July 7, 2011

Ms. Lori Podolak
Senior Regulatory Affairs Specialist
Regulatory Affairs Department
QSA Global, Inc.
40 North Avenue
Burlington, MA 01803

SUBJECT: REVISION NO. 0 OF CERTIFICATE OF COMPLIANCE NO. 9357 FOR THE MODEL NO. SENTRY PACKAGE

Dear Ms. Podolak:

As requested by your application dated November 5, 2010, supplemented December 1, 2010, and April 20, 2011, enclosed is Certificate of Compliance No. 9357, Revision No. 0, for the Model No. SENTRY package. The staff's Safety Evaluation Report is also enclosed.

QSA Global, Inc., has been registered as a user of the package under the general license provisions of 10 CFR 71.17. This approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact Pierre Saverot of my staff at (301) 492-3408.

Sincerely,

/RA/

Michael D. Waters, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9357
TAC No. L24487

Enclosures: 1. Certificate of Compliance No. 9357, Rev. No. 0
2. Safety Evaluation Report

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

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SAFETY EVALUATION REPORT
Docket No. 71-9357
Model No. SENTRY Package
Certificate of Compliance No. 9357
Revision No. 0

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SAFETY EVALUATION REPORT
Model No. SENTRY Package
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SUMMARY

By application dated November 5, 2010, as supplemented December 1, 2010, and April 20, 2011, QSA Global, Inc., requested approval of the Model No. SENTRY package as a Type B (U)-96 package. Revision No. 1 of the package application, dated April 20, 2011, supersedes in its entirety the application dated November 5, 2010.

The package, designed for the transport of Type B quantities of special form Co-60 radioactive material, includes three models, the Model Nos. SENTRY 110, SENTRY 330, and SENTRY 867. These models share the same common design but incorporate some variations to improve their functionality as radiography devices.

The primary components of the Model No. SENTRY package include (i) a depleted uranium shield completely encased and supported in a cylindrically shaped, stainless steel, welded body, (ii) the rear plate lock and front plate assemblies, (iii) the handling rib and link plate, and (iv) the source assembly. The inner cavity of the welded body around the shield is filled with polyurethane foam. The Model Nos. SENTRY 110 and 330 packages can contain only one source wire assembly during transport, while two source wire assemblies can be loaded into the Model No. SENTRY 867 package. The radioactive contents are securely positioned by either a lock slide for the Model Nos. SENTRY 110 and 330 packages or locking pins for the Model No. SENTRY 867 package. All lock assemblies include a dust cover with a plunger lock to prevent rotation of the selector ring and further secure the source in the package during transport. The optional rib/link assemblies provide lifting attachments and are bolted to the body weldment. The maximum weight, including the optional rib/link assemblies, is 780 pounds (354 kg) for the Model Nos. SENTRY 330 and 867 package, and 580 pounds (263 kg) for the Model No. SENTRY 110 package.

NRC staff reviewed the application using the guidance in NUREG 1609, "Standard Review Plan for Transportation Packages for Radioactive Material" and NUREG-1886, “Joint Canada-United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages.” The analyses and tests performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, and shielding protection under normal and accident conditions. Staff also found that the highlighted areas of emphasis in NUREG-1886 have been appropriately addressed.

Based on the statements and representations in the application, and the conditions listed below, the staff concludes that the package meets the requirements of 10 CFR Part 71.

References

QSA Global, Inc., “Safety Analysis Report for the Model Nos. SENTRY 110, 330, and 867 Type B(U)-96 Transport Packages,” Revision No. 1, dated April 20, 2011.

1.0 GENERAL INFORMATION

1.1 Package Description

The Model Nos. SENTRY 110, SENTRY 330, and SENTRY 867 packages are three variations of essentially one package design. All three packages are designed to transport a type B quantity of ^{60}Co in the form of one or two (for the Model No. SENTRY 867 source changer) special form capsules. The Model No. SENTRY 110 can contain up to 110 Ci of ^{60}Co while the Model Nos. SENTRY 330 and 867 packages can contain up to 330 Ci of ^{60}Co.

Two configurations, i.e., basic and standard, exist for these packages: the standard configuration includes handling ribs and link plates that are absent on the basic configuration. The standard configuration's dimensions for all three models are 19 inches wide by 19 inches deep by 19 inches tall, whereas the dimensions of the basic configuration for all three models is 19 inches wide by 18 inches diameter by 12 inches tall. Due to differences in the weight and size of the shield, the Model No. SENTRY 110 weighs 500 lbs, while the Model Nos. SENTRY 330 and 867 packages weigh 700 lbs in their basic configuration. For all three packages, the weight of the handling ribs and link plates is 80 lbs.

The licensing drawings R86000, Rev. C, sheets 1-10, provide a detailed description of the Model Nos. SENTRY 110, 330, and 867 packages, including dimensions and materials.

1.2 Packaging

The shield for all three models is made of cast depleted uranium (DU) with a 99% minimum DU in the "as-cast" condition. The shield for the Model No. SENTRY 110 package is smaller than that for the Model Nos. SENTRY 330 and 867 packages which have an identical size of the DU shield. In all cases, an S-shape tube made of Ti-3Al-2.5V is placed at the center of the shield to store the ^{60}Co source(s). The Model No. SENTRY 867 shield S-tube has a partition in its center (also made of Ti-3Al-2.5V) to prevent the ^{60}Co sources from being able to exit the shield on the side opposite from which they were inserted.

The shell of the Model Nos. SENTRY 110, 330 and 867 packages is a welded cylindrical body fabricated with Type 304 or 304L stainless steel. Two tube shaped access ports made of the same material are welded to the body of the package in diametrically opposed locations. For the Model No. SENTRY 110, Type 304 or 304L stainless steel tubular spacers are welded to the body of the package to hold the shield in place. For the Model Nos. SENTRY 330 and 867, spacers are not required due to the larger dimension of the DU shield.

The DU alloy shield is placed inside the welded body of the package, and closed cell polyurethane foam with a minimum density of 18 pounds per cubic foot (pcf) fills the gap between the shield and the welded shell. The shield is attached to the access ports of the welded body using 0.73" Ti-6Al-4V pins that pass through holes in the shield and through shield mounting bars that are welded to the access port structures. Wherever the depleted uranium shield would normally be in contact with stainless steel, copper alloy Type C101 or C110 discs, brackets and cups are used to prevent direct contact and avoid galvanic corrosion of the depleted uranium shield.

Lock assemblies are used to secure the ^{60}Co sources in the center of the shield during transport. There is one lock assembly per ^{60}Co source, thus the Model Nos. SENTRY 110 and 330 have one lock assembly each, while the Model No. SENTRY 867 has two lock assemblies.

The lock assemblies are bolted with stainless steel bolts to the back plate of the Model Nos. SENTRY 110 and 330, and to both access ports of the Model No. SENTRY 867 package. The lock assemblies for the Model Nos. SENTRY 110 and 330 are essentially identical with the exception of a spacer plate, and have a lock slide mechanism in addition to a selector ring to lock the source into position. The Model No. SENTRY 867 lock assemblies also have a selector ring, but use a locking pin mechanism instead of a lock slide mechanism to secure the ^{60}Co source(s) into position.

The lock assemblies are protected by a dust cover. A brass bar alloy plunger lock is inserted in the lock cover assembly to prevent rotation of the selector ring and thus movement of the ^{60}Co source(s).

The front plate assembly for the Model Nos. SENTRY 110 and 330 are identical, and are bolted to the front access port of these packages using stainless steel bolts. In order to open the shielded port, a special guide tube connector is required in order to prevent easy inadvertent opening of the port.

The optional rib and link assemblies that can be bolted to the basic package configuration to make it into the standard package configuration are made of stainless steel. The bolts used to attach the ribs are also made of stainless steel. Optional rib inserts can be attached to the ribs using 300 series stainless steel screws. The ribs are bolted to the links using 300 series stainless steel heavy duty bolts and nuts.

The description of the package, including information provided in the licensing drawings R86000, Rev. C, is detailed enough for staff to make a determination regarding the dimensions, weights, shielding features, structural features, and materials.

The special form contents ensure proper containment of the radioactive material to be transported and the inner S-tubes contain the special form capsules during NCT and HAC; thus, the containment boundary needs not to be defined for these packages.

Consequently, the staff finds that the description of the package provided by the applicant is adequate and satisfies the requirements of 10 CFR 71.31(a)(1), 10 CFR 71.33(a), and 10 CFR 71.43(a).

1.3 Contents

The radioactive contents of the Model Nos. SENTRY 100, 330, and 867 packages consist of ^{60}Co in a special form capsule.

1.3.1 Maximum Quantity of Materials

The maximum activity of the source(s) is 110 Ci for the Model No. SENTRY 110 package, and 330 Ci for the Model Nos. SENTRY 330 and 867 packages. The maximum decay heat resulting from the ^{60}Co content is 5.5 watts.

The maximum weight of one source assembly is 0.09 lbs. The Model Nos. SENTRY 110 and SENTRY 330 packages can only transport one ^{60}Co source assembly, while the Model No. SENTRY 867 can transport up to two ^{60}Co source assemblies.

1.3.2 Loading Restrictions

Loading operations are restricted to dry loading only. The package is not approved for wet loading.

1.4 Drawings

The packaging is constructed and assembled in accordance with QSA Global, Inc. Drawing No. R86000, Rev. C, sheets 1-10.

1.5 Evaluation Findings

A general description of the Model No. SENTRY package is presented in Section No. 1.0 of the package application, with special attention to design and operating characteristics and principal safety considerations. Drawings for structures, systems, and components important to safety are included in Section No. 1.3 of the application.

The package application identifies the QSA Quality Assurance Program for the Model No. SENTRY package and the applicable codes and standards for the design, fabrication, assembly, testing, operation, and maintenance of the package.

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

2.0 STRUCTURAL EVALUATION

The objective of the structural review is to verify that the structural performance meets the requirements of 10 CFR Part 71, including performance under normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

2.1. Description of Structural Design

The main structural components of the package are the Shield, Welded Body, Lock Assembly, Front Plate Assembly, and Source Assemblies. These components are illustrated in detail in the licensing drawings R860000, Rev. C, sheets 1-10.

The overall packaging diameter is 18 inches and its cylindrical height is 12 inches. The standard configuration (with addition of handling rib and link plates) adds an additional inch to the overall package width.

2.1.1 Descriptive Information Including Weights and Centers of Gravity

The Model Nos. SENTRY 110 and 330 packages have a maximum weight of 580 lbs (780 lbs respectively) in the standard configuration, or 500 lbs (700 lbs respectively) in their basic configurations. Both models have a maximum content capacity of 0.09 lbs of Special Form Co-60.

The Model No. SENTRY 867 package has a maximum weight of 780 lbs in the standard configuration or 700 lbs in the basic configuration. It has a maximum content capacity of 0.18 lbs of Special Form Co-60, i.e., two source wire assemblies.

The center of gravity for each model is approximately in the geometric center of the package.

2.1.2 Identification of Codes and Standards for Package Design

The packages are designed and fabricated to meet ANSI N432-1980 and ISO 3999:2004(E).

2.2. Materials

The materials used in the fabrication of the components of the package are specified in the licensing drawings R86000, Rev. C. The room temperature mechanical properties of the principal materials of construction are provided in Table No. 2.2a of the application.

2.2.1 Material Properties and Specifications

For every material listed in Table No. 2.2a of the application, the staff verified that the form listed was in agreement with the standard specification for that material.

The staff also verified that the chosen material's types and conditions (where applicable) were covered by the standard specification cited for that material, and found this to be the case in every instance.

The minimum tensile strength, minimum yield strength, and elongation of the materials used in the SENTRY family of packages are listed in Table No. 2.2a. The staff checked these material properties against those provided in the corresponding standards and found that these properties were correct for every combination of material type and condition listed in Table No. 2.2a.

2.2.2 Prevention of Galvanic, Chemical, or other Reactions

Section No. 2.2.2 of the application addresses potential galvanic or chemical reactions for the SENTRY family of packages.

Permanent dissimilar metal contacts in the Model Nos. SENTRY 110, 330, and 867 packages models exist between the alloys used in the fabrication of the packages. Staff has verified that the galvanic potential difference between all of the alloys is small enough to prevent any galvanic reactions.

Galvanic corrosion and eutectic formation during HAC conditions could potentially take place if the depleted uranium shield came into contact with stainless steel; thus copper discs, brackets, and cups are used to prevent any contact between the shield and any part of the stainless steel body of the transport package. Staff finds that the galvanic potential difference between copper and uranium is low enough to prevent any galvanic corrosion of the shield.

The application states that the galvanic reaction between titanium and uranium is expected to result in some oxidation of the shield but will not be significant. The reasons stated are the large mass of the shield compared to the titanium alloy tube holding the source(s) and the heavy duty titanium pins used to attach the shield to the welded shell, as well as the presence of the polyurethane foam and elastomer seal that prevent any electrolyte or corrosive medium from being present at the titanium uranium interfaces. The staff agrees with the above rationale for NCT conditions of transport.

At staff's request, the applicant changed the basic configuration of the package to include stainless steel set screws in all unused threaded holes with a diameter larger than ¼ inch to ensure that no oxygen flows into the foam through these openings during an HAC fire. This will protect the shield from oxidation or loss of shielding ability.

The application states that the lubricants, sealants, and other chemical ingredients used in the package do not contain halides that could cause unexpected corrosion under NCT. The staff has checked the chemical composition of the abovementioned lubricant, sealants and other chemicals against numerous publicly available resources, and finds that this statement is correct.

Based on these findings, the staff concludes that the requirements of 10 CFR 71.43(d) regarding galvanic, chemical, and other reactions are satisfied for both NCT and HAC conditions of transport.

2.2.3 Effects of Radiation on Materials

Based on decades of operational experience, the staff finds that the metallic materials used for the Model No. SENTRY packages are not significantly affected by radiation and the staff concludes that the requirements of 10 CFR 71.43(d) regarding the effects of radiation on materials are satisfied.

2.2.4 Special Form

The ^{60}Co source assemblies are special form source capsules attached to a flexible source wire assembly Model A424-14 or A424-13 depending upon the package model.

The special form source capsules are approved by the U.S. Department of Transportation. Therefore, the staff concludes that the special form requirements of 10 CFR 71.75 will be met.

2.3. Fabrication and Examination

The package is fabricated per Drawings No. R860000, Rev. C. All welding and examination of the welds will be done in accordance with AWS D1.6:1999 or ASME B&PV Code Section VIII.

Based upon the contents listed in Table No. 1.2a of the application, the package is categorized as Type B, Category II, per Regulatory Guide 7.11 "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)." Per Table No. 1.1 of NUREG-CR/3854 "Fabrication Criteria for Shipping Containers," the proposed fabrication and examination methods are acceptable.

2.4. Lifting and Tie-down Standards for All Packages

2.4.1 Lifting Devices

The applicant provides a detailed analysis of the heaviest possible (780 lb) package in Technical Report No. 171, Appendix No. 2.12.9 of the application. As required by 10 CFR 71.45(a), the applicant provides three analyses, the rib assembly lifting, link plate lifting, and rivnut (basic configuration) lifting which assume only one lift point being used (which is very conservative) and result in a minimum safety factor of at least 3 for all structural components.

It is also determined that, if the lifting were to fail during excessive loading, the package is designed so that the failed provision would not impair the ability of the package to meet the other requirements of 10 CFR Part 71.

2.4.2 Tie Down Devices

Since the basic configuration for the package does not have any tie down devices, the basic configuration can be blocked and braced according to standard transportation practices, e.g., with the use of dunnage, cargo nets, or an equivalent system. These types of tie down methods do not exert failure magnitude stress levels on the structure of the package.

The applicant provides detailed analyses of the heaviest possible (780 lbs) package using the standard configuration in Technical Report No. 172, Appendix No. 2.12.10 of the application. As required by 10 CFR 71.45(b), the package must be capable of withstanding a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of 5 times the weight of the package with its contents.

The applicant considers two specific tie down arrangements, i.e., (i) the applied load is taken by only one provision in the direction of vehicle travel and, (ii) two provisions share the applied load in the direction of vehicle travel. The results of the technical report provided in the application show that the intended tie down method is capable of withstanding the regulatory loading.

It is also determined that, if the tie down attachments were to fail due to excessive loading, the package is designed so that the failed provision would not impair the ability of the package to meet the other requirements of 10 CFR Part 71.

The staff agrees with the chosen methods of lifting and tie-down. The applied loads during lifting and tie down would not exert excessive stresses on the package, and therefore, the requirements of 10 CFR 71.45 are met.

2.5. General Requirements for All Packages

2.5.1 Minimum Package Size

The packaging exceeds the minimum size requirement (4 in), and the requirements of 10 CFR 71.43(a) are met.

2.5.2 Tamper-Indicating Feature

The packaging incorporates a seal wire attached to the locked protective cover over the front plate outlet port which, if broken during transport, serves as evidence of possible access to the contents. Therefore the requirements of 10 CFR 71.43(b) are met.

2.5.3 Positive Closure

The packaging uses a security screw, in addition to the four hex head bolts, to attach and secure the lock assemblies (which house the sealed sources) to the packaging. In addition, a locked cover plate covers the source wire, and is in place during transport. Therefore the requirements of 10 CFR 71.43(c) are met.

2.6. Normal Conditions of Transport (NCT)

2.6.1 Heat

As required by 10 CFR 71.71(c)(1), the package must be evaluated in an ambient temperature of 38°C, (100.4°F) in still air and insolation.

Assuming the entire decay heat of 5.5 watts is absorbed by the package, the maximum surface temperature caused by the effects of solar input and content decay is 127°C (260.6°F). This temperature is well below the maximum service temperature of the packaging materials.

2.6.1.1 Differential Thermal Expansion

Due to solar heat, and the package initial temperature, the temperature difference is 89°C (192.2°F), which is equivalent to 0.029 inches of thermal expansion. Since the thermal expansion that is encountered during NCT is small relative to the manufacturing tolerances of the package, the stresses and damage are considered to be negligible.

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(1) are satisfied.

2.6.2 Cold

As required by 10 CFR 71.71(c)(2), the package is subjected to temperature of -40°C (-40°F) in still air and shade.

All the materials that have been designated as important to safety have a service temperature capable of withstanding -40°C (-40°F).

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(2) are satisfied.

2.6.3 Reduced External Pressure

As required by 10 CFR 71.71(c)(3), the package is subjected to a reduced external pressure of 25 kPa (3.5 lbf/in^2) absolute.

The Model No. SENTRY package does not have a leaktight containment boundary that would be affected by the reduced external pressure of 25 kPa absolute. The special form capsule, which is the package containment boundary, is subjected to an external pressure to certify the special form capsule (25 kN/m^2 to 2 MN/m^2 – ISO 2919-1999 standard).

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(3) are satisfied. Staff also noted that the ISO 2919-1999 standard to certify the special form capsule (external pressure of 2MPa on the capsule) bounded the tests specified in paragraph Nos. 643 (reduction of ambient pressure to 60kPa) and 619 (reduction of ambient pressure to 5kPa) of TS-R-1, per the regulatory guidance in Section No. 2.6.3 of NUREG-1886.

2.6.4 Increased External Pressure

As required by 10 CFR 71.71(c)(4), the package is subjected to an external pressure of 140 kPa (20 lbf/in^2) absolute.

The package does not have a leaktight containment boundary that would be affected by the increase external pressure of 140 kPa absolute. The special form capsule, which is the package containment boundary, is subjected to an external pressure to certify the special form capsule (25 kN/m^2 to 2 MN/m^2 – ISO 2919-1999 standard).

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(4) are satisfied.

2.6.5 Vibration

As required by 10 CFR 71.71(c)(5), the package is subjected to vibration normally incident to transport.

The package includes the use of cotter pins (used routinely in vibration applications) to retain the shields to the welded body with shield pins. In addition, all bolts and screws are tightened to a prescribed torque to prevent unintentional release.

Packages of similar design have provided sufficient operating experience to conclude that the Model No. SENTRY packages are capable of withstanding vibration normally incident to transportation.

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(5) are satisfied.

2.6.6 Water Spray

As required by 10 CFR 71.71(c)(6), the package must be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm/hour (2 inch/hour) for at least 1 hour.

Due to the packaging materials of construction, the water spray test will not affect the form, fit, or function of the shielding or structural integrity. Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(6) are satisfied.

2.6.7 Free Drop

As required by 10 CFR 71.71(c)(7), a 1.2 m (4 ft) free-drop of the package should be performed, between 1.5 and 2.5 hours after the conclusion of the water spray test, onto a flat unyielding horizontal surface in a position for which maximum damage is expected.

The Model No. SENTRY 330 package basic configuration was chosen to undergo the NCT Free Drop testing because of its maximum weight (700 lbs). The height was adjusted to 4.9 ft from the regulatory 4 ft due to the difference in weights between the basic and standard configurations. The basic configuration was chosen for conservatism, because the standard configuration would provide cushioning and reduce the impact decelerations associated with the test.

Test Plan 180, Section 2.12.1 of the application documents the 4.9 ft NCT free drop height for test specimen TP180A (square hit), TP180B (edge hit), TP180C (weld seam hit), TP180D (seam hit), and TP180E (top surface hit) prototype packages.

Test specimens TP180A, TP180B, TP180C, and TP180D had minor damage but maintained source integrity and radiation dose rate limits after the NCT free drop test.

Test specimen TP180E survived the NCT free drop test, but indicated a potential problem with the attachment of the lock cover. Therefore, the roll pins used to secure the dust cover were modified.

All test specimens (with the modified dust cover roll pins) were successfully tested under HAC free drop conditions and NCT free drop tests demonstrated that the Model Nos. 110, 330, and 867 packages met the requirements of 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

As required by 10 CFR 71.71(c)(8), a free drop of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) must be performed onto a flat, essentially unyielding, horizontal surface.

This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs). Therefore, the corner drop test is not applicable.

2.6.9 Compression

As required by 10 CFR 71.71(c)(9), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following: (i) the equivalent of 5 times the weight of the package; or (ii) the equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package.

The Model No. SENTRY package was evaluated for the compression test (5 times maximum package weight criterion) and shown to have more than adequate capability, with a safety factor greater than 150.

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.71(c)(9) are satisfied.

2.6.10 Penetration

As required by 10 CFR 71.71(c)(10), the impact of a hemispherical end of a vertical steel cylinder of 3.2 cm (1.24 in) diameter and 6 kg (13 lbs) mass must be evaluated when dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncture.

The dust cover was targeted during the penetration test, as it protects the rear plate lock features and is the most vulnerable zone of the packaging.

Test prototype TP180A underwent the penetration testing. The test produced a small denting on the plastic dust cover. The impact damaged the plunger lock; however, the source remained secure, and no loss to shielding effectiveness or structural integrity resulted. Thus, it was demonstrated that the requirements of 10 CFR 71.71(c)(10) are met.

2.7. Hypothetical Accident Conditions (HAC)

The test sequence as specified in 10 CFR 71.73 was determined to be the order which would result in the maximum damage to the package, considering the subsequent application of the fire test. This is because the source containment will be more vulnerable to a puncture test after damage to the outer packaging has occurred from the free drop.

The staff agrees with this assessment, and determines the selected testing sequences are acceptable.

2.7.1 Free Drop

As required by 10 CFR 71.73(c)(1), a free drop must be performed from a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the package surface in a position for which maximum damage is expected.

The Model No. SENTRY 330 package configuration was chosen to undergo the HAC free drop testing because of its maximum weight (700 lbs in the basic configuration, 780 lbs in the standard configuration). The assumptions and conditions (package similarities between the Model Nos. SENTRY 110, 330, and 867, drop orientations, and height adjustments due to weight) that were discussed for the NCT free drop are the same for the HAC free drop tests. The tests are detailed in Section No. 2.12 of the application.

Four test specimens TP180A, TP180B, TP180C, and TP180E, were built to the basic configuration. Two test specimens, TP180D and TP180G, were built to the standard configuration. The flat, essentially unyielding, horizontal target surface size and design were adequate per Section 717 of IAEA Safety Guide No. TS-G-1.1 (ST-2). Staff noted that all the specimens (basic and standard) were altered with the modified dust cover roll pins, described in the application, after the NCT free drop.

TP180A underwent two 30 ft side drops onto the rear plate (lock assembly side) port. This orientation was done twice since the first drop did not appear to hit the edge on the dust cover. The second drop did hit the rear plate port as planned. The second test produced a fracture through the dust cover and compressed the plunger lock into the rear plate assembly, however the source assembly remained secure and the source did not move. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The TP180B underwent the 30 ft free drop onto the corner (port tube). The impact caused the access port tube to flatten into the access port, compressing the dust cover against the rear plate assembly. The source assembly remained secured, and the source shifted slightly (1/16 inch). The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The TP180C underwent two 30 ft side drops onto the package weld seam. This orientation was done twice since the first drop rotated slightly and impacted on the corner weld at the weld seam intersection with the longitudinal weld of the package (oblique drop). This first impact caused localized deformation and flattening to the circular corner of the package. The source assembly remained secured, and the source shifted slightly (1/32 inch). The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The second TP180C 30 ft side drop onto the package weld seam impacted as planned. This impact caused the curved surface of the body to flatten along the full length of the longitudinal weld seam, but no breach of the body occurred. After the test, the source assembly remained secure, and the source did not move. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The TP180D underwent the 30 ft side drop onto the rear plate (lock assembly side) port. This impact caused slight deformation to the access port and deformed the handling rib. After the test, the source assembly remained secure, and the source did not move. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The TP180E was subjected to the 30 ft end drop onto the flat body top. The package rotated slightly and did not achieve the intended impact orientation (more representative of slapdown orientation). The TP180E was not inspected until after the puncture test. After the puncture test, the package did not have an opening in the package exterior, and the post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The TP180G was also subjected to the 30 ft end drop onto the flat body top, since the TP180E slightly missed the planned orientation. This test was performed twice, since the first drop rotated and slightly caused two of the ribs to impact first, then immediately impacting the rest of the bottom rib surfaces of the package. Some of the ribs were bent and cracked, and the bottom ribs were slightly compressed into the bottom endplate of the package. After the test, the source assembly remained secure, and the source shifted slightly (0.06 inch).

For the second TP180G 30 ft end drop onto the flat body top, the damaged rib assemblies were removed. The impact caused the brass shaft of the front plate outlet port knob to fracture. The post accident dose rates showed 550mR/hr at the surface and 2.5mR/hr at 3.3 ft, which are within regulatory HAC dose rates. Staff noted that the knob fracture could locally increase the dose rates, but the tested rates are within regulatory requirements.

It was demonstrated by HAC free drop tests that the Model No. SENTRY package meets the requirements of 10 CFR 71.73(c)(1).

2.7.2 Crush

The crush test is not applicable, as the package does not contain fissile or greater than 1000 A_2 contents.

2.7.3 Puncture

As required by 10 CFR 71.73(c)(3), a free drop of the package must be performed from a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. Test prototypes TP180A, TP180B, TP180C, and TP180E underwent the HAC puncture test. The test orientations were chosen following the HAC free drop test to ensure that the position chosen would represent the maximum expected damage. The drop height was 43.3 in, due to the difference in weights between the basic and standard configurations. The tests are detailed in Test Plan 180 #2, included in the application.

TP180A and TP180B were dropped onto the dust cover of the rear plate assembly at an angle. The puncture test did not create an opening in the TP180A or the TP 180B packagings. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

TP180C was dropped onto the corner and longitudinal weld seam. The puncture test did not create an opening in the TP180C packaging. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

TP180E was dropped onto the lock plate. This test was performed twice, since it appeared that the first drop missed the target. The puncture test did not create an opening in the TP180D packaging. The post accident dose rates showed no appreciable dose elevation, and were within regulatory HAC dose rates.

The HAC puncture drop test results demonstrate that the package meets the requirements of 10 CFR 71.73(c)(3).

2.7.4 Thermal

As required by 10 CFR 71.73(c)(4), the package must be exposed to an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes.

The thermal stresses generated by the 1475°F, 30 minute duration, HAC fire test are assessed in Section No. 2.7.4 of the application. Because the package is constructed of the same stainless steel material and does not create a leaktight containment boundary that could increase in pressure due to temperature, the stresses due to the HAC thermal test are too insignificant to cause failure. Thermal expansion will occur (0.85 inches) but is not constrained, and stressing will not occur.

The application states that the absence of holes in the package will prevent oxygen from entering the welded body and oxidizing the depleted uranium shield, as well as ensure that the charred polyurethane foam will remain in the welded body of the package after the hypothetical fire accident condition. In addition, the application states that the oxygen inhibitive characteristic of the charred foam is relied upon to ensure that the shield will not be oxidized. These statements rely on the testing of two different packages that used similar materials to the Model No. SENTRY packages, but no actual thermal testing of the packages has been performed under HAC. In one of the tests performed on a different package (Test Plan 80) where a hole was present in the welded body, significant oxidation of the shield occurred. In the other package test described in Test Plan 72-S2, no direct observation of the shield is described or shown. The staff determined that the original design of the package had holes that could allow for oxygen to come into contact with the depleted uranium shield, and that insufficient proof of the oxygen inhibitive nature of the charred foam was provided. The applicant then changed the basic configuration of the package design by including stainless steel set screws in all unused threaded holes with a diameter larger than ¼ inch to ensure that no oxygen flows through such openings into the foam. This will prevent combustion and protect the shield from oxidation or loss of shielding ability.

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.73(c)(4) are satisfied.

2.7.5 Immersion – Fissile Material

The HAC immersion test for fissile materials is not applicable, as the package does not contain fissile contents.

2.7.6 Immersion – All Packages

As required by 10 CFR 71.73(c)(6), a separate, undamaged specimen must be subjected to a water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For test purposes, an external pressure of water of 150 kPa (21.7 lbf/in^2) gauge is considered to meet these conditions.

The package does not create a leaktight containment boundary that would be affected by the increase external pressure of 150 kPa gauge. The special form capsule, which is the package containment boundary, is subjected to an external pressure to certify the special form capsule (25 kN/m^2 to 2 MN/m^2 – ISO 2919-1999 standard).

Therefore, the staff determines that the regulatory requirements of 10 CFR 71.73(c)(6) are satisfied.

2.7.7 Summary of Damage

Table No. 2.7c of the application tabulates the NCT and HAC analyses and test results for the package.

2.8. Evaluation Findings

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

3.0 THERMAL EVALUATION

The objective of the thermal review is to verify that the thermal performance meets the requirements of 10 CFR Part 71, including performance under NCT and HAC.

3.1. Description of Thermal Design

3.1.1 Design Features

The Model Nos. SENTRY 110, 330, and 867 packages are completely passive thermal devices with no mechanical cooling system or relief valves. Heat transfer is achieved through free convection and radiation. The corresponding decay heat for the maximum source of 330 Ci of ^{60}Co is approximately 5.5 watts.

Table No. 3.2a of the application shows the components important to safety, along with the materials and alloys used in their construction. The components important to safety are designed to maintain adequate mechanical and thermal properties at and within the temperature range of -40°C (-40°F) to 800°C (1472°F).

The large mass of the depleted uranium shield supplies a considerable heat sink for decay heat dissipation through the source tube. The absorbed heat within the shield is conducted out to the exterior surfaces of the welded body, mainly at the top and bottom inner contact surfaces of the package. Conduction heat transfer occurs through the sides of the package through the shield pin connections at the access ports of the body.

Foam, made of polyurethane, surrounds and partially insulates the shield within the body. Additionally, the foam acts as a thermal and oxidizing barrier during high temperature conditions similar to the hypothetical accident fire test. The large surface area of the welded body exterior enables the heat to be transferred to the external environment through radiation and convection.

3.1.2 Contents Decay Heat

The maximum decay heat energy to be absorbed by the package is 5.5 watts.

3.1.3 Summary Table of Temperatures

Table No. 1 provides a summary of the temperatures during insolation, decay heating, fire testing, and post-fire (maximum temperature) conditions.

Table No. 1: Summary Table of Temperatures

Condition	**Temperature for the Model Nos. SENTRY 110, 330, & 867 Packages**
Insolation (38°C -104°F in full sun)	70.7°C (159°F)
Decay Heating (38°C-104°F in shade)	40°C (104°F)
Fire Testing	800°C (1472°F)
Post-Fire (Maximum Temperature)	800°C (1472°F)

3.1.4 Summary Table of Maximum Pressures

Table No. 2 provides a summary of the maximum pressures during NCT and HAC conditions. The packages are vented to atmospheric pressure; thus, no pressure will build up during both of these conditions.

Table No. 2: Summary of Maximum Pressures

Void Volume (in.^{3})	**Normal Conditions Pressure Developed at 88°C (190°F)**	**Hypothetical Accident Conditions Pressure Developed at 800°C (1472°F)**
0	0	0

Staff concludes that the thermal design features are adequate for the design of the package.

3.2. Material Properties and Component Specifications

Table No. 3.2b of the application shows the thermal properties, i.e., melting temperature, maximum service temperature, specific heat (measured in J/kg°K), thermal conductivity (measured in W/m°K), and the coefficient of thermal expansion (measured in °C^{-1}) for the main materials of the package. All components are specified and described on the licensing drawings. Stainless steel, titanium, tungsten and DU retain their mechanical properties at the minimum allowable service temperatures of -40°C (-40°F).

3.2.1 Material Thermal Properties

The staff has checked the melting temperatures, maximum service temperatures, specific heats, thermal conductivities and thermal expansion coefficients provided for DU, stainless steel, Titanium, and Tungsten Class 1 against the ASME B&PV code Section II, Part D when available (stainless steels), and against numerous other publicly available sources whenever standard material properties were not readily available. The staff finds that the thermal properties listed in Table 3.2b are correct.

3.2.2 Component Specifications

All the metallic alloys used for structural components of the packages have melting points above 800°C (1472°F), and retain sufficient strength around 800°C. These alloys are 300 series and 17-4 PH stainless steels, titanium alloys, and tungsten. The melting point of the depleted uranium shield is 1,130°C (2,066°F), i.e., above 800°C, and the shield is not relied upon for any structural purposes; thus its decreased strength at 800°C is acceptable. All of the aforementioned alloys retain their strength at -40°C (-40°F). The 300 series stainless steel, 17-4 PH stainless steel, Ti-6Al-4V and Ti-3Al-2.5V are used for structural components important to safety and retain sufficient ductility at -40°C to prevent brittle fracture.

The staff concludes that the maximum allowable service temperatures for the materials of the package are adequate.

3.3. General Considerations

3.3.1 Evaluation by Analysis and Test

Test plans and results are included in the application along with additional thermal analyses. Staff reviewed them and concludes that the evaluations performed by both analysis and testing are adequate for the design of the packages.

3.4. Thermal Evaluation under NCT

3.4.1 Heat and Cold

3.4.1.1 Insolation and Decay Heat

The analysis, performed in accordance with 10 CFR 71.71(c)(1), determined the maximum surface temperature produced by solar heat and the maximum decay heat generation for a package loaded with an activity of 330 Ci of ^{60}Co. The maximum surface temperature was comparable to the maximum operating temperatures of the materials identified in Table No. 3.2b of the application. The worst case estimate of the package's surface temperature is obtained by using exclusively radiant heat transfer and ignoring cooling provided by the conductive and convective exchanges.

The equations used in calculating the heat input includes the following:

$$Q_{TS} = e^{*}S_{F}{}^{*}A_{T} \qquad (1)$$

where Q_{TS} is the local solar heat input on top surface (W), ε is the emissivity of clean stainless steel, S_F is the insolation value of other horizontal flat surfaces (W/m^2), and A_T is the top surface area (m^2),

$$Q_{TL} = Q_{TS} + Q_D \quad (2)$$

where Q_{TL} is the combined solar and decay heat inputs applied locally to the top surface (W) and Q_D is maximum heat decay (W),

$$Q_{SS} = \varepsilon * S_C * A_S \quad (3)$$

where Q_{SS} is the local solar heat input on side surface (W), ε is the emissivity of clean stainless steel, S_C is the insolation value of the curved surfaces (W/m^2), and A_S is the side surface area (m^2),

$$Q_{SL} = Q_{SS} + Q_D \quad (4)$$

where Q_{SL} is the combined solar and decay heat inputs applied locally to the side surface (W),

$$Q_{IN} = Q_{TS} + Q_{SS} + Q_D \quad (5)$$

where Q_{IN} is the combined solar and decay heat inputs applied uniformly over the top and side surfaces (W),

The equations used in calculating the heat output includes the following:

$$Q_{TR} = \sigma * \varepsilon * A_T * (T_w^4 - T_a^4) \quad (6)$$

where Q_{TR} is the heat output radiating from the top surface (W), σ is the Stefan-Boltzmann's constant (W/m^{2}*K^4), ε is the emissivity of clean stainless steel, A_T is the top surface area (m^2), T_w is the average top and side surface temperature (degrees Kelvin), T_a is the ambient temperature (degrees Kelvin),

$$Q_{SR} = \sigma * \varepsilon * A_S * (T_w^4 - T_a^4) \quad (7)$$

where Q_{SR} is the heat output radiating from the side surface (W), A_S is the side surface area (m^2),

$$Q_{OUT} = Q_{TR} + Q_{SR} \quad (8)$$

where Q_{OUT} is the heat output radiating from the top and side surfaces (W).

The maximum local top surface temperature, T_T, is 126°C (259°F), while the maximum local side surface temperature, T_S, is 89°C (192°F). In determining the average top and side surface temperature, T_w, Equations (5) and (8) were used to calculate a value of 98°C (208°F). The value calculated for T_T will not adversely affect the containment or shielding integrity of components important to safety as the temperature is well below the maximum service temperature for these materials.

3.4.1.2 Still Air (Shaded) Decay Heat

The analysis was performed to determine the maximum surface temperature of the packages in the shade (i.e., without insolation effects), using an ambient temperature of 38°C (100°F) per 10 CFR 71.43(g). Equations (5) and (8) were used to determine the maximum surface temperature. The value calculated, 41°C (105.8°F), is less than the maximum temperature, 50°C (122°F), which is the allowed value stipulated in 10 CFR 71.43(g).

3.4.2 Maximum Normal Operating Pressure

The Model Nos. SENTRY 110, 330, and 867 packages allow venting to the atmosphere during pressure changes through small openings in the package design to prevent buildup in the package during NCT. No other gas sources are present and the pressure differential shown is 0 psi for NCT.

3.4.3 Maximum Thermal Stresses

3.4.3.1 Package Surface

With an initial temperature of 38°C and solar heat applied to the top of package, the temperature reaches 126°C (259°F), leading to an increase of the diameter of the stainless steel top plate of 0.029 inches (0.73 mm). In addition, with solar heat applied at the side of the package, the side surface would rise to 89°C (192°F) from an initial temperature of 38°C, leading to a diameter increase of the stainless steel top plate of a maximum of 0.017 inches (0.043 mm).

Through the expansions of the top and side surfaces, a relative expansion or strain was calculated to be 0.012 in (0.30 mm). This strain produces an internal stress ($\sigma_{internal}$) of 19.3 ksi, which is half of the allowable yield strength of the stainless steel. Such a stress would not cause rupture in the base material or the weld seams. The internal stress was calculated as follows:

$$\sigma_{internal} = \frac{M_{steel} * (D_{top} - D_{side})}{D} = \frac{29e6psi * (0.029\ in. - 0.017\ in.)}{18\ in.} = 19.3\ ksi$$

3.4.3.2 Depleted Uranium Shield Connection

Section No. 3.4.2.2 of the application provides a discussion about the thermal stresses within the depleted uranium shield connection. Within the worst-case scenario, the temperature difference between the pin and the shield is 51°C (124°F). The size of the sized pin-mounting hole in the shield at the ambient temperature of 38°C is 0.740 inches (18.8 mm). The largest pin diameter at 38°C is 0.730 inches (18.54 mm), which provides a difference of 0.010 inches

(0.25 mm) of minimum design clearance between the pin and the hole. The expansion of the diameter of the titanium pin because of the 51°C temperature change is calculated to be 0.0004 inches, which is significantly less than the 0.010 inches allowed from design clearance; therefore, the packages will maintain their structural integrity and shielding effectiveness under NCT.

Staff performed confirmatory calculations and compared its results with the values listed in the application. Staff concludes that the design is adequate for NCT conditions.

3.5 Thermal Evaluation under HAC

3.5.1 Initial Conditions

The applicant did not perform a thermal test. However, an assessment was made to demonstrate that a thermal test would not create sufficient additional damage that would cause the package to fail the source containment integrity requirement. The thermal characteristics of the materials used for package fabrication, coupled with the data from both the 30 foot free drop and puncture tests, provide evidence that the package would not fail and that its shielding integrity would not be significantly degraded by a thermal test.

The worst-case initial temperature scenario for the package and its contents is -40°C because it provides the highest thermal differential between the contents, shield, and exterior surface of the package during an 800°C fire test. There is no worst-case initial pressure within the package to be balanced within the surrounding environment.

3.5.2 Fire Test Conditions

Section No. 3.5.2 of the application provides a discussion of the fire test conditions and criteria for acceptability of the packages. These criteria are:

1) The welded stainless steel body must remain intact to ensure the polyurethane foam protects the shield during the fire test. Test Plan Reports Nos. 180 and 195 demonstrate that the package can withstand high impact and puncture loads without a substantial breach in the exterior of the package. In addition, Test Plan Reports Nos. 72-S2 and 80, in support of Certificate of Compliance Nos. 9035 and 9269 respectively, show that there is no breach of the shield containment, thus preventing oxygen ingress to the shield and any resulting deterioration of the depleted uranium shield during the thermal test.

2) The shield mounting structure must retain enough strength at 800°C for 30 minutes and during cool down to support the shield at its post puncture test location. The radiation profile results after the 30-foot drop and puncture tests confirm that the shield support structure provides sufficient shielding of the package contents after the puncture test and before the thermal test. With the maximum service temperature of the stainless steel body above 800°C for continuous use, this will ensure the shield will remain confined within the package in the location found after the 30 foot and puncture tests.

3) The shield material must retain its ability to sufficiently shield the package contents during and after the HAC thermal test. The applicant demonstrates that the package exterior remains intact, the shield does not completely oxidize or sufficiently degrade during and after the thermal test. The melting temperature of the shield, 1100°C, is much higher than the 800°C test temperature, thus it would be unlikely that the foam-

insulated shield will reach 800°C during the 30-minute test. The package maintains the capability to sufficiently shield its contents during and after the HAC thermal test.

4) The package contents must remain intact enough to prevent dispersal of radioactive material within and outside the package. The source capsule, used as the primary containment for the radioactive contents in the package, successfully passed the ANSI N542-1978 Class 6 thermal test where it was subjected to an oven temperature of 800°C for one hour and then was checked for leakage. No leakage occurred; therefore, the package will remain intact and prevent dispersal of radioactive material in or out of the package under thermal test conditions.

Overall, the package complies with the HAC thermal tests without exceeding the final radiation profile criteria.

3.5.3 Maximum Temperatures and Pressure

The Model Nos. SENTRY 110, 330, and 867 packages allow venting to the atmosphere during pressure changes to prevent buildup in the package during HAC and/or relieve any internal generation or expansion of gases created by the elevated temperatures. No other contributing gas sources are present and the pressure differential shown is 0 psi as vented to the atmosphere with no means for creating a pressure differential for HAC.

3.5.4 Temperatures Resulting in Maximum Thermal Stresses

During the HAC analysis, the maximum thermal stresses during a fire test were examined in two areas which could potentially experience the highest temperature extremes because of the fire heat input at the pin shield connection points with the welded body at the access ports and at the center of the shield at the source wire assembly. In the worst-case scenario, the temperature differential between the pin and the shield is 840°C.

Within the shield, the smallest hole is 0.740 inches at room temperature (38°C) while the largest pin diameter at the same temperature is 0.730 inches. When the temperature drops to -40°C, the shield hole shrinks to 0.739 inches while the pin diameter expands to 0.736 inches when the temperature rises to the HAC temperature of 800°C.

A thermal gradient exists between the source wire assembly and capsule contents when the exterior surface of the package is at 800°C and the radioactive source at the center of the package is at -40°C. The gradient could cause thermal stresses to occur at the source wire assembly while in the package. However, the source wire assembly contains the freedom to slightly expand, contract, and pivot within the shield source tube channel, thus preventing thermal stresses from building up within the source wire assembly.

The 0.15 inch increase in the length of the longest source wire caused by the 762°C temperature increase of the fire test is not enough to increase the external radiation dose rate over 10 mSv/h at 1 m from the external surface of the package. Thus, the Model No. Sentry package maintains its structural integrity and shielding effectiveness under HAC and staff concludes that the design is adequate for HAC conditions.

3.6. Evaluation Findings

Staff performed a confirmatory analysis, along with a review of the equations listed within the application. Staff calculated values similar to those listed in the application, which did not exceed the maximum allowable NCT and HAC temperatures.

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

4.0 CONTAINMENT EVALUATION

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

4.1 Description of Containment System

The primary containment system for the package is the welded source capsule, certified as Special Form under 10 CFR Part 71, and 49 CFR 173.

4.2 Containment under NCT

Results from Test Plan No. 180 demonstrate that NCT conditions do not cause any breach of the capsules contained in the package.

4.3 Containment under HAC

Results from Test Plan Nos. 180 and 195, included in the application, demonstrate that radiation levels do not exceed 1R/hr at one meter from the surface of the package after performance of the HAC tests, and that there is no breach of the capsules contained in the package.

4.4 Leak Rate

The source capsule is leak-tested during fabrication and every six months to ensure that any potential contamination release from the package would be below the regulatory limit.

4.5 Evaluation Findings

Based on the review of the statements and representations in the application, the staff concludes that the Model No. SENTRY package meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING EVALUATION

5.1 Description of the Shielding Design

5.1.1 Packaging Design Features

The Model Nos. SENTRY 110, 330, and 867 packages have depleted uranium shields which are completely encased and supported in a cylindrically shaped, stainless steel, welded body.

The center of gravity for each model is approximately in the geometric center of the package. Therefore, it is acceptable to use the point source geometry at the center of the package for gamma exposure calculations.

5.1.2 Summary Table of Maximum Radiation Levels

In order to evaluate the package's shielding adequacy, the applicant performed direct radiation measurements both before and after the Test Plan Nos. 180 and 195 (as explained in Section No. 2.12 of the application). A Co-60 test source was used for dose measurements and the measured dose rates were then extrapolated to the maximum content of 330 Ci. The maximum radiation levels are presented in Table No. 5-1(a-g) of the application for both non-exclusive and exclusive use of the package. The addition of handling rib assemblies and link plates to the package basic configuration increases the weight of each package by approximately 80 lbs. Since, the handling ribs provide protection and substantial impact energy absorption in certain free drop orientations, the worst case scenario for NCT testing was determined to be for the Model No. SENTRY 330 Basic design, adjusted for the worst case package weight**.**

5.2 Radiation Source

The Model No. SENTRY packages are designed to transport special form capsules containing Co-60 isotopes. The source capsule, attached to a flexible steel wire, form the source wire assembly. The Model Nos. SENTRY 110 and 330 packages can transport one source wire assembly with a maximum capacity of either 110 or 330 Ci respectively. The Model No. SENTRY 867 package design can transport up to two source wire assemblies with maximum capacity of 330 Ci.

These packages are not used for the transportation of neutron emitting sources, and Co-60 does not emit any neutron. A shielding model was not developed but direct measurements were performed on the test units.

5.3 Material Properties

No material properties are provided for shielding analyses because testing is used to evaluate shielding performance.

5.4 Shielding Evaluation

The shielding performance and evaluation are based on direct measurement. Results from tests, as well as additional radiation profiles, are provided in the application.

All dose rates measurements are based on direct measurement for both NCT and HAC conditions. Radiation measurements are then adjusted to the maximum activity capacity for the package by using activity correction factor, which is the ratio of maximum capacity to activity used during each measurement. The surface measurements are also adjusted to correct for off-set of the survey meter probe thickness from the true surface of the package, which is the ratio of distance from the activity center to the surface of the container plus the radius probe of the survey meter to the distance from the activity center to the surface of container probe. These correction factors are used for both initial build NCT and after HAC conditions. These measurements did not show an increase in external surface radiation levels above 200-mR/hr after any NCT test and above 1-R/hr at 1 meter (40 inches) from the package's external surface after HAC tests.

Since the shielding evaluation is based on direct measurement, flux rates were not used to convert to dose rates in any shielding evaluation.

The maximum adjusted dose rates for the Model No. SENTRY 330 package during NCT for non-exclusive use transport were well below 200 mrem/hr at the surface of the package and 10 mrem/hr at a distance of one meter from the surface. The dose rates were also well below 1000 mrem/hr at one meter during HAC for non-exclusive use.

The maximum extrapolated dose rates for the Model No. SENTRY 330 package during NCT in an exclusive use transport are well below 1000 mrem/hr at the surface of the packages and 10 mrem/hr at a distance of two meters from the surface. The dose rates were also well below 1000 mrem/hr at one meter during HAC for exclusive use.

These values comply with the requirements of 10 CFR 71.47(a). Under HAC, the maximum dose rates measured were 5 mrem/hr at a distance of one meter, which meets the requirements of 10 CFR 71.51(a)(2).

5.5 Evaluation Findings

Based on review of the statements and representations in the amendment, the staff concludes that the design of the Model No. SENTRY package has been adequately described and evaluated and that the package meets the shielding requirements of 10 CFR Part 71.

6 CRITICALITY EVALUATION

Compliance with 10 CFR criticality requirements is not applicable for this package since contents exceeding the fissile mass limits set forth in 10 CFR 71.15 are not authorized.

7.0 PACKAGE OPERATIONS

The objective of this review is to verify that the operating controls and procedures meet the requirements of 10 CFR Part 71 and are adequate to assure that the package will be operated in a manner consistent with its evaluation for approval.

7.1 Package Loading

Prior to loading the contents of the package, bolts and fasteners are visually inspected for signs of fatigue cracking and replaced if necessary. The package is also inspected for signs of degradation and to also ensure that the shipping cover can be installed and secured and that the lock plungers properly operate.

Package loading operations are only authorized for “dry” loading. The removal and installation of the source must be performed in a shielded cell/enclosure or by using remote transfer operations for wire mounted sources. The source assembly shall be fully inserted into the source tubes with the active end of the source assembly inserted first, and secured by the lock assembly. Once the source is loaded, the lock cover is installed, the plunger lock is depressed and the key removed.

In preparation for transport, contamination and radiation surveys are performed.

7.2 Package Unloading

Upon receipt, a loaded package is surveyed and actual radiation levels are recorded. The radioisotope, activity, model numbers, and serial numbers of the source and of the package are also recorded. The package is also inspected for physical damage and for leaking.

The package is transferred to a remote handling cell to remove the sealed source assembly prior to transferring it to a shielded storage location.

7.3 Preparation of Package for Empty Transport

Prior to shipment of an empty package, a survey is performed to verify that the external surface radiation level does not exceed 5 μSv/h.

7.4 Evaluation Findings

The staff reviewed the Operating Procedures in Chapter No. 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 provide adequate measures and reasonable assurance for safe operation of the proposed design in accordance with 10 CFR Part 71.

Further, the Certificate of Compliance is conditioned such that the package must be prepared for shipment and operated in accordance with the Operating Procedures specified in Chapter No. 7 of the application.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The objective of this evaluation is to verify that the acceptance tests for the packaging meet the regulatory requirements, and that the maintenance program is adequate to ensure packaging performance during its service life.

8.1 Acceptance Tests

Each package component is visually inspected prior to shipment, weld examinations are performed in accordance with the licensing drawings requirements, and a radiation profile survey is performed at the time of manufacture of the package. The maximum allowed dose rate at one meter from the surface is limited to 5 mR/hr at the time of manufacture. Any failure of the radiation profile test for any model of the package indicate the potential of significant shielding porosity and leads to the rejection of the package.

8.2 Maintenance Tests

The package is inspected for tightness of fasteners, proper seal wires, and general condition prior to each use, while the source assembly is leak-tested at least once every six months to ensure that removable contamination is less than 185 Bq (0.005μCi).

8.3 Evaluation Findings

The staff reviewed the acceptance tests and maintenance programs for the Model No. SENTRY package. The staff found them acceptable. 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. Further, the Certificate of Compliance is conditioned to specify that each package must meet the Acceptance Tests and Maintenance Program of Chapter No. 8 of the application.

CONDITIONS

The following conditions are included in the Certificate of Compliance:

(a) The package shall be prepared for shipment and operated in accordance with Chapter 7 of the application.

(b) The package must be tested and maintained in accordance with Chapter 8 of the application.

CONCLUSION

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

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