1 kg (44.4-lb).

1.3 Criticality Safety Index

The Criticality Safety Index (CSI) for the package is zero, as an unlimited number of packages will remain subcritical under the procedures specified in 10 CFR 71.59(a).

1.4 Drawings

The packaging is constructed and assembled in accordance with the following drawings:

DWG No. R-R2-G-00078, Rev. 0, 9975 Shipping Package Drum with Flange Closure Assembly.

DWG No. R-R2-G-00083, Rev. 0, 9975 Shipping Package Insulation Assembly, Subassemblies and Details.

DWG No. R-R2-G-00079, Rev. 0, 9975 Shipping Package Shielding.

DWG No. R-R2-G-00080, Rev. 0, 9975 Drum with Flange Closure Subassembly and Details.

DWG No. R-R2-G-00081, Rev. 0, 9975 Shipping Package Primary and Secondary Containment Vessels Subassemblies.

DWG No. R-R3-G-00063, Rev. 0, 9975 Shipping Package Containment Vessel Weldments.

DWG No. R-R3-G-00064, Rev. 0, 9975 Shipping Package Air Shield Weldment.

DWG No. R-R4-G-00102, Rev. 0, 9975 Shipping Primary (PCV) and Secondary (SCV) Containment Vessel Details.

DWG No. R-R4-G-00103, Rev. 0, 9975 Shipping Package PCV Sleeve and 3013 Top Spacer Details.

DWG No. R-R2-G-00082, Rev. 0, 9975 Packaging Alternate 3013 Spacer Components Details.

DWG No. R-R2-G-00107, Rev. 0, Model 9975 Plug and Gland Nut.

1.5 Evaluation Findings

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. 9975 package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL REVIEW

The objective of the structural review is to verify that the structural performance of the package meets the requirements of 10 CFR Part 71, including performance under the tests and conditions for both NCT and HAC.

2.1 Design Features and Design Criteria

2.1.1 Design Features

The major components for the packaging consists of the drum with flange closure, insulation assembly, shielding body, PCV and SCV, and impact absorbers and/or spacers among structural and content components within the containment vessel cavities.

The 20.9-inch diameter by 36.1-inch high 35-gallon drum and the lid with bolted-flange closure are fabricated of the 18-gauge Type 304L stainless steel. Twenty-four ½-inch bolts are used for securing the lid to the drum body. The insulation assembly, which includes the bottom and top subassemblies, is fabricated from cane or softwood fiberboard to fit the drum and surround the shielding body. In addition to providing thermal protection, it also protects the package internals from impact forces associated with the package free-drop scenarios.

The stainless steel-lined lead cylinder shielding body with a 7-1/4-inch inside diameter and a ½-inch thick nominal lead wall closes the nested PCV and SCV. It provides shielding protection during the NCT. No structural integrity credit is taken, however, for the shielding body for ensuring radiation safety performance during the HAC test sequence.

The PCV is fabricated from the 5-inch, Schedule 40, seamless, Type 304L stainless steel (SS) pipe, and has a standard Schedule 40 Type 304L SS pipe cap at the blind end. A head machined from a 6-inch diameter by 2¼-inches long, Type 304L SS bar, is welded to the pipe top end.

Weld joints for both of the vessel bodies are with full penetration/complete fusion circumferential welds. The PCV is closed by a cone-seal plug and nut assembly that holds the O-ring to form the containment boundary at the open end of the vessel. The closed PCV has a cavity, which measures approximately 15 inches deep with a minimum diameter of 5 inches. A 4-inch, Schedule 40, Type 304L SS pipe, is welded to the convex side of the cap to form a skirt to vertically support the PCV.

The SCV is similarly designed and fabricated to the PCV. The assembled SCV has a cavity approximately 21.5 inches deep with a minimum diameter of 6 inches to allow the PCV to be nested within. A 5-inch, Schedule 40, Type 304L SS pipe, is welded to the convex side of the cap to form a skirt to vertically support the SCV

To ensure that containment boundaries are protected from the axial impact loading, aluminum honeycomb spacers and/or impact absorbers are designed for proper stack-up alignment in axial direction for the structural or content components within the containment vessels. This includes: (1) the PCV bottom spacer for contour fitting the curved bottom of the PCV and providing a flat surface for the 3013 container, (2) the SCV bottom impact absorber for contour fitting the curved bottom of the SCV and providing a level top surface on which the PCV stands, and (3) the ring-shaped SCV top impact absorber for separating the PCV cone-seal nut from the SCV cone-seal plug.

To prevent the 3013 container from impacting the PCV cone-seal plug in the event of package mishandling or a transportation accident, the 4.92-inch diameter by 5.06-inches tall 3013 top spacer, which is fabricated of aluminum tubing, is placed on top of the 3013 container to take up the remaining axial space within the PCV cavity.

2.1.2 Design Criteria

The applicant evaluated the packaging design by a series of regulatory drop tests of full-scale prototype specimens of identical and/or similar design as well as supplemental analyses to demonstrate that the containment vessel maintains leak tightness under NCT and HAC. The applicant required that package performance test results must support the assumptions used in the criticality safety evaluations. For structural integrity qualification supplemented by analysis, the design criteria are as follows:

(i) The containment boundaries of PCV and SCV, designated as Category 1 per NUREG/CR-3854, are analyzed in accordance with the methodology and stress criteria specified in ASME Code, Section III, Division 1, Subsection NB, which is consistent with the guidance provided in Regulatory Guide 7.6.

(ii) The bolts of the drum closure are designed to meet the stress criteria specified in ASME Code, Section III, Division 1, Subsection NF.

Structural failure modes such as brittle fracture, fatigue, and buckling were also considered. As noted in Section 2.1.2 of the application, local buckling of the containment vessel wall is evaluated per the Section III of the ASME Code. The application also considers other miscellaneous structural failure modes, including creep of the containment vessels.

2.2 Weights and Centers of Gravity

The gross weight of the package, including the maximum contents weight of 44.4 lbs., is 404 lbs. Table 2.3 of the application lists weights and corresponding center-of-gravity locations for major packaging components. The package's center of gravity is at 17.5 inches, measured from the package bottom.

2.3 Mechanical Properties of Materials

The Model No. 9975 package description is discussed in Section 1.2 of the application. The principal structural members of the Model No. 9975 package are as follows: (1) Drum with Flange Closure (Insulation Assembly, Shielding Body), (2) Primary Containment Vessel, and (3) Secondary Containment Vessel (PCV Bottom Spacer, SCV Impact Absorbers, 3013 Spacer).

The drum is fabricated with a removable head, a bolted-flange closure and no gasket. The drum and lid are fabricated of ASME SA-240, 18-gauge, Type 304L stainless steel (SS). The drum lid is secured by twenty-four 1/2-13UNC-2A, ASME SA-220, Grade L7 bolts, threaded into 1/2-13UNC-2B, ASME SA-194, Grade 8 nuts, which are tack welded on the underside of the flange.

A circular ring, 304/304L SST, ASME SA-479 (bar) is welded to the outer section of the lid for reinforcement and to prevent it from shearing away from the bolts during a HAC event. Four 1/2-inch diameter vent holes, 90-degrees apart, are drilled into the drum 1-inch below the drum flange and are covered with fusible plastic plugs, CAPLUG Model BP 1/2-inch, to prevent water from entering the drum through the vent holes under NCT. In an HAC fire, the plugs combust or melt, allowing the drum to vent gases generated from the insulation to prevent rupture.

The Insulation Assembly surrounds the shielding, and is fabricated from cane or softwood fiberboard insulation, ASTM C-208. The fiberboard is regular grade wall sheathing with a nominal density of 15 lb/cu.ft, cut into 1/2-inch thick disks and rings bonded together with a water-based carpenter's glued into top and bottom subassemblies. Two, ASTM B-209, alloy 1100 aluminum bearing plates provide load bearing surfaces between the shield assembly and the fiberboard insulation. A 24-gauge ASME SA-240, SS air shield, is glued to the top insulation subassembly as a fire-shield to prevent smoldering of the fiberboard in the top subassembly when exposed to air in a fire. A length of 300 series SS sash chain welded to the top of the air shield serves as a handle for removing the top subassembly. In addition, a 1/2-inch thick Firemaster encapsulated blanket is placed between the top insulation subassembly and the drum closure lid. The blanket, manufactured from a ceramic fiber (Kaowool) (6 lbs/cu. ft.) encapsulated in 2 mil SS foil and heat-sealed.,serves as packing to reduce axial movements of the components in the drum.

The radiation shield for the packaging is ASTM A-240, Type 304, 20-gauge SS-lined ASTM B-749 or B-29 cast lead cylinder used to nest the Primary Containment Vessel (PCV) and Secondary Containment Vessel (SCV). Four threaded ASTM A-276, Type 304 SS blocks, are welded along the circumference of the liner to accept closure lid 1/4-inch ASME SA-320 SS screws. The lead is machined after casting to a nominal thickness of 1/2-inch. The lid of the shielding body is ASTM B-209 alloy 1100 aluminum.

The PCV is fabricated from both a 5-inch, ASME SA-403, Grade 304L WP-S (seamless) Type 304L SS pipe (0.258 inch nominal wall) and similar pipe cap welded at the blind end. A head machined from a 6-inch diameter ASME SA-479, Grade 304L, Type 304L SS bar, is welded to the pipe top end. The head is machined to include 5-1/2-12UN-2B internal thread and a female cone-seal surface. A 4-inch, ASME SA-312, Grade TP-304L, Schedule 40, SS pipe, is welded to the convex side of the cap to form a skirt for vertical support of the PCV. The skirt has two slots on the bottom edge 180-degrees apart to engage a rectangular key to prevent vessel rotation during removal and installation of the closure. The PCV closure assembly consists of a Type 304L SS cone-seal plug shaped as a truncated cone and a Nitronic 60 threaded cone-seal nut.

Two O-ring grooves (outer/inner) are machined in the face of the male cone-seal plug. Viton GLT or GLT-S O-rings fit into these grooves to form a leak-tight seal. The cone-seal plug leak-test port is connected by a radial passage drilled to the annular volume between the two O-ring grooves on the sealing surface of the cone-seal plug. The leak-test port is closed by the leak-test port plug and tested after closing. The containment boundary for the vessel is formed by the containment vessel body, the cone-seal plug, outer O-ring and the leak-test port plug.

The SCV is fabricated from both a 6-inch, ASME SA-312, Grade TP-304L, Schedule 40 (seamless), Type 304L, SS pipe (0.280-inch nominal wall) a similar pipe cap welded at the blind end. A head machined from ASME SA-479, Type 304L, SS bar, is welded to the pipe top end. The head is machined to include 6-1/2-12UNS-2B internal threads and a female cone-seal surface. A 5-inch, ASME-SA312, Grade TP-304L, Schedule 40, Type 304L SS pipe, is welded to the convex side of the cap to form a skirt for vertical support of the SCV. The skirt has two slots on the bottom edge 180-degrees apart to engage a rectangular key to prevent vessel rotation during removal and installation of the closure. The SCV closure design is identical to the PCV, however the SCV closure is scaled for its larger height and diameter.

An aluminum honeycomb spacer, contoured to fit the curved bottom of the PCV to provide a flat surface for the 3013 container. The spacer is fabricated from a 3-mil minimum thick foil.

Aluminum honeycomb impact absorbers are used in the SCV to reduce the impact loads transmitted between the containment vessels. The SCV bottom impact absorber is contoured to fit the curved bottom of the SCV cavity and has a flat top, providing a level surface for the PCV. The SCV top impact absorber is ring shaped and separates the PCV cone-seal nut from the SCV cone-seal plug. Both impact absorbers are fabricated from 3-mil minimum thickness.

A 3013 top spacer is fabricated from alloy 6061-T6 aluminum tubing. The spacer is placed on top of the 3013 container to take up the remaining axial space within the PCV cavity and prevents the 3013 container from impacting the PCV cone-seal plug in the event of package mishandling or a transportation accident.

The KRYTOX 240 AC fluorinated grease, used as a cone seal nut thread lubricant, is fully compatible with all grades of stainless steel, as well as the Viton O-rings. Experience with KRYTOX 240 AC also indicates that it helps prevent galling of stainless steel threads.

The staff reviewed the materials selected and determined that they are acceptable and provide reasonable assurance for safety of the package. 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.

2.4 General Standards for All Packages (10 CFR 71.43)

2.4.1 Minimum Package Size

The smallest overall dimension of the package is the drum body diameter at 18.25 inches. This is greater than 4 inches in meeting the minimum size requirements of 10 CFR 71.43(a).

2.4.2 Tamper-Proof Feature

A 0.19-inch diameter hole is drilled through the shank of each of the twenty four ½-inch diameter bolts used for attaching the drum lid to the drum body. Tamper-indicating devices, to meet the requirements of 10 CFR 71.43(b), can thus be installed on the package.

2.4.3 Positive Closure

The package includes securely closed containment vessels by positive fastening devices that cannot be opened unintentionally. The drum lid is held in place by twenty four ½-inch diameter bolts threaded into hex nuts, which welded to the drum flange. Removal of the drum lid requires the breaking of the tamper indicating devices and removal of the 24 bolts. This ensures that the package meets the positive closure requirement of 10 CFR 71.43(c).

2.4.4 Chemical and Galvanic Reactions

Section 2.4.4 of the application discusses reactions due to chemical, galvanic, or other reactions. The applicant states that the Model No. 9975 packaging is designed for dry handling and loading. The absence of water significantly reduces the potential for adverse chemical and galvanic reactions. The packaging is constructed of materials that do not react (chemical, galvanic, or other) with the packaging components or with its contents. A number of dissimilar materials are in physical contact and presented in Table 2.12.

An assessment of corrosion within the package from fiberboard insulation interaction shows that the potential for chemical and galvanic reactions is minimal for components other than the lead shielding bodies. One potential reaction has been identified where the lead of the shielding body may form lead carbonate corrosion as a result of contact with acetic acid from the fiberboard. All lead shielding bodies manufactured after 2007 incorporated an outer jacket to isolate the exterior surface of the lead from the acetic acid environment and minimize the potential for corrosion. Neither the fiberboard, nor the glue presents a significant cross-section for nuclear interaction. Consequently, they are not susceptible to deterioration from radiation.

Table 2.13 summaries the interactions between the radioactive material and other materials inside the PCV. No significant damage will occur to O-rings exposed to radiation from the package contents. A radiation dose in excess of 10^7 rads is required before significant changes to physical properties of the O-ring are observed. No degradation or activation of the structural components is expected at these radiation levels. The Viton GLT and GLT-S elastomer O-rings are compatible with the atmosphere that will be in contact with them; therefore, a chemical reaction that may affect changes in mechanical properties for transportation is not expected.

In a radioactive material packaging, the formation of eutectic at the Pu/SS interface is a concern and will be avoided to prevent the leakage of fissile material to the environment. The eutectic temperature for the Pu/SS is rather low (410°C) and could impact the structural integrity of the containment vessel under HAC involving fire. The Model No. 9975 packaging is also used for long term storage of Pu bearing materials in the DOE complex where the Pu comes in contact with the stainless steel containment vessel. Due to the consequences of the containment breach, the Pu/SS interface temperature is kept well below the eutectic formation temperature of 410°C.

The staff concludes that, during NCT, the PVC/SCV internals will not be subject to continuous or frequent exposure to moisture or that water intrusion is not likely to occur. 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 Important-to-Safety PVC/SCV payload or shielded cavity at various timed intervals provide reasonable assurance against any significant corrosion occurring unnoticed. The staff finds that radiation effect on the elastomeric seals is not a concern, as the seals are replaced on an annual basis.

The staff finds that, by avoiding the use of ferritic steels, brittle fracture concerns are precluded. Specifically, most primary structural packaging components are fabricated of Type 300 series SS. Since this material does not undergo a ductile-to-brittle transition in the temperature range of interest (down to -40ºC), it is safe from brittle fracture. The staff states that, in austenitic SS metal, the force required to move dislocations, is not strongly temperature dependent and dislocation movement remains high (i.e., will deform more readily under load before breaking) even at low temperatures and the material remains relatively ductile.

The staff concludes that the Model No. 9975 packaging Pu/SS interface temperature is safely below the eutectic temperature.

2.4.5 Package valves or other devices

The package design does not incorporate any valves or other such devices. Therefore, the requirement of 10 CFR 71.43(e) does not apply.

2.4.6 Continuous venting

The package design does not incorporate any venting devices and, therefore, the requirement of 10 CFR 71.43(h) is satisfied.

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

2.5.1 Lifting Devices

There are no lifting devices that are a structural part of the package. Therefore, the requirements of 10 CFR 71.45(a)(1) for lifting devices are not applicable.

2.5.2 Tie-Down Devices

The package does not incorporate any structural feature that is used as a tie-down device. Thus, the requirements of 10 CFR 71.45(b)(1) are not applicable.

2.6 Normal Conditions of Transport (10 CFR 71.71)

2.6.1 Heat

Section 2.6.1 of the application considers an ambient temperature of 100°F in still air and isolation for determining the maximum NCT temperatures of 225°F and 239°F for the SCV and the PCV, respectively. The corresponding containment vessel maximum normal operating pressures (MNOP) are 365.4 psig and 165.8 psig. The application notes that each PCV is proof-tested at 1,365 psig and SCV at 1,235 psig, prior to first use. These test pressures are at least 50% greater than the respective design pressures of 900 psig and 800 psig, which bound the MNOPs, and demonstrate satisfactory containment vessel stress performance.

Section 2.6.1.2 of the application notes that, except for an axial stress of 3,303 psi in the PCV, assuming loading the content to PCV with zero clearance, there is no interference stress due to differential thermal expansions among package components, including those between PCV and SCV. The maximum through-wall temperature differential is calculated to be less than 2°F across the PCV and SCV walls. However, a temperature differential of 10°F across the walls is conservatively assumed for calculating thermal stresses for various parts of the containment vessels. The maximum calculated thermal stresses range from 1,720 psi to 2,070 psi, which are evaluated in Table 2.19 for various stress categories for load combinations. They are below the ASME code allowables and are, therefore, acceptable.

Section 2.6.1.3.1 of the application performs closure stress analysis to demonstrate that the containment vessel closure remains seated at internal pressures up to 515 psig and 563 psig for the PCV and SCV, respectively, considering minimum design closure torques. These pressures are much higher than the respective MNOPs of 365.4 psig and 165.8 psig for demonstrating satisfactory closure structural performance.

Section 2.6.1.3.2 considers the design pressures of 900 psig and 800 psig for the PCV and SCV stress analyses, respectively. Table 2.19 also evaluates maximum containment vessel stresses for various load combinations and for relevant ASME Code stress categories, including primary membrane, primary membrane-plus-bending, and total primary-plus-secondary stresses at key locations. The minimum stress margins, which range from 41% to 89%, are all positive and, therefore, acceptable.

On the basis of the above evaluations, the staff concludes that the package meets the 10 CFR 71.71(c)(1) requirements for heat conditions and tests.

2.6.2 Cold

Section 2.6.2 of the application recognizes the use of Type 304L austenitic stainless steel to fabricate the containment vessels and Nitronic-60 alloy the cone-seal nuts, which is effective for resisting brittle fracture at low temperatures. It also notes the tensile strength increases for the temperatures much lower than the ambient cold condition of -40°F. Thus, the staff has reasonable assurance to conclude that the package meets the requirements of 10 CFR 71.71(c)(2) for cold conditions and tests.

2.6.3 Reduced External Pressure

The containment vessels are evaluated under reduced external pressure of 3.5 psia or 11.2 psig (14.7 - 3.5 = 11.2). This amounts to considering an equivalent MNOP of 177 psia (165.8 + 11.2 = 177.0) for the SCV and 376.6 psia (365.4 + 11.2 = 376.6) for the PCV for which the respective MNOPs have previously been determined to be 165.8 psig and 365.4 psig. These pressures are bounded by the design pressures for the SCV and PCV of 800 psig and 900 psig, respectively. Therefore, the staff agrees with the applicant's conclusion that the reduced external pressure has no effect on the package for meeting the requirement of 10 CFR 71.71(c)(3).

2.6.4 Increased External Pressure

The containment vessels are evaluated under an increased external pressure of 20 psia or 5.3 psig (20 - 14.7 = 5.3). Section 2.6.4 of the application performs buckling analyses of the PCV and the SCV, per the ASME Code, Section III, methodology, which consider the effect of the increased external pressure combined with minimum internal containment pressurization. The evaluation concludes, and the staff agrees, that the stresses due to external pressure are very small and will not cause localized buckling of the containment vessels. This satisfies the requirements of 10 CFR 71.71(c)(4).

2.6.5 Vibration

Section 2.6.5 of the application references a 1999 Sandia National Laboratories report, "Tiedown Procedures for Type B Containers Shipped in Safe-Secure Trailer/Safeguards Transporter (SST/SGT) and Ross Aviation Aircraft," and notes that vibration and shock loadings are small and would not cause any fatigue concerns for the package. By also noting that the Model No. 9975 packages have been transported for decades by DOE, with no known damages attributed to vibration, the applicant concludes, and the staff agrees, that NCT vibration loads are very small to cause any loosening of the drum closure bolts. This satisfies the requirements of 10 CFR 71.71(c)(5) for vibration conditions and tests.

2.6.6 Water Spray

As stated in Section 2.6.6 of the application, the drum closure design does not incorporate a seal between the drum flange and the closure lid. By noting, however, the satisfactory tests performed on similar metal-to-metal flange designs to prevent entry of water into the drum, the applicant concludes, and the staff agrees, that the package meets the requirements of 10 CFR 71.71(c)(6) for water spray conditions and tests.

2.6.7 Free Drop

Section 2.6.7 of the application evaluates effects of a 4-ft free drop of the package by making reference to the test results evaluated for the multiple 30-ft free drop tests of the Model No. 9975 packages and/or its equivalent, earlier, prototypes to demonstrate satisfactory package performance. On this basis, the staff agrees with the applicant's conclusion that the package meets the requirements of 10 CFR 71.71(c)(7) for free drop conditions and tests.

2.6.8 Corner Drop

The corner drop test does not apply because the cylindrical package weighs more than 220 lbs in accordance with 10 CFR71.71(c)(8).

2.6.9 Compression

Section 2.6.9 of the application evaluates effects of the compression test by considering a stacking load that is five times the package weight on the Model No. 9975 package and a Model No. 9968 package, which is essentially identical to the previous version of the Model No. 9975 package with a single bolt/nut/ring closure design. The results of the evaluation show that the stresses in the drum and drum flange were below the code allowables. This provides reasonable assurance for the staff to agree with the applicant's conclusion that the requirements of 10 CFR 71.71(c)(9) are satisfied for the compression conditions and tests.

2.6.10 Penetration

Section 2.6.10 of the application evaluates effects of the penetration tests by referring to a previous penetration testing of dropping a vertical steel cylinder onto the closure ring, seam, and surface of each of several 6M style drums with cane fiberboard insulation similar to that of the Model No. 9975 package.

The application notes that the maximum deflection of the drum surface was 1/4 inch and no rupture of the drum or damage to the insulation occurred. On this basis, the staff has reasonable assurance to agree with the applicant's conclusion that the penetration tests do not challenge the integrity of the package for meeting the requirements of 10 CFR 71.71(c)(10).

2.7 Hypothetical Accident Conditions (10 CFR 71.73)

Section 2.7 of the application evaluates the structural performance of the package subject to the HAC tests sequence, per 10 CFR 71.73(a), of free drop, crush, puncture, thermal, and immersions to determine the cumulative effect on the package.

The applicant used a combination of physical testing on the Model No. 9975 package, package prototypes, and its predecessor packages of similar design, to demonstrate how the package meet the performance requirements of 10 CFR 71.73. Section 2.7 also discusses design differences between the current bolted-flange drum closure and the original bolt/nut/ring closure and determines that the differences have an insignificant effect on the structural loads imparted on the containment vessels or the resulting temperatures of the drum internals.

Thus, upon further reviewing of detailed comparisons between the packaging specimens as presented in Appendix 2.5 to the application, the staff concludes that the applicant's approach to supplementing the HAC tests of the current Model No. 9975 package with those of its predecessors provides reasonable assurance to demonstrate adequate package structural performance for the HAC tests.

Also noted in Section 2.7 is the small effect of the ambient temperature change, within the range of -20^{o}F to 100^{o}F, on the capability of the cane fiberboard to provide containment vessels with impact load protection and thermal insulation. This constituted the basis for considering results of package free-drop tests conducted essentially all at ambient temperature of approximately 70°F as acceptable for the subject temperature range. The structural performance for different drop orientations is evaluated below.

2.7.1 Thirty-Foot Free Drop

Table 2.30 of the application lists the tests, each characterized with drop orientation, performed on the Model No. 9975 package, prototypes, and its predecessors that are considered, in aggregate, for demonstrating the package structural performance. Sections 2.7.1.1 through 2.7.1.3 evaluate the tests associated with the top- and bottom-down end drop, side drop, and corner drop test orientations, respectively. The tests demonstrated the ability of the containment vessels to withstand the free drop while continuing to maintain their leakage tightness. A few drops also revealed deficiencies, which had resulted in damages to packaging internals, such as the shifting of lead shield and local crushing of the fiberboard. The deficiencies were corrected subsequently, nevertheless, by design changes, which enhance the free-drop performance of later package designs.

As presented in Section 2.7.1.4 of the application, two oblique drops, the slap-down and shallow-angle drops were performed of the package. The slap-down tests were conducted, with the horizontal side of the drum at angles less than 15 degree, to demonstrate that the angular momentum imparted from the point of impact to the non-impacting end of the drum would not result in failure of the drum closure or significant damage to the fiberboard such that it would not protect the containment vessels during the HAC thermal test. For the bolted-flange closure design, two shallow-angle drops were conducted with the drum oriented at 17.5° and 22.5°, respectively, from horizontal.

The applicant noted that these tests, preceded with 4-ft drops at 60° from horizontal and followed with 40-inch puncture pin drops, produced no observable damage to the drum bolts or evidence of weld breakage.

On the basis of the above review, the staff has reasonable assurance to conclude that the structural performance of the package is acceptable to meet the requirements of 10 CFR 71.73(c)(1) for the free drop tests.

2.7.2 Crush

The crush test is not applicable to this package since the package density of 74.4 lb/ft^3 is greater than 62.4 lb/ft^3 to satisfy the requirements of 10 CFR 71.73(c)(2) for crush tests.

2.7.3 Puncture

Section 2.7.2 of the application notes that puncture tests for various drop orientations were preceded with 30-ft free drops for which the puncture pin is targeted on drum closure. The maximum deflection of the drum surface was observed to be approximately 1-1/2 inches with no rupture of the drum or significant damage to the adjacent Celotex fiberboard.

For the puncture drops following the shallow angle drops, no additional, appreciable damage was added to the drum. Thus the staff has reasonable assurance to conclude that the package is acceptable to meet the requirements of 10 CFR 71.73(c)(3) for puncture tests.

2.7.4 Thermal

The package allows the maximum decay heat of 19 watts in a 3013 container (the content envelope C.12 is limited to 16.7 kW), and utilizes the passive cooling to maintain internal temperatures below the allowable limits. The container shall be inerted with helium or nitrogen to keep the oxygen content in all void spaces less than 5% by volume at the time the container is weld-sealed.

2.7.5 Immersion—Fissile Material

Section 2.7.5 of the application notes that the design of the Model No. 9975 package is similar to the Model No. 9966 package for which the double-containment package has been subject to immersion test under a head of water of at least 3 ft. The staff reviewed comparisons of the details of the two packages presented in Appendix 2.5 to the application and agrees with the applicant's conclusion that the containment vessels design are similar.

Thus, the satisfactory immersion tests on the Model No. 9966 package also demonstrates the capability of the Model No. 9975 package to meet the requirements of 10 CFR 71.73(c)(5) for immersion test for fissile material.

2.7.6 Immersion—All Packages

Section 2.7.6 of the application considers an undamaged Model No. 9966 package, as representative of the Model No. 9975 package, because of the similarity in the containment vessel design. The Model No. 9966 package was immersed in 52-ft of water for 24 hours; an inspection, after retrieval, revealed that the insulation was slightly damped but did not break apart when removed from the drum. The containment vessel was also opened and inspected, which confirmed that water had not leaked into the containment vessel cavity. This demonstrated that the Model No. 9975 package meets the requirements of 10 CFR 71.73(c)(6) for immersion test for all packages.

2.7.7 Deep Water Immersion Test

Section 2.7.7 evaluates the package containment vessel structural design for withstanding an external water pressure of 290 psi for a period of not less than 1 hour without collapse, buckling, or inleakage of water. The calculated stress intensities for both containment vessels are shown to be below the allowables. A buckling analysis was also performed for the containment vessels in Appendix 2.2, which includes a description of how the maximum acceptable external pressure bounds the deep water submersion pressure. Thus, the staff has reasonable assurance that the package is acceptable for meeting the structural performance requirements of 10 CFR 71.61.

2.8 Evaluation Findings

On the basis of the review of the statements and representations in the application, the staff concludes that the structural design and materials of construction have been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71. The staff also finds that the package meets the regulatory requirements for 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.

3.0 THERMAL REVIEW

3.1 Review Objective

The objective of this review is to verify that the package design satisfies the thermal requirements of 10 CFR Part 71 under NCT and HAC.

3.2 Description of Thermal Design

The Model No. 9975 package has an insulation assembly which surrounds the shielding and is fabricated from cane or softwood fiberboard insulation. The package has also an encapsulated blanket which is placed between the top insulation subassembly and the drum closure lid for additional thermal protection. The blanket is manufactured from a ceramic fiber encapsulated in stainless steel foil and heat-sealed. The PCV has the thermal design conditions of 900 psig and 400°F. The SCV has thermal design conditions of 800 psig and 400°F.

The O-ring material is Viton GLT or Viton GLT-S which are fluorocarbon elastomers with a service temperature range between -40°F and 400°F. The temperatures of the lead shield are required to be below 622°F under NCT and HAC. The fiberboard has a bulk design limit of 250°F under NCT even if it can be held at 300°F for an extended period without decomposition and does not ignite below 425°F.

The staff has reviewed the package description and evaluation and concludes that they satisfy the thermal requirements of 10 CFR Part 71.

3.3 Material Properties and Component Specifications

The applicant described the package components in Section 3.3 of the application and listed material properties of the packaging components in Tables 3.5 and 3.6 used for the thermal model. The staff verified and accepted the material properties provided by the applicant.

As described in Appendix 3.5, the char fiber properties were obtained by adjusting the fiberboard thermal conductivity such that the analytical model thermal results matched the HAC thermal testing performed on the actual Model No. 9975 package. The charring of fiberboard (insulation) may extend inward to a depth of 1.4~2.3 inches during HAC, but the remaining thickness of fiberboard is sufficient to ensure that the internal packaging components remain below their thermal design limits. The HAC temperature limit of the fiberboard is not specified since charring of the fiberboard is permitted.

The applicant calculated a highest average gas temperature of 313°F in Appendices 3.3 and 3.17 which bounds the average PCV air temperature of 271°F for the content envelope C.12, as calculated in Appendix 3.22. The highest average gas temperature of 313°F also bounds the maximum average gas temperature of 299°F for the content with very low density Pu oxide and Argon fill gas. The staff reviewed the MNOP calculations based on a 313°F temperature, and agrees with the results.

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

3.4 General Considerations

The thermal models assume fill gas as air inside the 3013 containers, CO_2 inside the PCV, and air inside the SCV. The thermal models are described in Section 3.4 of the SAR for NCT and in Section 3.5 for HAC. The NCT thermal evaluation is provided in SAR Appendix 3.3 and the HAC thermal evaluation, with insolated NCT, is described in Calculation No. M-CLC-A-00441.

The staff has reviewed the methods used in the thermal evaluation and concludes that they are described in sufficient detail to permit an independent review of the package thermal design.

3.5 Thermal Evaluation under NCT

The applicant performed the NCT thermal analysis with the thermal model, a heat generation of 19 watts, insolation with insolation values shown in SAR Table 3.9, external heat transfer with heat transfer coefficients listed in SAR Table 3.10, and internal heat transfer with surface emissivities listed in Table 3.11 of the SAR. The minimum ambient temperature is assumed to be -40°F with zero heating from decay heat of the contents.

The applicant calculated a maximum package surface temperature of 114°F under 100°F ambient and without insolation which is below the limit of 122°F for a nonexclusive shipment. The analyses of worst-case deflagration scenarios show that the maximum possible deflagration pressure pulses in the PCV and SCV are 62.1 psig and 192.4 psig, respectively, which are well below the respective design pressures of 900 psig for PCV and 800 psig for the SCV.

The staff has reviewed the package design and evaluation for shipment and concludes that the package material and component temperatures will not extend beyond the specified allowable limit during NCT consistent with the tests specified in 10 CFR 71.71.

3.6 Thermal Evaluation under HAC

The applicant performed the HAC thermal analysis as described in Section 3.5 of the application and Calculation No. M-CLC-A-00441. The applicant described the thermal model of the 30-minute fire as below:

a) The insolated NCT results are used as initial conditions of the 30-min HAC fire simulation.

b) The forced convection heat transfer coefficients from all surfaces of the drum are 5.9 Btu/hr-ft^2-°F for the top and bottom of the drum and 3.0 Btu/hr-ft^2-°F for the side of the drum.

c) The thermal radiation emissivity from the ambient fire to all surfaces of the drum is 0.9. The ambient temperature is 1475°F with no insolation.

The applicant described the thermal model of the post-fire cooldown as:

a) The natural convection heat transfer coefficients from top and side surfaces of the drum to the ambient are listed in Table 8 of Calculation Report M-CLC-A-00441, Rev. 1.

b) The thermal radiation emissivity from all surfaces of the drum to the ambient is 0.8. The ambient temperature is 100°F with insolation.

As stated in Section 3.5 of the SAR, the applicant assigned: (1) the non-charred fiberboard properties to all fiberboard during the 30-minute fire, (2) the charred fiberboard properties to the 1.4-inch charred region and the non-charred fiberboard properties to the non-charred region of the fiberboard during the post-fire cooldown, and (3) the air properties to the 1.4-inch charred region (conduction only) and the virgin fiberboard properties to the non-charred region of the fireboard for the post-fire steady state phase.

The calculated component temperatures under HAC are shown in Table 2 below. All component temperatures are below their respective temperature limits.

Table 2

Design Limits and Max. Temperatures of Packaging Components under NCT and HAC (Fluent Analysis)

Components	Design Limit (°F)	NCT (insolation) (°F)	HAC Fire (°F)
PCV	400	239	296
SCV	400	225	309
PCV O-rings	400	219	262
SCV O-rings	400	216	262
Lead Shield	622	216	498
Fiberboard Insulation	250	214	NA
Drum	2650	187	1475
Contents		466	506

The staff has reviewed the package design and evaluation for shipment and concludes that the package material and component temperatures will not exceed the specified allowable limits during HAC consistent with the tests specified in 10 CFR 71.73.

3.7 Maximum Pressures under NCT and HAC

The PCV and SCV are pressurized by heated air, helium generation from alpha decay, and hydrogen generation. As described in Appendix 3.22 and Calculation No. M-CLC-A-00441 (Rev. 1), the applicant calculated the maximum NCT pressures of 244.8 psig (PCV) and 126.8 psig (SCV), which are bounded by the MNOPs of 365.4 psig (PCV) and 165.4 (SCV) from Appendix 3.6.

As described in Appendix 3.22 and Calculation No. M-CLC-A-00441, Rev. 1, the applicant calculated the maximum HAC pressures of 256.2 psig (PCV) and 133.0 psig (SCV) when the insolated NCT temperatures are used as the initial phase of the HAC fire. The maximum design pressures are below design pressures of 900 psig for the PCV and 800 psig for the SCV, respectively.

The staff reviewed the pressure calculations for NCT and HAC, and concludes that the NCT pressures in PCV and SCV are below the MNOP limits and the HAC pressures in PCV and SCV are below the design pressures. Therefore, there is no impact on the structural integrity and the containment performance of the package.

3.8 Gas Generation and Detonation

The applicant evaluated the potential detonation and detonation cell width in the Model No. 9975 package, as described in Appendix 3.9 and Calculation M-CLC-A-00175, by using the gas space volumes, temperatures, pressures and chemistries within the 3013 container, PCV and SCV. The applicant predicted the cell widths for the four PCV and 3013 container dilution scenarios. The applicant's calculations show that with 75% CO_2 in the PCV, the cell widths are 61 mm and 98 mm, respectively, without and with helium diluting of the 3013 container, which are greater than the threshold cell width of 20.3 mm for a detonation.

The staff reviewed the calculations in Appendix 3.9 and Calculation M-CLC-A-00175 and agrees that the calculated cell widths under a 75% CO_2 dilution of the PCV are greater than the threshold cell width of 20.3 mm; thus, detonation is precluded in the Model No. 9975 package.

The applicant described the CO_2 dilution procedures of the PCV in the report WSRC-TR-2001-00304, Rev. 2 (Air Replacement Testing for the 9975 Primary Container Vessel), and concluded that: (1) the replacement of air with CO_2 in the PCV can be reliably performed using gas injection through a purge wand, and (2) air replacement in excess of 75%, as required by the SAR, can be consistently achieved in the PCV.

The staff reviewed the report WSRC-TR-2001-00304, Rev. 2, and concludes that, with a purge wand in location #2, a purge rate greater than 12 standard cubic feet per hour (scfh), and a purge time greater than 15 minutes, the air concentration average is less than 10%, which is much lower than the deflagration-to-detonation (DDT) air concentration limit of 52%.

3.9 Thermal Stress

The applicant described the space between packaging components, and listed the thermal expansion coefficients of the cone-seal plug, the containment weldment, and the cone-seal nut in Table 2.9 of the SAR. The applicant stated in Section 3.5.5 that (1) the maximum temperature change through the vessel weldment and shielding body was less than 2^{o}F throughout the fire and cooling transient, and (2) the maximum temperature change is below the satisfactory stress of 10^{o}F in the containment vessels for through-the-wall gradients.

The staff reviewed the configuration of the Model No. 9975 package, and agrees that the package sustains no significant thermal stresses under NCT, even at an ambient temperature of -40°F and maximum allowable internal heating.

3.10 Evaluation Findings

The decay heat of the Model No. 9975 package is thermally limited to 19.0 kW. However, the maximum heat load for the C.12 content envelope is only 16.7 watts. The local atmosphere should be diluted to less than 5% oxygen within the 3013 container by helium gas; the atmosphere within the PCV should have a 75% minimum CO_2 dilution for all plutonium oxide contents. In the CO_2 dilution to the PCV, the purge wand location #2, a purge rate greater than 12 scfh, and a purge time greater than 15 minutes are required to assure the effectiveness of the CO_2 dilution.

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 Model No. 9975 package design meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT REVIEW

The Model No. 9975 is a Type B(M)-96 package designed to transport solid form contents consisting of plutonium oxides and uranium oxides. The content is loaded into nested "leak-tight" vessels: (i) inner and outer DOE-STD-3013 dual containers that are sealed by welding, backfilled with helium or nitrogen resulting in no more than a 5% (vol.) oxygen concentration, (ii) the 3013 containers are placed within a "leak-tight" PCV backfilled with carbon dioxide resulting in no more than a 5% (vol.) oxygen concentration, (iii) the PCV is then placed within a "leak-tight" SCV. The "leak-tight" criterion, as defined by ANSI N14.5, meets the regulatory release limits specified in 10 CFR 71.51. Design, fabrication, welding, and examination of the PCV and SCV vessels are in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB. The containers are placed within a 35 gallon-sized drum package having a bolted-flange closure.

The staff reviewed the application to verify that the package containment design was described and evaluated for NCT and HAC, per 10 CFR Part 71. Regulations applicable to the containment review include 10 CFR 71.31, 71.33, 71.35, 71.43, 71.51, 71.61, and 71.63.

4.1 Description of Containment System

Contents are loaded, per DOE-STD-3013, into inner and outer 3013 stainless steel containers that are seal welded. Although the 3013 containers are seal welded and tested to the "leak-tight" criterion, they are not considered part of the package's containment boundary. Rather, the PCV and SCV both serve as containment boundaries to form a double containment boundary. The containment boundary includes the PCV and SCV vessels and their cone-seal plug, outer O-ring, and leak-test port plug, as shown in Figure 4-2 of the application.

The PCV is fabricated from 5-inch schedule 40 Type 304L stainless steel seamless pipe that is closed at one end by welding a schedule 40 stainless steel pipe cap. Likewise, the SCV is fabricated from 6-inch schedule 40 Type 304L stainless steel seamless pipe that is closed at one end by welding a schedule 40 stainless steel pipe cap. The other end of each vessel consists of a stayed head with a beveled surface which is closed with a 304L stainless steel cone-seal plug. The cone-seal plug includes two concentric O-ring grooves with a 32 μ-inch surface finish. A drilled through-hole between the O-ring grooves is used to perform leakage testing.

The concentric O-rings are either Viton GLT (Parker #V0835-75) or Viton GLT-S (Parker #VM835-75) with a continuous service temperature range of -40^{o} F to 400^{o} F. The outer O-ring acts as the containment boundary and the inner O-ring forms a test volume for the pre-shipment leakage test. The two O-rings are compressed against the stayed head's beveled surface by the cone-seal plug and a Nitronic-60 steel cone-seal nut that is threaded to the top of the vessel stayed head and torqued to 55 ft-lb and 110 ft-lb for the PCV and SCV, respectively. A 316 stainless steel leak-test port plug and 410 stainless steel gland nut are installed and torqued to 30 ft-lb to seal the through-hole.

The drum lid is secured using twenty-four ½-inch bolts, which are tightened to 30 ft-lb torque, to prevent the inadvertent opening of the outer drum package. A 1/8-inch thick circular ring that is 1-¼ inch wide is welded to the outer section of the lid as reinforcement to prevent the lid from shearing during a HAC event.

The staff concludes that the applicant adequately described the package's containment features, as discussed above.

4.2 General Considerations – Flammable Gas Generation

The potential for flammable gas generation varies with the content type and water vapor existing within the content. This gas generation is minimal when shipping uranium oxides because the associated decay heat is small. The potential for hydrogen generation is larger when shipping plutonium oxides because of its larger decay heat. Therefore, the applicant's analyses assumed radiolysis of all water vapor in the plutonium oxide content. Although resulting in conservative hydrogen concentrations, such analyses do not consider the actual reactions that reduce the flammability of the gas mixture in the vessel. For example, oxygen within the 3013 container, whether from that generated by radiolysis of water vapor or existing within the 5% (vol.) oxygen concentration after the vessel is backfilled with helium or nitrogen, can be chemically bound to the plutonium oxide.

As a result of such reactions, the applicant's measurements indicate that measureable oxygen concentrations are below 5% (vol.) when hydrogen is generated at trace levels. Conversely, measurements indicate oxygen concentrations at the detection threshold of 0.1% when hydrogen concentrations are above 5% (vol.). The reduced oxygen concentration because of the reactions between oxygen, hydrogen, and the plutonium oxide as well as the helium, nitrogen, and carbon dioxide backfill, limits the conditions for conflagrations and detonations within the vessels. In addition, the applicant's analyses have shown that the gap dimensions inside and between the nested vessels within the Model No. 9975 package are below the detonation cell widths that preclude detonations.

The staff has reviewed and agrees with the applicant's description of the potential flammable gas generation.

4.3 Containment under NCT

Detailed containment release calculations that include release fractions, etc., were not necessary because the containment boundaries are tested to the ANSI N14.5 "leak-tight" criterion. The applicant performed analyses and conducted tests to show that leak-rate acceptance criteria were satisfied for NCT. NCT thermal analyses indicated that the 216^{o}F SCV O-ring and 219^{o}F PCV O-ring temperatures were below their 400^{o} F allowable limit. Additional analysis by the applicant showed that the PCV MNOP of 365.4 psig was less than the PCV design pressure of 900 psig.

Likewise, the SCV MNOP of 165.8 psig was less than the SCV design pressure of 800 psig.

The applicant's analysis showed that the containment vessels and O-rings could withstand an external pressure of 290 psi, per 10 CFR 71.61. As stated above, fabrication, maintenance, and periodic leakage tests meet the ANSI N14.5 "leak-tight" criterion. After content loading, the subsequent pressure-drop or rate-of-rise pre-shipment leakage test meets the 10^{-3} cm^3/sec ANSI N14.5 criterion.

The staff reviewed and agrees with the applicant's description of the containment system's response under NCT.

4.4 Containment under HAC

As stated above, detailed containment release calculations that include release fractions, etc., were not necessary because the containment boundaries are tested to the ANSI N14.5 "leak-tight" criterion. Numerous HAC drop and puncture tests of the Model No. 9975 package and similar packages (prototypes, 9973 package, etc.) were performed by the applicant to confirm the structural integrity of the nested vessels. Results showed some crushing of the Model No. 9975 package's fiberboard insulation, but no tearing or penetration of the drum wall or drum lid. Subsequent leakage tests met the leak-rate acceptance criterion of less than 2.10^{-7} std cm^3/sec (helium).

In addition, the inner and outer 3013 vessels were confirmed to be "leak-tight" after being dropped bare (without being surrounded by the PCV, SCV, and 9975 cask) through a distance of four feet and 30 feet, respectively, in order to confirm the robustness of the vessel design. Post HAC fire steady-state temperatures for the PCV and SCV O-rings were 262°F and below the O-ring's 400°F allowable limit. A prototype package that underwent drop and puncture tests and subsequent HAC thermal test met the leak-rate acceptance criterion of less than 2.10^{-7} std cm^3/sec (helium).

The staff reviewed and accepted the applicant's description of the containment system's response under HAC.

4.5 Leakage Rate Testing

Prior to leakage rate testing, a pressure test at an internal pressure that is at least 1.5 times the design pressure is performed on the PCV and SCV containers as part of the initial acceptance test. A similar pressure test is performed as a maintenance test after rework or repair. Fabrication, maintenance, and periodic leakage tests, as defined in Table 1 of ANSI N14.5-1997, are performed on the PCV and SCV.

SAR, Section 8.1.3, states that, for each of these tests, the entire containment boundary is leak tested with helium using the evacuated envelope method, as defined in Section A.5.4 of ANSI N14.5. Results of the fabrication, maintenance, and periodic leakage tests demonstrate that the leak rate is less than or equal to 10^{-7} ref-cm^3/sec (air) with a sensitivity of 10^{-8} ref-cm^3/sec, in accordance with the ANSI N14.5 definition of "leaktight.. Likewise, the 3013 vessel is helium leak tested to the 10^{-7} ref cm^3/sec "leak-tight" criterion, per ANSI N14.5.

A pressure-drop or rate-of-rise pre-shipment leakage test, as defined by Table 1 of ANSI N14.5, is performed on the PCV and SCV after content is loaded. These tests confirm that the cone-seal plug/cone-seal nut closure and leak-test port plug/gland nut closure are properly sealed. All leakage test procedures are written and approved by leakage test personnel certified to Level III NDE as defined by the American Society of Nondestructive Testing training document "Recommended Practice No. SNT-TC-1A."

The staff reviewed the leakage rate test descriptions and concludes that the leakage rate tests are to be performed in accordance with ANSI N14.5.

4.6 Evaluation Findings

Based on a review of the containment sections of the application, the staff concludes that the containment design has been adequately described and evaluated and has reasonable assurance that the package meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING REVIEW

The objective of the review is to verify that the shielding of the DOE's Model No. 9975 transportation 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 Description of Shielding Design

5.1.1 Shielding Design Features

The Model No. 9975 is designed as a drum-style Type B(M)F-96 package, for transport of fissile radioactive materials. The Model No. 9975 packaging consists of a stainless steel PVC and SVC subassemblies enclosed within the package shielding, and a 35-gallon stainless steel drum with a flanged closure assembly. The shielding design consists of a cylindrical lead shielding body subassembly with an aluminum shielding lid. The insulation assembly consists of a bottom and top subassembly. The insulation is fabricated by laminating discs of fiberboard, and both subassemblies have an aluminum bearing plate. The insulation top subassembly is covered with an air shield weldment. The weldment is attached to the top of the fiberboard with a silicone rubber sealant. These components are overpacked in the drum with a flanged closure assembly. The drum provides impact and thermal protection during transport, and the lid is secured with 24 screws.

The lead shielding body subassembly provides gamma radiation shielding for the drum side wall and bottom. The containment vessel stainless steel closures provide gamma shielding for the top of the drum. Neither the package geometry nor its materials of construction are specifically designed to provide neutron shielding. Neutron dose rate attenuation is provided primarily by the distance between the source and points external to the package, with some additional attenuation provided by the materials of the PCV and SCV such as lead, fiberboard, and the drum.

5.1.2 Summary Table of Maximum Radiation Levels

The applicant performed shielding analyses only for content envelope C.12. Some of the radioisotopes contained in envelope C.12 are PU-238, Pu-239, Pu-240, Am-241, Am-243, Np-237, U-238, U-236, U-235, and many more. Table 5-2 shows the content envelope evaluated for transport, including fissionable mass limits. The applicant analyzed an additional case with reduced thickness of the lead shield to account for the effects of lead corrosion. The applicant's NCT shielding model includes radial and axial components of the package with geometric simplifications. The applicant's HAC shielding model assumes that all packaging components external to the SCV are consumed by HAC events. The application provided radiation dose rates for the package in Table 5-1 of the SAR. For the content envelope C.12 (NCT), the total dose rate at the surface (side) was 186.34 mrem/hr. At the surface (top), the total dose rate was 10.54 mrem/hr. At the surface (bottom), the dose rate was 179.95 mrem/hr while it was 6.19 mrem.hr at 1 m away (side). For HAC, the dose rates were respectively 8.81 mrem/hr at 1 meter away (side), 0.74 mrem/hr at 1 meter away (top), and 7.99 mrem/hour at 1 m away (bottom).

5.2 Radiation Source Specification

The contents of the package consist of the content envelop, C.12, as documented in Appendix

1.4 and presented in Table 1.2 of the SAR. The contents are in solid form as oxides. Liquid contents are not permitted. Except as stated in Table 1.2, small concentrations of other actinides, fission products, decay products, and neutron activation products are permitted as long as the concentrations are less than 1,000 ppm each. Assessment of these impurities may be based on process knowledge. The maximum mass of the content envelope is 5 kg. The maximum mass of the package contents is 20.1 kg (44.4-lb.).

5.2.1 Gamma Source

The contributing mechanisms for photon (gamma) production include: (1) nuclide decay, (2) decay of daughter products, (3) fission product decay, (4) spontaneous fission, (5) bremsstrahlung, (6) neutron activation of the stainless steel containers, and (7) alpha interaction with light nuclides ((α, n) reactions). Table 5-3 shows the source spectrum and total source strength (photons/sec). The applicant used the RASTA code to calculate the energy dependent decay source terms in the BUGLE-80 twenty-group structure. The applicant used a combination of the ORIGEN-S code, and the RASTA code to calculate source terms. The ORIGEN-S code is part of the NRC-sponsored SCALE code package available through the Radiation Safety Information Computational Center. The RASTA code is a proprietary code of Westinghouse Safety Management Solutions, a subcontractor to the applicant. The applicant input the source spectrum into MCNP as a histogram and used the total activity as a multiplier to convert the dose rates from units of per source particle to total dose rate. Appendix 5.3 of the SAR describes the shielding codes used in this analysis.

5.2.2 Neutron Source

The predominant neutron source is from the interactions of alpha particles with the light elements heterogeneously mixed with the plutonium. The applicant used the RASTA code to calculate the energy dependent neutron source terms in the BUGLE-80 forty-seven-group structure. The applicant did not include the effect of subcritical multiplication in the source strength, but accounted for it during the radiation transport calculations. The applicant showed the neutron source spectra and the total neutron source strength in Table 5-4 of the SAR.

Among the isotopes of the content envelopes, the main contributors to the neutron source are Pu-238, Pu-239, Pu-240, Pu-242, and Am-241.

5.3 Shielding Model

As mentioned, the packaging consists primarily of the stainless steel PCV and SCV. These containments are inserted into a 35-gallon, 18-gauge stainless steel drum. Lead shielding, aluminum bearing plates and honeycomb spacers. The package has fiberboard insulation (cellulose $C_6H_{10}O_5$, with a 0.20 g/cm^3 density). As presented for transport, the PCV is within the SCV, and the SCV is inside the lead shielding body subassembly in the drum. Within the PCV, the radioactive material may be packed in various configurations as described in Section 1.2.3 of the SAR.

The applicant showed the package design in the engineering drawings in Appendix 1.1 of the SAR. The applicant's MCNP shielding models used for the content envelopes are shown in Figures 5.1 through 5.3 and in Appendix 5.4 of the SAR. The applicant took into the account dimensional tolerances in developing the model dimensions. The tolerances were applied in a manner that minimizes the amount of shielding material present. The MCNP model for NCT is shown in Figure

5.1 of the SAR. The applicant showed the containment vessel closure arrangement model is common to NCT and HAC in Figure 5.2 of the SAR. Figure 5.3 of the SAR showed the HAC model.

5.3.1 Configuration of Source and Shielding

The applicant's shielding model for NCT assumes that the package is transported in an upright position and is undamaged. The structural evaluation discusses the effects of NCT on package configuration, and concludes that changes in the package during NCT do not adversely impact the shielding properties. In this configuration, the SCV is surrounded on the sides and bottom by ½ inch of lead shielding lined with 20 gauge stainless steel. Other components of the package include: aluminum plates, aluminum honeycomb spacers inside the PCV and SCV, and on top of the PCV, and 3013 container. The 3013 container is the assembled combination of containers. The container consists of a minimum of two individually sealed, nested containers to isolate the stored materials from the environment. According to the applicant, the outer and inner containers are sealed by welding. The use of convenience containers within the inner container is optional.

The applicant used a cylinder with the radius of the convenience can and height based on 5 kg of powder with a density of 7 g/cc for the source term geometry of the model. The applicant developed the HAC model from the NCT model by conservatively deleting all of the package components outside the SCV. Consequently, the applicant ignored the distance and attenuation capabilities provided by the package materials outside the SCV.

5.3.2 Material Properties

The shielding materials used by the applicant in the models consisted of stainless steel, aluminum, lead, and fiberboard. The applicant gave source material densities in Appendix 5.4 of the SAR and gave shielding materials densities and compositions in Appendix 5.5 of the SAR.

5.4 Shielding Evaluation

5.4.1 Methods

The applicant utilized RASTA code to generate the source term for the content envelope C.12. RASTA (Radiation Source Term Analysis) is a code that computes neutron and photon source terms arising from (α,n) events, spontaneous fission, bremsstrahlung, and decay. According to the applicant, the code was written to consolidate existing capabilities into a single, easy to use code with flexible, extensive output edits, while also adding new capabilities. Some of the codes that are incorporated in RASTA are GAMSRC, BREMRAD, and SOURCES. In addition, RASTA provides calculational routines to find the photon source arising from decay of the product isotope resulting from an (α,n) calculation, and to find the photon source arising from both prompt and delayed spontaneous fission events. The Monte Carlo code MCNP was used to calculate. The applicant used the MCNP code, version 5, with continuous ENDF/B-VI photon cross sections to calculate the gamma and neutron dose rates from the source material. MCNP is a three dimensional Monte Carlo transport code developed and maintained by Los Alamos National Laboratory. This code and cross section set has been widely used in shielding evaluations and the staff found it acceptable for use in this application. In additional to the use of these codes, the applicant utilized several conservative assumptions throughout the shielding calculations. The assumptions includes: tolerances that were applied in a manner that minimizes the amount of shielding material present in minimum dimensions, a reduction on the lead thickness due to 50 years of hypothesized corrosion, modeling the plutonium oxide powder as a compressed powder at 7 g/cc filling the bottom portion of the inner convenience can, conservatively deleting all of the package components outside the SCV for the HAC model, and ignoring the distance and attenuation capabilities provided by the package materials outside the SCV.

The staff independently confirmed the dose rates of the Model No. 9975 package. The staff used the ORIGEN-ARP depletion code to calculate the source term. The staff also created a model of the Model No. 9975 using the MAVRIC/MONACO shielding code as part of SCALE 6.1. The staff used the source term it calculated from ORIGEN-ARP in its MAVRIC/MONACO model. The staff's dose rates were within 15% of the applicant's. This comparison helps demonstrate that the applicant's model and methods calculate an appropriate dose rate.

5.4.2 Input and Output Data

The applicant provided the input and output files in Appendix 5.6 of the SAR.

5.4.3 Flux-to-Dose-Rate Conversion

The applicant obtained the gamma and neutron dose conversion factors from the American National Standards Institute standard, ANSI/ANS-6.1.1-1977. The applicant used the values from the 1977 version of the standard rather than those from the 1991 version of the standard because the neutron dose conversion factors in the 1977 version more closely reflect those provided in 49 CFR 173.403, and the photon dose conversion factors in the 1977 version more closely correspond to the response measured by instrumentation.

5.4.4 External Radiation Levels

The applicant presented the external dose rates on the surface of the package in Tables 5.1 of the SAR. All NCT dose rates comply with 10 CFR 71.47(a) and 71.47(b). For HAC, the applicant also calculated maximum dose rates at 1 meter from the surface of the cask. All HAC dose rates comply with 10 CFR 71.51(a)(2).

5.5 Evaluation findings

The staff reviewed the description of the package design features related to shielding and the source terms for the design basis fuel and found them acceptable. The applicant used methods that are consistent with accepted industry practices and standards. The staff reviewed the maximum dose rates for NCT and HAC and determined that the reported values were below the regulatory limit in 10 CFR 71.47 and 71.51.

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 REVIEW

6.1 Areas of Review

The applicable regulations considered in the review of the criticality safety portion of this application include the fissile material requirements in 10 CFR Part 71, specifically the general requirements for fissile material packages in 10 CFR 71.55, the standards for arrays of fissile material packages in

10 CFR 71.59, and the additional requirements of 10 CFR 71.63 for packages containing more than 20 Ci of Pu. The staff also used the review guidance contained in NUREG-1609.

Staff reviewed the information in the SAR and verified that the information is consistent as well as all descriptions, drawings, figures and tables are sufficiently detailed to support an in-depth staff evaluation. The staff evaluated the package design to determine if there were any criticality safety concerns.

6.1.1 Packaging and Design Features

The Model 9975 packaging is comprised of an outer drum with a removable head and a gasketless bolted-flange closure. The drum contains the insulation assembly and the shielding body. The insulation consists of cane or softwood fiberboard insulation, which is modeled, in the SAR, as Celotex. The shielding container is a stainless steel lined, lead container with an aluminum lid. The PCV consists entirely of stainless steel and is nested within the SCV. A 4-inch (10.16 cm) stainless steel pipe is welded to the convex side of the end cap to vertically support the PCV. The internal cavity is 18.6 inches (47.24 cm) long with a usable length of approximately 15 inches (38.10 cm) and a minimum diameter of 5 inches (12.70 cm). The SCV is also a stainless steel pressure vessel with a 5 inch (12.70 cm) pipe welded to the end cap to vertically support the SCV. The internal cavity is 24 inches (60.96 cm) long with a usable length of approximately 21.5 inches (54.61 cm) and minimum diameter of 6 inches (15.24 cm). A contoured, aluminum honeycomb spacer provides a flat surface for the innermost 3013 container. A top spacer is used to take up the remaining axial space within the PCV cavity.

6.1.2 Summary Table of Criticality Evaluations

Table 3

Case	Maximum $k_{eff} + 2\sigma$
Single Unit	0.916
NCT Infinite Array	0.655
HAC Infinite Array	0.938
$k_{safe} = 0.943$	

6.1.3 Criticality Safety Index (CSI)

The applicant demonstrated that an infinite array of Model No. 9975 packages with the most reactive contents in both NCT and HAC remains adequately subcritical. Therefore the CSI is 0.0 in accordance with 10 CFR 71.59(b).

6.2 Fissile Material Contents

The C.12 content envelope is 5 kg of fissile material in solid form plutonium and/or uranium oxides. Liquids are not permitted. Except as stated in Table 1.2 of the SAR, impurities consisting of less than 1000 ppm each may include other actinides, fission products, decay products, and neutron activation products.

6.3 General Considerations

6.3.1 Model Configuration

The Model No. 9975 package is modeled using assumptions that have been recognized by prior reviews as being conservative. When necessary, the applicant modeled the package with reduced or altered dimensions consistent with a damaged package. The structural integrity of the Celotex is ignored by the applicant for criticality control under certain accident scenarios.

For a single package evaluation, the applicant assumed that the convenience can and 3013 container are both absent. The applicant's model includes the PCV within the SCV cavity. The applicant assumes varying levels of water intrusion until both the PCV and SCV are filled with an assumed homogeneous solution of $^{239}PuO_2$ and water.

Under NCT, the containment vessel locations remain centralized in the drum.

Under HAC, the Model No. 9975 package is modeled with the containment vessels displaced to the maximum position within the drum, assuming that the Celotex has been destroyed by fire. Water intrusion is assumed in various locations within and the space surrounding the drum. The applicant reduced drum dimensions to account for damage due to a package having been dropped.

The array is modeled as infinite with periodic axial boundary conditions while the remaining boundary conditions are reflective. The top layer of packages has the fissile material modeled as close to the bottom of the package as possible, and the bottom layer modeled as close to the top as possible to minimize axial distance. The position of the components is modeled against the side edge of the drum, closest to the center of the resulting quadrupole arrangement.

6.3.2 Material Properties

Fissile material is modeled as ^{239}Pu oxide, with 0.5 wt % water to account for moisture. Water is modeled at full density. The fissile material is modeled inside a "convenience can" as a right circular cylinder with a 1:1 height to diameter ratio.

Water intrusion into either the PCV or SCV is treated as a homogeneous solution of ^{239}Pu oxide.

6.3.3 Computer Codes and Cross-Section Libraries

The applicant used the KENO-VI module in the SCALE 5 code suite driven by the CSAS26 utility for criticality analysis. KENO-VI is a three-dimensional Monte Carlo transport code. The cross-section library used by the applicant was the 238-group library based on ENDF/B-V nuclear data. Both this software and cross-section library have been previously evaluated and found to be appropriate for use in this application.

6.3.4 Demonstration of Maximum Reactivity

In single package evaluations, the applicant demonstrated that maximum reactivity is achieved at or near full flooding of the SCV with full density water. The applicant's analysis shows a slight maximum when the uncertainty is conservatively applied at a point where the SCV is less than completely filled.

The applicant's analysis included several scenarios which varied the geometry of the fissile materials in package arrays under HAC. The applicant's quadrupole arrangement that results from adjacent packages having the fissile mass moved as close as possible to each other minimizes the spacing amongst as many as 8 payloads (4 in each of two axial layers). However, the applicant recognizes that the same arrangement maximizes the distance between groups of fissile cylinders. A series of calculations were done with both the displaced containment vessels and a symmetrical infinite array.

Tables 6.9 through 6.25 of the SAR show the results of the calculations and sufficiently demonstrate the configuration of maximum reactivity.

6.3.5 Confirmatory Analysis

Staff, using the same assumptions as the applicant, analyzed the model 9975 package using KENO-VI in the SCALE 6.1 suite with a continuous energy ENDF/B-7 cross-section library. The geometric configuration assumed by the applicant was retained, and all other dimensions used in the analysis were obtained from the SAR.

Staff's models included incremental flooding of the PCV and SCV in single package analysis and reproduced the increase of reactivity with the addition of water. Staff bounding analysis replaced Celotex with water, but did not produce a relative maximum short of completely filling both the SCV and PCV. The difference in reactivity between the cases, after 6 liters of water are assumed to have intruded, is statistically very small. Staff results fell within 3% of the applicant's results, and the staff's calculated maximum k_{eff} was below k_{safe}.

Under HAC, the staff was able to confirm that the most reactive configuration is with a flooded convenience can and 3013 container in the minimized distance between 8 closest payloads, with the rest of the package remaining dry. The addition of water to the surrounding material, and outside the drum, increases the neutron shielding between canisters of fissile material. Staff confirmed that the additional flooded regions external to the SCV result in a corresponding drop in the modeled system reactivity.

6.4 Single Package Evaluation

6.4.1 Configuration

The single package analysis under NCT scenarios include: (i) dry oxide, (ii) inclusion of special moderating material, i.e., carbon and beryllium, (iii) various preferentially flooded scenarios, and (iv) presence of 3013 containers. The preferential flooding cases model 0.1 liter of water to a completely flooded convenience can. Flooding of both the PCV and SCV were evaluated, as well as one or both of the 3013 containers.

6.4.2 Results

The most reactive configuration assumes that (i) no 3013 containers are present, (ii) the entire Model No. 9975 package is closely reflected and all containers within are flooded with water, and (iii) any Celotex filler material is absent. The most reactive configurations results in a k_{eff} of 0.916 after consideration of bias and uncertainty.

The applicant demonstrates that a fully flooded and reflected package will remain subcritical.

6.5 Evaluation of Package Arrays Under NCT

6.5.1 Configuration

The applicant models the single package array with reflective boundary conditions to analyze and infinite array of packages.

6.5.2 Results

The applicant demonstrates that a fully flooded and reflected array will remain subcritical.

6.6 Evaluation of Package Arrays Under HAC

6.6.1 Configurations

The applicant repeats the boundary conditions used to analyze an array of packages under NCT. The changes reflect reduced dimensions to the Celotex and drum due to the fire and drop analysis and are summarized in Table 6.7 of the SAR. The array is modeled as a 2x2x2 infinite array with mirror boundary conditions to the sides (x and y faces) and periodic axial boundary conditions (z faces).

6.6.2 Results

The applicant demonstrates that the addition of hydrogenous material between the drums and in the space occupied by the Celotex filler reduces reactivity. The applicant demonstrated that the most reactive scenario is one where the fissile material has shifted inward to the center of the 2x2x2 cell to the maximum credible extent, with both the convenience can and 3013 containers flooded with full density water, while the rest of the package remains dry. In this case, the maximum k_{eff} considering bias and uncertainty is 0.938. The applicant shows that the system will remain acceptably subcritical under HAC.

6.7 Air Shipment

This package is not permitted for air transport.

6.8 Benchmark Evaluations

The applicant applied the standards in ANSI/ANS-8.1-1998 to validate the criticality analysis. Biased k_{eff} values rely on previous validation from the SRNS Criticality Safety Advanced Computing

Center. Table 6.27 of the SAR summarizes the bias values based on the Lower Tolerance Band for the systems considered.

6.8.1 Experiments and Applicability

No critical experiments similar to the Model No. 9975 package with Pu/U oxide powder are available. The applicant instead chose a wide range of validation experiments.

6.8.2 Bias Determination

The applicant used the lowest value derived from the validations and determines that to be a $k_{safe\ of}$ 0.943.

6.9 Evaluation Findings

The staff has reviewed the description of the packaging design and concludes that it provides an adequate basis for the criticality evaluation.

The staff reviewed the design and materials and concludes that it is prepared for shipment such that there will be no significant reduction in the effectiveness of the packaging under the tests specified in 10 CFR 71.71.

The staff has reviewed the applicant's criticality evaluation of a single package and concludes that it will remain subcritical under the most reactive credible conditions.

The staff has reviewed the criticality evaluation of an infinite array of the most reactive configuration under both NCT and HAC and concludes that it is subcritical under these conditions.

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

7.0 PACKAGE OPERATIONS

Chapter 7.0 of the application provides a summary description of package operations, including package loading and unloading operations, to ensure that the package is operated in a safe and reliable manner under NCT and HAC. The preparation of an empty package for shipment is also described.

7.1 Package Loading

The application lists a number of procedural steps to be included in the package operating procedures to ensure that the condition of the packaging is unimpaired and that all its components are in an acceptable condition before loading the contents.

These steps include the following: (i) verify that the contents in the 3013 meet the allowable contents listed in the CoC, (ii) verify that decay heat from the contents is less than the maximum allowable, (iii) verify that the atmosphere within the 3013 was diluted at the time of closure with helium or nitrogen such that the oxygen content in all void spaces is no greater than 5% by volume, and (iv) verify that the 3013 does not exhibit signs of bulging or buckling prior to placement inside the PCV.

The applicant assumes a flammable gas mixture is prevented by limiting oxygen rather than hydrogen. This approach is used because of the unique nature of the plutonium oxide content. The applicant determined that, for the plutonium oxide with 0.5 wt. % moisture, the theoretical amount of hydrogen available for release by radiolysis may exceed the hydrogen flammability limit if oxygen is not limited.

In addition, the applicant found that oxygen generated by dissociation of water is absorbed in the plutonium oxide and no net oxygen is produced.

Using this finding together with the initial inert gas purging of the oxygen in all gas spaces within the 3013 and PCV containers of the Model No. 9975 package ensures that the oxygen present will never be sufficient to support a flammable mixture.

With a heat load of 19 watts and in shade under NCT, the maximum accessible drum-surface temperature is 114°F which is 8°F below the limit of 122°F for a non-exclusive shipment, and therefore the package can be shipped in either an exclusive or non-exclusive shipment.

Pressure-drop or rate-of-rise pre-shipment leakage tests are performed on the PCV and SCV after loading of contents. These pre-shipment leakage tests follow ANSI N14.5-1997 and have a leakage rate criterion of 10^{-3} ref. cm^3/sec (air).

7.2 Package Unloading

The packaging components and the 3013 container are surveyed and monitored for external radioactive contamination as they are unloaded. If a measurement exceed the allowable limits of 10 CFR 71.87(i), unloading operations are stopped and the appropriate contamination and radiation control procedures are implemented.

The applicant has defined procedures to remove and survey the spacers, the 3013 container, and the PCV bottom spacer from the PCV. A special tool for handling the 3013 is also described in Appendix 7.1 of the application

7.3 Preparation of Package for Empty Transport

The external surfaces of the packaging components are monitored for radiation and contamination to ensure compliance with 10 CFR 71.47 and 10 CFR 71.87(i).

Several verifications are performed to prepare an empty package for transport, including the verification that (1) the drum (top, bottom, and side) is not breached by holes or by cracks, (2) the Caplugs® are properly installed in the drum vent holes, (3i) the PCV is empty, and (4) the SCV Bottom Impact Absorber, the PCV, and the SCV Top Impact Absorber into the SCV are installed.

7.4 Evaluation Findings

The staff reviewed the Operating Procedures in Chapter 7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation.

On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures, as outlined in the application, provide adequate measures and reasonable assurance for safe operation of the package in accordance with 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Chapter 8 of the application identifies the inspections, acceptance tests, and maintenance programs to be conducted on the Model No. 9975 package and verifies their compliance with the requirements of 10 CFR Part 71.

8.1 Acceptance Tests

Acceptance inspections and tests are performed prior to first use of the packaging to ensure compliance with applicable requirements of Subpart G of 10 CFR Part 71.

Visual inspections are performed to ensure that the packaging is complete and operable upon receipt. Shielding integrity testing per NUREG/CR-3854 is required for the acceptance of the package. Alternatively, fabrication may be sequenced such that the package shielding is dimensionally inspected and verified, either visually or by ultrasonic testing, to be free of gaps, holes or pits, prior to installation of the stainless steel jacket. Particularly, the service life of shielding bodies fabricated to the R-R2-G-00079 A configuration shall not exceed 50 years, i.e., these shielding bodies may be used until August 2047.

Prior to leakage rate testing, a pressure test is performed on the PCV and SCV containers as part of the initial acceptance test. A pressure test is also performed as a maintenance test after rework or repair. The design pressures for the PCV and SCV are 900 psig and 800 psig and shall be tested at 1,365 (± 10) psig and 1,235 (± 10) psig, respectively.

Fabrication, periodic, and maintenance helium leakage tests are performed on the PCV and SCV, using the evacuated envelope method, and have a "leak-tight" leakage rate criterion of 10^{-7} ref-cm^3/sec (air), as defined by ANSI N14.5-1997.

Specific ANSI N14.5 procedures are called out for all leakage tests. All leak test procedures are written and approved by leakage test personnel certified to Level III NDE, as defined by the American Society of Nondestructive Testing training document "Recommended Practice No. SNT-TC-1A." The pre-shipment leak rate test shall be capable of indicating a rate less than 1.10^{-3} ref cm^3/sec (air) using the pressure drop leak-test method, or rate of rise leak-test method, in accordance with Section 7.6 of ANSI N14.5

Inert gas purging with CO_2 is performed to limit oxygen in the loaded configuration and not to facilitate leak testing.

No thermal testing is required for the acceptance of the package. The package does not include active mechanical or thermal features.

8.2 Maintenance Tests

No annual maintenance of the package's passive thermal features or of the shielding integrity is required. However, the package is subjected to inspections and tests annually to ensure the continued and proper functioning of the packaging. The shipper verifies, through direct inspection, or confirms, through QA records, that all inspection and test requirements are satisfied prior to package use.

Replacement of the "Gland Nut", leak-test port Plug, or O-rings does not constitute a structural modification and does not require repeated pressure testing of the containment vessel.

If an annual leak-rate test has not been performed within the preceding 12 months, a leak-rate test shall be performed prior to use of the packaging. The annual leak-rate test is performed in accordance with Section 8.1.3 of the application.

The sealing surfaces and O-rings are inspected for gouges, nicks, cuts, cracks, or scratches that could affect containment performance. Any surface damage on the vessel shall be reworked or repaired, and the vessel retested using the leak-rate test given in Section 8.1.3. Damaged O-rings are replaced in accordance with Section 8.2.4.3.

A corrosion mechanism exists for exposed lead on the shielding body, forming lead carbonate and it has been estimated to have a maximum rate of 0.002 inches per year (radially); therefore, after 50 years of service life, shielding bodies fabricated to the R-R2-G-00079 A configuration, could have a reduction of lead wall thickness to 0.370 inches. The thinning of the lead corresponding to 50 years of corrosion at 2 mils/year, i. e., 100 mils, does not have any impact on the dose rate outside the Model No. 9975 shipping package.

The shielding bodies, fabricated to the R-R2-G-00079 A configuration, may be used until August 2047, which is 50 years after their fabrication date of August 1997.

Section 8 of the application discusses acceptance tests and maintenance program. The metallic materials of construction are procured and fabricated to consensus industry standards. The various structural components are fabricated from ASTM standard materials in accordance with American Society of Mechanical Engineers (ASME) Section III. A summary of the maintenance requirements is discussed in Section 8.2 of the application. The maintenance program includes periodic testing, inspection and replacement schedules. The staff finds that visual inspections at various timed intervals provide additional reasonable assurance against corrosion occurring unnoticed.

8.3 Evaluation Findings

The dual containment boundary is subject to fabrication, maintenance and periodic leakage testing demonstrating a leakage rate less than or equal to $1x10^{-7}$ ref-cm^3/s. The PCV and SCV O-ring seals and leak-test port plugs are subject to a pre-shipment leakage testing demonstrating a leakage rate less than or equal to $1x10^{-3}$ ref-cm^3/s (air).

Based on the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71.

CONDITIONS

The following conditions were included in the certificate of compliance:

The package is designated as Type B(M) in accordance with the definition of a package in 10 CFR 71.4.

The Reference Section includes Revision No. 1 of the safety analysis report for the Model No. 9975, referenced S-SRA-G-0001, dated April 7, 2014, supplemented on September 16, 2014.

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. 9975 package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9975, Revision No. 0,
on October 21, 2014.