SAFETY EVALUATION REPORT

Docket No. 71-9337
Model No. 3979A
Certificate of Compliance No. 9337
Revision No. 1

SUMMARY

By application dated April 19, 2012, as supplemented September 5, 2012, Croft Associates Limited submitted an amendment request to revise the Certificate of Compliance (CoC) for the Model No. 3979A package. The application proposed changes to material and testing references in the Safety Analysis Report (SAR), changes to fabrication drawings, and corrected acceleration values utilized in an earlier report. These changes were proposed to facilitate packaging fabrication as well as ensure agreement between fabrication and design documents. NRC staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material." Based on the statements and representations in the application, as supplemented, the staff agrees that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

1.0 GENERAL INFORMATION

1.1 Drawings

The applicant added the important to safety classifications for components to licensing drawings 0C-6041, 0C-6042, 0C-6043, 1C-6044, 1C-6045, and 1C-6046. They revised the cork packing specification and provided options for verifying the specific weight of the cork used on drawing 0C-6043. The applicant modified drawing 1C-6044 to bring a test pressure into conformance with American Society of Mechanical Engineer (ASME) Section III Article NB 6000, to accommodate O-rings purchased during fabrication, to update the O-ring material specified on the drawing, to include testing options for molded O-rings and to revise the hardness/minimum tensile specification for O-rings. The applicant revised drawings 1C-6045 and 1C-6046 to identify the correct ASME Subsection for ultrasonic testing of stock material, to allow the use of lead containing slightly higher levels of impurities as well as to allow the use of larger helicoils. The applicant also revised drawing 1C-6045 to specify performance of a helium leak test of the inner O-ring on the containment vessel lid. They also revised drawing 1C-6040 to identify the most recent revision of these drawings.

The applicant revised drawings 2C-6171, 2C-6172, and 2C-6175 to identify the important to safety classification of components. In addition, they revised drawings 2C-6171 and 2C-6172 to allow the use of O-ring material with a wider range of operating temperatures and to correct a typographical error. The applicant also corrected an erroneous material specification on drawing 2C-6175. Finally, the applicant revised drawings 2C-6172 and 2C-6175 to show a three millimeter hole in the insert lid to facilitate testing once the Model No. 3979A is approved for transporting liquids.

1.2 Evaluation Findings

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

2.0 STRUCTURAL

2.1 Package Description

The package was designed to transport quantities of normal and special form nuclear material greater than $3000A_2$; therefore, it is classified as a Category I package as defined in Regulatory Guide 7.11. The standards to which the package was designed, fabricated, tested, and maintained have been selected based on the guidance provided in Regulatory Guide 7.6 and NUREG/CR-3854.

2.2 Package Design Standards

The structural design criteria used to assess the containment boundary were taken from Regulatory Guide 7.6 and the load combinations used were from Regulatory Guide 7.8. The buckling evaluation of the containment vessel inner shell was evaluated in accordance with the requirements of ASME code case N-284-2. The package containment system was designed in accordance with the applicable requirements of the ASME Code, Section III, Subsection NB. The non-containment structural components of the package were designed in accordance with the applicable requirements of ASME Code Section III, Subsection NF, for plate and shell type Class 2 supports. The package containment system was fabricated in accordance with the applicable requirements of Section III, Subsection NB, of the ASME code. The other safety items were fabricated in accordance with the applicable requirements of Section III, Subsection NF for Class 2 supports in the ASME code.

2.3 Structural Evaluation

Besides editorial corrections and updates to References, Tables, and Figures, the applicant made minor changes to the lead shielding and the cork impact limiters. These are special materials for which an ASTM standard does not exist. The applicant used lead containing 4% antimony fabricated and tested in accordance with standard industry practices. The cork was fabricated in accordance with the vendor’s standard practice and tested per the requirements of licensing drawing 0C-6043.

The most significant change reviewed by the staff was the “g” loads applied to the package during the normal conditions of transport (NCT) drop scenarios. The applicant had determined that the radial deceleration value of 112g used in the original analytical models was erroneous. However, they argued that this fact did not impact the original findings. They based their argument on the fact that, because the results of analytical models for the NCT corner drop (axial deceleration of 264g and radial deceleration of 278g) satisfied the regulatory criteria, the regulatory criteria for the NCT side drop would also be satisfied since the radial deceleration values (273g) associated with prototype testing was less than predicted by the model for the corner drop.

In evaluating this assertion, staff reviewed SAR Section 2.6.7 to verify compliance with the requirements of 10 CFR 71.71(c)(7). Staff also requested additional information of the applicant to identify bounding stress design margin due to ambiguity in the previous version of the SAR.

After reviewing the information provided in the applicant's response, and verifying that the applicant had updated "g" loads in the SAR associated with the NCT free drop tests, staff concurs with the applicant's argument that a corner impact would impose a greater loading on the components due to the smaller impact area than the equivalent side impact.

It was also noted by the staff that under this NCT drop scenario, the minimum design margins due to bearing stress under the bolts was caused by thermal stress around the bolts. Staff reviewed the calculated values for average shear, average stress, and maximum stress of the closure bolts for each free drop condition summarized in Tables 2-31 and 2-32 of the updated SAR. As the design margins for all drop conditions are greater than 0, staff concludes that the bolts satisfy the requirements of Regulatory Guide 7.6. Consequently, there is a reasonable assurance that the applicant is in compliance with 10 CFR 71.71(c)(7).

2.4 Materials

The Safkeg-LS 3979A package description is discussed in Section 1.2 of the application. The principal structural members of the Safkeg-LS 3979A package are as follows:

- Keg
- Cork Packing
- Containment Vessel

KEG:
The keg has an outer shell and a liner both fabricated from American Society for Testing and Materials (ASTM) A240, Type 304L stainless steel (SS). The shell of the keg is rolled and welded to form a cylinder. A SS base plate ASTM A240, Type 304L, SS top flange ASTM A240, Type 304L, top/bottom SS skirts ASTM A240, Type 304L and top/bottom SS rims ASTM Type MT304 are welded to the rolled cylinder to form the keg body.

The keg is closed by a flat SS lid, ASTM A240, Type 304L, which is bolted down with 8 SS studs, ASTM A276, Type 304L and nuts ASTM A2-70, Type 304 against a single weather preventing (water) O-ring Nitrile (NBR). All closure studs are fitted with seal holes for incorporating a tamper indicating device (i.e., lock wire) in accordance with 10 CFR 71.43(b). In addition, a padlock can be attached to a SS lock pin, ASTM A276, Type 304L, welded to the keg SS closure flange, ASTM A240, Type 304L, to prevent unauthorized removal.

There is a low melting SS fuse plug, ASTM A2 alloy fitted at the center/bottom of the keg which will vent to provide over pressure relief during Hypothetical Accident Condition (HAC) fire. This alloy has a melting point of 95°C ±5°C.

CORK PACKING:
Outer cork (OC) packing is placed inside the keg body described above. A SS keg liner ASTM A240, Type 304L, is placed within the outer cork packing. Inner cork (IC) packing is inserted into the keg liner. A top cork packing is placed on the Containment Vessel (CV), described below, when preparing the packaging for shipment. There is no cork directly underneath the Containment Vessel as it sits on the base of the keg liner.

Both the IC and OC packing is machined from resin bonded agglomerated cork (i.e., granulated cork bound by a resin and coated in a water base varnish). The cork packing may be formed from one agglomerated piece or from several glued together with a contact adhesive. The OC is not intended to be replaced. The IC packing is readily removable and intended to be replaced if required at pre-shipment or annual maintenance.

CONTAINMENT VESSEL:
The CV consists of a body and a removable lid assembly bolted together with 8 closure bolts and sealed with an inner and outer O-ring.

The CV body is fabricated from three pieces of solid SS as follows:

- CV flange/cavity wall
- CV outer wall
- CV base

The CV flange/cavity wall ASTM A276, Type 304L, is welded to the CV outer wall ASTM A511, Type MT304L which is welded to the SS base ASTM A240, Type 304L or A276, 304L and forms the cavity into which the CV body lead alloy shielding (4% antimony) is cast. The lead alloy forms the shielding for the walls and base of the CV body shielding. The lead alloy may only contain a maximum of 0.5% impurities.

The CV removable lid is fabricated from two pieces of SS as follows:

- CV lid top
- CV lid shielding casing

The SS CV lid shielding casing ASTM A276, Type 304L, has the lead alloy shielding cast inside and is then welded to the SS CV lid top ASTM A276, Type 304L. The CV lid is held in position by eight recessed alloy steel screws ASTM A320, Type L43. The seal between the CV body and the CV lid is achieved by two O-ring Ethylene Propylene (EP) Rubber ASTM D2000 seals (3 mm cord diameter). Access to the interspace between the two EP O-rings is provided for operational and maintenance leak testing required in 10 CFR 71.51.

PAYLOAD INSERTS:
The radioactive contents are transported within payload containers or inserts placed inside the CV. Any one of the three inserts specified in Section 1.3.2 shall be used to provide further shielding and confinement for the contents. Two of the inserts are machined from tungsten with one machined from SS. All inserts consist of a body and a lid which are machined from a solid piece. The lid screws onto the body with an O-ring seal. All three types of inserts each have different cavity sizes and provide varying levels of shielding.

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.

2.4.1. Chemical or Galvanic Reactions

Section 2.2.2 of the application discusses reactions due to chemical, galvanic, or other reactions. The applicant states that the package has been evaluated for all the material interactions of chemically or galvanic dissimilar materials and there is no potential for chemical, galvanic, or other reactions between the components of the package which are SS and cork in dry conditions, and SS and encapsulated lead which is sealed and therefore dry. The only contents which could cause reactions or generate gases are liquids carried in product containers within the tungsten or steel inserts which are fitted with an EP O-ring seal.

The staff concludes that, during normal conditions of transportation, the CV internals will not be subject to continuous or frequent exposure to moisture or that any water intrusion is not likely to occur in great quantities. Because the number of materials used in fabrication is minimized, the 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 will be performed of the Important-to-Safety (ITS) CV payload cavity at various timed intervals providing reasonable assurance against any significant corrosion occurring unnoticed.

2.4.2. Effects of Radiation on Materials

Section 2.2.3 of the application discusses the effects of radiation. The contents of the package emit one or all of alpha, beta, gamma, and neutron radiation. Austenitic SS, lead, and cork were chosen for the construction of the package because they are durable materials that are able to withstand the damaging effects from the radiation. The EP O-ring seals fitted to the containment system are the only material on which the radiation may have an effect; however it has been shown that for the radioactive contents the maximum dose to the containment seal is less than 1×10^6 rad whereas no change of physical properties of the EP containment seal is expected at radiation levels up to 1×10^6 rad. These seals are required to be replaced annually at maintenance.

The staff finds that radiation effect on the elastomeric seals is not a concern as the seals are replaced on an annual basis. In addition, finite element analysis predicts the maximum temperature of the elastomeric seal during accident conditions reached is 116°C which is below the acceptable stated heat resistance for EP rubber.

2.4.3. Brittle Fracture

Section 2.1.2.5 of the application discusses material brittle fracture concerns. All the structural components of the package are fabricated from austenitic SS which is ductile at low temperatures. Regulatory Guide 7.11 states austenitic SS is not susceptible to brittle facture at temperatures encountered in transport. The HAC drop tests have been conducted at minus 40°C to determine if brittle fracture has any effect on the package, with compliance demonstrated if the containment vessel is undamaged and leak tight on completion of testing.

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 304L SS. Since this material does not undergo a ductile-to-brittle transition in the temperature range of interest (down to minus 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.

2.4.4. Acceptance Tests and Maintenance Program

Section 8 of the application discusses acceptance tests and maintenance program. The metallic materials of construction (keg and CV) 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 Sections III, V, and IX. A summary of maintenance requirements is discussed in Table 8-1 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.

2.4.5. Conclusion

The staff finds that the Croft Safkeg-LS 3979A transportation 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.

2.5 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 CONTAINMENT

3.1 Description of the Containment System

The containment boundary of the Safkeg-LS 3979A package is formed from the containment vessel (CV) flange/cavity wall, lid top, and containment seal O-ring. All containment boundary components are important to safety, Category A, in accordance with NUREG-6407. The containment system is designed and fabricated in accordance with the applicable sections of the ASME B&PV Code Section III, Division 1, Subsection NB, as shown in Table 2-8 of the SAR. Table 2-9 of the SAR lists alternatives to the ASME Code. In addition to the previously approved containment boundary seal material, ethylene propylene rubber (EPM or EP), ethylene propylene diene rubber (EPDM) may also be used. Both materials offer a temperature range from -40°C to 150°C for continuous operation and are able to withstand short excursions up to 200°C.

3.2 Containment Evaluation

The applicant specified that sample O-rings shall be tested to ensure satisfactory performance at the temperatures reached during NCT and HAC conditions. Inner and outer O-rings from each batch will be leak tested after maintaining an operating temperature of 150°C for 1000 hours. Inner and outer O-rings will also be leak tested after maintaining an operating temperature of 200°C for 24 hours. This testing is separate from and in addition to the ANSI N14.5 fabrication, periodic, and maintenance leakage rate testing that is performed on every package containment boundary seal.

The applicant repeated the finite element analysis of the containment vessel for the NCT and HAC free drops using corrected g values that were equal to measured values. The FEA analysis with higher g values showed some changes in design margin, but it demonstrated that no areas of the containment vessel exceed the required design margin, which indicates that the containment vessel will maintain containment.

This amendment removed reference to containment vessel stock material helium leak testing. In accordance with ANSI N14.5, helium leakage rate testing will continue to be performed on the entire containment boundary, including the base material, once the material is machined into component parts. The containment vessel lid top, flange, and vessel cavity wall are tested using the gas filled envelope method to a leakage rate of 1×10^{-7} ref-cm^3/s with a sensitivity of 5×10^{-8} ref-cm^3/s. The containment vessel lid top is helium leak tested at the component stage prior to machining, as well as after machining the O-ring grooves and welding of the CV lid shielding casing to ensure the containment vessel lid top leakage rate is less than 1×10^{-7} ref-cm^3/s. The containment vessel closure is also tested to a leakage rate of 1×10^{-7} ref-cm^3/s with a sensitivity of 5×10^{-8} ref-cm^3/s, but is tested using the evacuated envelope gas detector method. This testing is described in Section 8.1.4 of the SAR. The ANSI N14.5 fabrication leakage rate test on the entire containment boundary will demonstrate that each packaging, as fabricated, provides the required level of containment.

The ANSI N14.5 periodic and maintenance leakage rate testing is described in Section 8.2.2 of the SAR. This testing will be performed using the evacuated envelope gas detector method to a leak rate of 1×10^{-7} ref-cm^3/s with a sensitivity of 5×10^{-8} ref-cm^3/s. Periodic testing is performed within 12 months prior to shipment, maintenance testing is performed after the following activities: 1) replacement of the containment seal, 2) repair of the containment sealing surface, or 3) either repair or replacement of the containment vessel lid or body.

Section 7.1.3 of the SAR described the ANSI N14.5 pre-shipment leakage rate testing. This testing is performed on the double o-ring closure using either the gas pressure rise or gas pressure drop method to a sensitivity of 1×10^{-3} ref-cm^3/s.

3.3 Evaluation Findings

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

4.0 PACKAGE OPERATIONS

4.1 Evaluation

Instructions were added in Section 7.1.1 to check for condensation between the keg and keg liner as well as for drying of the keg and lid if water was found. In addition, a typographical error was corrected in Section 7.1.2.

4.2 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the operating procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

5.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

5.1 Evaluation

The applicant modified maintenance instructions either to ensure agreement with manufacturing drawings or to eliminate redundant information. The applicant added instructions to perform both temperature tests on O-rings, and helium leak test the containment vessel lid as well as removed instructions to perform helium leak tests on stock material. They deleted the reference from the Maintenance Section, but incorporated text from the deleted procedure into Section 8.1.5.2. Since the chemical composition of the lead shielding was revised to allow a slightly higher impurity content, the applicant modified the maintenance instructions accordingly. Finally, the applicant changed the time at which the lead shielding was tested during packaging fabrication and corrected typographical errors.

5.2 Evaluation Findings

Based on review of 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, and that the maintenance program is adequate to assure packaging performance during its service life.

CONDITIONS

The CoC includes the following condition(s) of approval:

Condition 5(a)(3) was revised to incorporate the most current revision to the drawings.

Condition No. 9 was revised to authorize use of Revision No. 0 of the CoC until November 30, 2013.

Minor editorial corrections were made.

CONCLUSIONS

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Model No. 3979A package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9337, Revision No. 1
on November 16, 2012.