December 27, 2013

Mr. Steven E. Sisley
Cask Licensing Manager
Energy*Solutions* Products and Technology Group
Suite 100, Center Point II
100 Center Point Circle
Columbia, SC 29210

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9204, REVISION NO. 21, FOR THE MODEL NO. 10-160B PACKAGE

Dear Mr. Sisley:

As requested by your letter dated July 18, 2013, supplemented September 20, 2013, and November 4, 2013, enclosed is Certificate of Compliance No. 9204, Revision No. 21, for the Model No. 10-160B package. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's safety evaluation report is also enclosed.

The 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 John Vera of my staff at (301) 287-9165.

Sincerely,

/RA/ B. J. Davis for

Michele Sampson, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9204
TAC No. L24770

Enclosures:
1. Certificate of Compliance No. 9204, Rev. No. 21
2. Safety Evaluation Report
3. Registered Users

Upon removal of Enclosure 3, this document is uncontrolled

cc w/encl 1 & 2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy

Mr. Steven E. Sisley
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ADAMS P8 Package No.:ML13365A306 ADAMS P8 Letter No.: ML13365A303, CoC ML13365A304

OFC:	SFST	SFST	SFST	SFST	SFST	SFST
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DATE:	12/2/2013	12//2013	12/11/2013	12/24/2013	12/27/2013	

SAFETY EVALUATION REPORT
Docket No. 71-9204
Model No. 10-160B
Certificate of Compliance No. 9204
Revision No. 21

SUMMARY

By application dated July 18, 2013, supplemented September 20, 2012, and November 4, 2013, Energy*Solutions* requested an amendment to Certificate of Compliance (CoC) No. 9204 to add a new safety analysis report (SAR) addendum for a new variant of the existing 10-160B shield insert, designated as Shield Insert B, for shipping dry-loaded sources. The application also requested changes to the existing SAR addendum for the 10-160B shield insert (re-designated as Shield Insert A). These included revisions to the insert and cribbing drawings, revisions to permit insert reuse, revision of the shielding analysis to correct the drain configuration, and other editorial corrections.

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 representation in the application, as supplemented, and the conditions listed below, the staff concludes that the package continues to meet the requirements of 10 CFR Part 71.

EVALUATION

1.0 GENERAL INFORMATION

1.1 Package Description

There are no changes to the Model No. 10-160B package as described in the January 24, 2011, application other than (i) provisions for the reuse of a shield insert (now designated as Shield Insert A), and (ii) the addition of a shield insert variant with no drain line, for use with dry-loaded contents (Shield Insert B). The shield insert designs are essentially the same as the previously approved shield insert design.

1.2 Licensing Drawings

The staff reviewed Licensing Drawing Nos. C-038-145083-004-01, Rev. 1, and C-038-145083-004-02, Rev. 1 (for Shield Insert A), as well as Drawing Nos. DWG-LIN-201588-ME-0001-01, Rev. 0, and DWG-LIN-201588-ME-0001-02, Rev. 0 (for Shield Insert B). The staff also reviewed Licensing Drawing No. C-038-145083-005, Rev. 1. The staff determined that the submitted drawings are adequate.

1.3 Findings

The staff concludes that the information presented in the application provides an adequate basis for the evaluation of the Model No. 10-160B package against 10 CFR Part 71 requirements.

2.0 STRUCTURAL EVALUATION

The staff reviewed the application to verify that the requested changes did not change the results of the previously approved structural analysis.

2.1 Structural Evaluation

The Quality Levels in the Bill of Materials in Addendum A, Section 1.3, have been updated in accordance with Energy*Solutions* QA procedure for Quality Levels. Because these Quality Levels apply to Shield Insert A, which does not provide containment, these revisions are determined to be non-safety significant. Furthermore, the Quality Levels were changed from the Category A, B, and C system to Quality Levels 1, 2, and 3. Many of the Quality Levels are designated as Level 3 and Level 2 according to the NRC-approved Energy*Solutions* QA procedure. Level 3 Materials, based on NUREG/CR-6407, are comparable to Category C items. Category C items have a minor impact on safety; "their failure or malfunction would not significantly reduce the packaging effectiveness and would not likely create a situation adversely affecting public health and safety." For consistency with this change, editorial changes were also made to note 4 and the Bill of Materials title block in Addendum A, Drawing No. C-038-145083-005. The staff has reviewed the revised Quality Levels and the editorial changes and finds that they are in accordance with 10 CFR Part 71, Subpart H.

An option was added to Drawing No. C-038-145083-004 to permit a larger hole size in the insert body lift lug, in order to accommodate a standard shackle size. Because all handling of Shield Insert A is performed within the confines of the controlled area of the shipper, this body lift lug is not governed by the regulations of 10 CFR Part 71. The staff finds this change acceptable.

Three additional changes have been made to Drawing No. C-038-145083-004:
- Modification of acorn nuts to include a plunger to facilitate underwater handling,
- Change of gasket design and specification to facilitate operations, and
- Insert lid weld backing detail change to facilitate fabrication.

These changes are being made to Shield Insert A, which does not provide containment, thus does not affect the ability of this package to perform its safety functions. Note 9 on the drawing, which was a revision to the insert lid weld backing detail now includes, "Location of the lid backing ring is dependent on vendor's closure weld location," for improved fabrication. However, all other aspects of the weld backing, including material and dimensions used, remain the same as written in the previous version. The staff has confirmed that these three changes have no safety-significant effects, and are acceptable.

Specified dimensions and tolerances of the cribbing in Addendum A, Section 1.3, Drawing No. C-038-145083-005 have been replaced with specifications of maximum allowable axial and radial gaps between the cribbing and cask cavity, and a note was added to permit shimming to achieve the required gaps. The staff has reviewed this change and finds it acceptable because it will not negatively affect the safety performance of the package.

Note 2 in Addendum A, Section 1.3, Drawing No. C-038-145083-005 has been revised to permit features such as notches and/or locating pins to be added to the steel cribbing to accommodate interferences such as vent/drain couplings, lugs, and lifting/rigging hardware. Since the modifications requested only apply to Shield Insert A, which is not part of the containment boundary, the staff finds this change acceptable.

Errors in Addendum A, Section 2.2, of the listed maximum weight of the 10-160B cask payload and the combined maximum load of Shield Insert A, with payload and cribbing were corrected for consistency with the rest of the document. The staff finds this editorial change acceptable.

Changes were made in Addendum A, to Section 7.0 and Section 8.2 (including subsections), to permit the reuse of Shield Insert A, and to describe the maintenance program for Shield Insert A necessitated by the reuse of Shield Insert A. This maintenance program outlines routine maintenance of fasteners, gaskets and seals, and painted surfaces for closure orientation, and is found to be acceptable to the staff under 10 CFR Part 71. Subsections 8.2.2 (Periodic Maintenance) and 8.2.3 (Subsystem Maintenance) are found to be non-safety significant because Shield Insert A does not provide containment. The staff has reviewed these changes and finds them acceptable.

Addendum B was added to the SAR to describe an alternative shield insert, identified as Shield Insert B, to be transported by the Model No. 10-160B cask, and to demonstrate compliance with regulatory requirements under both normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as required by 10 CFR Part 71. Shield Insert B, which is designed only for dry loaded sources, is physically identical to the previously accepted Shield Insert A, but without a drain line, the lack of which does not negatively impact safety. Other than the removal of the drain line, the only substantive difference between Addendum A, which describes Shield Insert A, and Addendum B, which describes Shield Insert B are changes in Chapter 7 to remove wet loading operations, which has no negative safety consequences, and is acceptable to the staff. The staff has reviewed Addendum B and finds that the safety determination for Shield Insert A can be extended to Shield Insert B, thus the staff finds the contents of Addendum B acceptable.

Section 8.2.6 was added to the 10-160B SAR to allow threaded inserts to be used to repair bolt holes on the 10-160B cask, and to lay out the repair procedure. The applicant stated in Section 8.2.6 of the SAR, and in Section 8.2.2.4 of both shield insert addendums that only helical threaded inserts may be used to repair bolt holes, and that the inserts are required to have a minimum tensile strength of 150ksi and a minimum length equal to one (1) bolt diameter. This clarification ensures that the repaired bolt hole is stronger than the original bolt hole, which was designed and analyzed to meet the required minimum safety factor of three against yielding when used to lift the package in the intended manner. The staff has confirmed that these revisions, which have been made to the SAR and shield insert addendums, ensure that the repaired bolt holes will meet the regulatory requirements of 10 CFR 71.45(a), and therefore finds the proposed bolt hole repair methods acceptable.

2.2 Materials Evaluation

The gasket material in Addendum A, Section 1.2.1, has been changed from “silicon rubber” to “elastomeric.” Because Shield Insert A does not provide containment, the staff finds that this material change will not affect the capability of the package to perform its safety functions and is acceptable.

ASTM designations to steel and lead material specifications have been added in Addendum A, Section 2.3. This change was editorial for consistency with the Bill of Materials listed in the drawing. In the previous 10-160B SAR, the steel and lead materials for the shield insert were written as “A516 Gr.70” and “B29” respectively. However in the drawing of the source insert, the Bill of Materials had the materials listed with the ASTM designations added. This was corrected in the current version of Addendum A, Section 2.3, to match what was written in the Shield Insert A drawings. The staff finds this editorial change acceptable.

In Addendum A, Section 2.7.1.1.3, the discussion of lead slump in Shield Insert A was expanded to address issues identified by NRC staff in a pre-submittal meeting, which focused on the process of lead pouring and solidification control that could lead to problems with lead shrink. The staff has reviewed the expanded discussion and finds that it satisfactorily explains the zone-solidification and gamma scanning processes used to assure adequate lead thickness and uniformity.

2.3 Evaluation Findings

The staff concludes that the changes and revisions made to the 10-160B SAR and Addendums A and B do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

3.0 THERMAL EVALUATION

3.1 Discussion

The thermal review of the amendment request is based on Addendum B of the SAR, which provides information for the new shielding insert (designated as Shield Insert B). The 10-160B cask SAR provides the analyses of the cask package with a generic heat load of 200 watts. The source container used in the 2-d finite element analyses discussed in Section 3.5.1.3 of the SAR was an arbitrary small size container. The thermal analyses of the shield insert for the NCT and HAC fire test have been performed using 2-d axisymmetric models with the appropriate dimensions and geometry.

For these analyses within this addendum, a conservative value of 200 watts of internal heat load is used. The results for the shield insert are summarized for NCT in Table 3.1-3 of this addendum and for HAC in Table 3.1-4 of this addendum. In the fore mentioned tables, it is shown that the summary presented in Tables 3.1-1 and 3.1-2 of the SAR envelop the corresponding results obtained for the shield insert.

3.2 Summary of Thermal Properties of Materials

No new thermal properties have been used in the analyses of the shield insert.

3.3 Technical Specifications of Components

The steel and the lead material used for the construction of the shield insert are the same as those specified in the SAR.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Thermal Model

The finite element model used for the thermal analysis of the 10-160B cask with the shield insert comprises of 2-dimensional axisymmetric solid and contact elements. The details of the finite element model used in the analyses are provided in Reference 12 of the SAR. The shield insert used some conservative simplifications that are documented in Reference 12 of the SAR. The boundary conditions used in the analysis of the shield insert are the same as those used in Section 3 of the SAR.

3.4.2 Maximum Temperatures

The maximum temperatures in various parts of the shield insert during NCT are reported in Table 3.1-3 of this addendum. The temperatures calculated are with those reported in Section 3 of the SAR. Staff finds that the values that were calculated acceptable.

3.4.3 Minimum Temperatures

No changes were made in this addendum.

3.4.4 Maximum Internal Pressures

The bulk air temperature of 231.2°F reported in Table 3.1-3 of this addendum is higher than that reported in the SAR. The maximum internal pressure of the cask is calculated assuming that the gas within the cask behaves as an ideal gas. In determining the maximum internal pressure during NCT in the cask (MNOP), the temperature of the gas mixture within the cask was evaluated. The maximum pressure is due to the increased temperature of the gas in the cavity. The insert and cask cavity are dry and there are no materials in the insert that will generate gas by radiolysis.

1. The cask on loading has an internal pressure equal to ambient, assumed to be 14.7 psi at 70°F (294.26 K).

2. The pressure in the cask at 240°F (388.71 K) (T_2, the maximum temperature under normal conditions), P_2 = 18.3 psi, may be calculated by the ideal gas relationship below where T is in degrees absolute:

$$P_2 = P_1 * \frac{T_2}{T_1} = 14.7\, psia * \frac{388.71\, K}{294.26\, K} = 19.4\, psia$$

The maximum normal operating pressure (in gage pressure) is calculated in the following manner:

$$MNOP = P_2 - P_1 = 19.4\, psig - 14.7\, psig = 4.7\, psig$$

The MNOP value is conservatively set at 35.0 psig. With the MNOP for the shield insert in the 10-160B cask is less than the value in the base SAR, no change is required. Staff finds the value that was calculated acceptable.

3.4.5 Thermal Stresses

No changes were made in this addendum.

3.5 Thermal Evaluation for Hypothetical Accident Conditions

3.5.1 Thermal Model

The finite element model used for the thermal analysis of the 10-160B cask with the shield insert comprises of 2-dimensional axisymmetric solid and contact elements. The details of the finite element model used in the analyses are provided in Reference 12 of the SAR. The shield insert used some conservative simplifications that are documented in Reference 12 of the SAR. The boundary conditions used in the analysis of the Shield Insert are the same as those used in Section 3 of the SAR with some conservative modifications detailed in Reference 12 of the SAR.

3.5.2 Package Conditions and Environment

No changes were made in this addendum.

3.5.3 Package Temperatures

The maximum temperatures in various parts of the shield insert during HAC fire test are reported in Table 3.1-4 of this addendum. The temperatures calculated are with those reported in Section 3 of the SAR. Staff finds the values that were calculated acceptable.

3.5.4 Maximum Internal Pressures

The bulk air temperature of 296°F reported in Table 3.1-4 of this addendum is higher than that reported in the SAR for evaluation of the cask internal pressure (200°F). The maximum internal pressure of the cask with the increased temperature of 296°F (rounded to 300°F) is shown below. The maximum internal pressure of the cask is calculated assuming that the gas within the cask behaves as an ideal gas.

The temperature of the gas mixture within the cask is evaluated (see Table 3.1-4 of this addendum). The average gas temperature in the cask under HAC is conservatively set at 300°F. Assuming 1 atm or 14.7 psia (see Section 3.3.2 of the SAR) exists inside the cask at 70°F, the pressure in the cask at 300°F, P_2 = 21.1 psia, may be calculated using the formula below using the ideal gas relationship:

$$P_2 = P_1 * \frac{T_2}{T_1} = 14.7\, psia * \frac{422.04\, K}{294.26\, K} = 21.1\, psia$$

The maximum pressure during the HAC fire is calculated in the following manner:

$$P_{max} = P_2 - P_1 = 21.1\, psig - 14.7\, psig = 6.4\, psig$$

The value for P_{max} is conservatively set at 100.0 psig. Since the P_{max} for the shield insert in the 10-160B is less than the value in the base SAR, no change is required. Staff finds the value that was calculated acceptable.

3.5.5 Maximum Thermal Stresses

No changes were made in this addendum.

3.6 Evaluation Findings

Staff performed analysis by doing the calculations as listed in the addendum. The values viewed in the SAR did not exceed any of the temperature barriers for NCT or HAC.

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

4.0 CONTAINMENT EVALUATION

Shield Inserts A and B do not provide containment; therefore periodic leak tests and assembly verification leak tests are not required on Shield Inserts A and B. There were no changes to the containment evaluation found in Chapter 4 of the base SAR. Chapter 3 of the SAR was modified to show that the HAC maximum seal temperature for the containment boundary secondary lid seal bound the optional containment boundary vent and drain port seals.

Pressure drop leakage rate tests are performed prior to each shipment on the containment boundary primary lid and secondary lid O-rings, and the vent and drain ports, except for LSA/SCO shipments that meet the exemption standards in 10 CFR 71.14(b)(3)(i) and do not require pre-shipment leakage rate testing. This addresses a potential scenario that could occur where Type B contents could be shipped without performing a pre-shipment leakage rate test on a vent or drain port that remained closed during the Type B loading operations, even if the vent or drain port had been opened during a prior loading of LSA/SCO contents.

4.1 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.

5.0 SHIELDING EVALUATION

The staff reviewed the application to verify that the changes made to the package, as part of this amendment request, provide adequate protection against radiation and meet the external radiation requirements of 10 CFR Part 71 under NCT and HAC. The staff also reviewed the application to determine whether the package fulfills the acceptance criteria listed in NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material.”

The applicant requested changes to the existing SAR addendum for the 10-160B Co-60 shield insert and re-designated it as Shield Insert A, and correction to the drain configuration and other editorial corrections. The applicant also adds a new addendum for a new shield insert (Shield Insert B) to existing 10-160B shipping cask for dry-loaded sources.

5.1 Description of Shielding Design (Insert A)

In this configuration, the 10-160B package consists of a Shield Insert A and a transportation cask. The Shield Insert A consists of photon shielding that is to be maintained centered as a shielded insert in the 10-160B cask cavity by a cribbing structure. Shield Insert A is loaded into the 10-160B cask, which is transported on an 8-foot wide trailer.

The 10-160B cask is designed for a payload of Type B quantity radioactive byproduct, source, or special nuclear material weighing no more than 14,250 pounds (6,463 kilograms). The 10-160B cask is designed and constructed in accordance with 10 CFR 71.71 to ensure that the maximum external dose rates do not exceed the criteria for exclusive use shipments in 10 CFR 71.47. The combined shielding of Shield Insert A and the Model No. 10-160B transportation cask for the 10-160B package containing 10,000 Curies of Co-60 makes the package meet the dose rate limit requirements of 10 CFR 71.71 for exclusive use shipments. Credit is not taken for the cribbing structure in the shielding evaluation for both NCT and HAC analyses.

5.1.1 Shielding Design Features

The shielding design features of the Shield Insert A include the following: (i) inner shell sidewalls of cast lead (density of 11.3 g/cm^3 and a total thickness of 6.72 inches) located between an inner 8.0-inch (nominal) SCH 40 steel pipe and an outer 24.0-inch (nominal) SCH 60 steel pipe, (ii) a base consisting of 6.0 inches of lead supported by a 0.75-inch thick steel base plate, and (iii) an upper shield lid consisting of 8.625 inches of lead encased with steel. The Co-60 source is loaded into Insert A.

The drain line of Shield Insert A comprises of 1/2 –inch SCH 40 steel with inner and outer diameters of 0.62 and 0.84 respectively. The pipe vertical and horizontal sections are connected by a 90-degree elbow. The horizontal pipe lies 2.25 inches above the bottom and the vertical one lies 0.75 inches from the edge of the Shield Insert A inner cavity

Additional shielding is provided by the 10-160B cask side consisting of a 2- inch thick steel, inner shell, 1-7/8 inches of lead, and a 1-1/2-inch thick steel of an inner containment wall. The inner and outer shells are consists of two layers of steel of total 5-1/2-inch thick. The package lid is a 5-1/2-inch thick carbon steel plate with a 31-inch diameter opening equipped with a secondary lid for preventing radiation streaming.

The stainless steel optional cavity liner of cask 10-160B is not modeled in shielding evaluation and therefore not credited in the shielding design analysis.

5.1.2 Summary Tables of Maximum Radiation Levels

The applicant performed the shielding analysis using the MCNP5 computer code (Reference 2) and calculated NCT dose rates with a 10,000 Ci ^{60}Co distributed source located in inside insert A.

Table 5-3 of the SAR summarizes the dose rates for NCT for the maximum allowable dose rates for exclusive use according to 10 CFR 71.47(b) and Table 5-4 of the SAR maximum doe rates for HAC in accordance with 10 CFR 71.53.

Peak NCT Dose Rates for the 10-160B Package with Source inside Insert A

NCT	Package Surface			2 Meters from 8-foot trailer side
Location	Top	Side	Bottom	
Gamma dose rates mSv/h (mrem/hr)	0.052 (5.20)	0.0087 (0.87)	0.0398 (3.98)	0.0007 (0.07)
10 CFR 71.47(b) Limits	2 (200)	2 (200)	2 (200)	0.1 (10)

Peak HAC Dose Rates

HAC	1 Meter from Package Surface		
Location	Top	Side	Bottom
Gamma dose rates mSv/h (mrem/hr)	0.0263 (2.63)	0.0018 (0.18)	0.081 (1.81)
10 CFR 71.51(b) Limit	10 (1000)	10 (1000)	10 (1000)

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The staff reviewed the shielding analyses, including the methodology, model, and results as presented in Tables 5-3 and 5-4 of the application, to ensure that the package meets the requirements in 10 CFR 71.47 and 10 CFR 71.51.

5.2 Radiation Source

5.2.1 Gamma Source

The maximum quantity of radioactive material that will be shipped with the Shield insert A is 10,000 Ci of ^{60}Co. Table 5-5 of the SAR lists the photon emission probability for ^{60}Co as a function of energy. The source region composition is modeled as air, self-shielding of the source material is not modeled in the shielding evaluation. Co-60 emits two photons per disintegration (1.176 and 1.333 MeV) with abundance of 100%. The photon source activity for 10,000 Curies of ^{60}Co is:

Co-60 Activity = (10,000 Ci) x (3.7x10^{10} disintegration/Ci) x (2 γ/disintegration) = 7.4 10^{14} γ/sec.

5.2.2 Neutron Source

The ^{60}Co source term contains no neutron emitting radioisotopes.

5.3 Shielding Model

Chapters 2 and 3 of the application show that NCT tests do not impact the geometry of the shield insert's shielding and that there will be no damage to the shielding of the Shield Insert A as a result of HAC. Thus, the packaging, previously reviewed and approved by the staff and documented in Reference 1, is not impacted by the addition of the Shield Insert A. The staff finds that the shielding model is consistent with the effects of the tests performed in compliance with 10 CFR 71.71 and 10 CFR 71.73. The staff finds that the package has been adequately described and evaluated against NCT and HAC, as specified in 10 CFR 71.71 and 10 CFR 71.73.

Figure 5-5 of SAR shows a detail of the Shield Insert A shielding model which is centered, axially and radially, inside the 10-160B cask cavity. There are no penetrations or discontinuities in either the 10-160B cask or Shield Insert A designs. All models have the insert A centered within the cask cavity. Figure 5-4 of the SAR shows the configuration of 10-160B cask and Shield Insert A. Figure 5-1 and Figure 5-3, of SAR shows respectively all dimensions of the 10-160B cask and Shield Insert A, as well as in Tables 5-1 and 5-which also illustrate component materials.

There is a physical change in the cask configuration which is a 0.02-inch lead slump at the top of the 10-160B cask radial lead shield. The gap is modeled in the NCT analysis. The impact limiter materials are neglected in the shielding model.

Two analyses are performed on a primary analysis and a second one which evaluates any effects of the drain penetrations, focusing on dose locations that may increase due to their presence. Since the 10-160B cask and Shield Insert A are not azimuthally symmetric around the drain penetrations as shown in Figure 5-4 of SAR.

5.3.1 Configuration of Source and Shielding

Figures 5-1 through 5-4 of the application and also in Figures 5-1 through 5-6 of shielding evaluation of 10-160B Shield Insert A describe of the modeling, and the MCNP input decks to determine how the shielding is modeled.

5.3.1.1 Normal Conditions of Transport

The insert is modeled as concentric cylinders surrounding a source cavity with an inner carbon steel shield, surrounded in the radial direction by a lead shield and then surrounded by an outer carbon steel shield as explained above.

The applicant has detectors at the following locations:

- External surface of the transport vehicle (axial and radial), and
- 2 meters from the surface of the transport vehicle.

5.3.1.2 Hypothetical Accident Conditions of Transport

As noted in Chapter 2 of the addendum to the SAR, HAC conditions do not affect the shielding of the Shield Insert A, and the cribbing remains stable and no significant deformation of the cask and Insert A. The only significant change with shielding is the axial lead slump at the top of the 10-160B ask radial lead cavity, as described in Section 2 of the SAR. This slump is included in the shielding models. The applicant selected four configurations for evaluation as the bounding geometries during HAC conditions as shown in Figure 5-5 of the SAR. Dose rates were determined at 1 meter from the package sidewall, top, and bottom. The staff finds this acceptable.

For all HAC cases, the ^{60}Co source term was tallied on surfaces 1 meter from the 10-160B package body side, top, and bottom ends. The one meter surface tallies are modeled for both primary and drain line evaluation.

The staff verified that the applicant has a dose point 1 meter from the surface of the package for HAC as specified by 10 CFR 71.51(a)(2). The dose point was located in line with the point source to give the highest results. The staff finds this acceptable.

5.3.1.2 Results:

The MCNP5 output files in unit of dose rates are multiplied by 7.4 x 10^{14} to yield dose rates (in mrem/hr) that correspond to a 10,000 Ci Co-60 source. The maximum dose rates at the cask exterior surface are presented in Table 6-1 for NCT and in Table 6-2 for HAC of the Shielding

Evaluation of 10-160B Shield Insert A. The NCT top and package bottom surfaces are presented in Table 6-1 which corresponds to the top and bottom end surfaces of the top and bottom impact limiters, respectively. The side surface in the Table 6-1 corresponds to the side surfaces of both the top and bottom impact limiters, as well as the section of the package body side surface that lies between the impact limiters.

The Table 6-1 shows the 2-meter surface is the vertical surface 322 cm from the cask system centerline which corresponds to a vertical surface two meters from an 8-foot-wide trailer side plus cask radius. The side, top, and bottom HAC surfaces presented in Table 6-2 of SAR are the surfaces that lie one meter from the cask body side, top, and bottom surfaces.

5.3.2 Material Properties

The staff verified that the applicant identified the materials and mass densities of the shielding materials for the shield insert. Table 5-6 of the application provides a summary of the materials and their properties used in the shielding models. The staff also finds that the selected material compositions and densities are appropriate and provide reasonable assurance that the materials densities are adequately modeled for the shielding of the Shield Insert.

5.4 Shielding Evaluation

5.4.1 Methods

For the shielding analysis the applicant used the MCNP5 computer code with photon and neutron cross-section sets designated ".04p," obtained from the ENDF/B-VIII photon data library and materials/cross section (ZAID) provided with MCNP5. MCNP is a three dimensional code, widely used for shielding analyses, that staff has accepted for similar shielding evaluations.

One modeled is used for both NCT and HAC to determine external radiation levels at the package surface, at 2 meters from the package surface for NCT, and at 1 meter from the package surface for HAC. The applicant assumed a distributed source, which is appropriate due to the nature of the Co-60 pin sources being evenly distributed inside the Shield Insert A.

For both NCT and HAC one primary run and one with impact of drain penetrations are performed. The results of peak dose rates for NCT and HCT primary runs are shown in Tables 6-1 and 6-2. In the second run the effect of drain line penetrations on peak dose rates were determined. The drain penetrations increase dose rates for NCT, the bottom and for HAC one meter from the surfaces by 33% and 26% respectively. These increases in dose rates are presented as surface peak dose rates in Tables 6-1 and 6-2 of addendum to SAR.

5.4.2 Key Input and Output Data

The staff performed a review of the MCNP input decks provided by the applicant to ensure that the geometry and materials were appropriately specified. The staff determined that the selected detector locations are appropriate to detect possible radiation streaming paths. The staff also reviewed the output files provided by the applicant and determined that the results were properly represented in the application. The staff verified that the Shield Insert A dimensions are consistent with the licensing drawings.

The staff confirmed that the applicant's calculated radiation levels under both NCT and HAC are in agreement with the summary tables and that they satisfy the limits in 10 CFR 71.47(b) and 10 CFR 71.51(a)(2).

5.4.3 Flux-to-Dose-Rate Conversion

The staff confirmed that the applicant used the ANSI/ANS 6.1.1-1977 (Reference 3) standard and finds this acceptable. The applicant performed the gamma flux-to-dose-rate conversion using the MCNP code and Table 3 from the standard.

5.4.4 Radiation Levels

The staff verified that the analysis showed that the locations selected are those of maximum radiation levels and include any radiation streaming paths. The staff also verified that the applicant's evaluation addresses damage to the shielding under NCT and HAC, as discussed in Section 5.3 of this SER.

5.4.5 Confirmatory Analysis

The staff performed independent confirmatory analyses using the MCNP5 to model gamma radiation and also hands calculation. The results of the staff's confirmatory analyses show reasonable agreement with the applicant's shielding analysis for the limiting point source case.

5.5 Evaluation Findings

The staff reviewed the description of the package design features related to shielding and the source term for the insert and found them acceptable. The methods used are consistent with accepted industry practices. The staff reviewed the maximum dose rates for NCT and HAC and determined that the reported values were below the regulatory limits in 10 CFR 71.47 and 10 CFR 71.51 for an exclusive use package.

Based on the its review of the statements and representations in the application and the results of staff's confirmatory analyses, the staff concludes that the design of the Model No. 10-160B package, with contents of 10,000 Ci of ^{60}Co placed in the Shield insert A, provides a reasonable assurance to meet 10 CFR Part 71 requirements.

5.6 Description of Shielding Design (Insert B)

The 10-160B cask is designed, and constructed, in accordance with 10 CFR 71.71 so that the maximum external dose rates do not exceed the criteria for exclusive use shipments in 10 CFR 71.47. The evaluation determine the maximum allowable source strength in particles/sec, that can be shipped with Insert B in cask 10-160B. The 10-160B cask is designed for a payload of Type B quantity radioactive byproduct, source, or special nuclear material weighing no more than 14,250 pounds (6,463 kilograms). With condition that external radiation dose rate will not exceed 1000 mrem/hr under HAC condition.

Shield Insert B consists of various photon, beta, and neutron source shielding that is to be maintained and centered as a shielded insert in the 10-160B cask cavity by a cribbing structure. Shield Insert B is loaded into the 10-160B ask, which is transported on an 8-foot wide trailer. Credit is not taken for the cribbing structure in the shielding evaluation for both NCT and HAC analyses.

5.6.1 Shielding Design Features

The shielding design features of the Shield Insert B include the following: (i) inner shell sidewalls of cast lead (density of 11.3 g/cm^3 and a total thickness of 6.72 inches) located between an inner 8.0-inch (nominal) SCH 40 steel pipe and an outer 24.0-inch (nominal) SCH 60 steel pipe, (ii) a base consisting of 6.0 inches of lead supported by a 0.75-inch thick steel base plate, and (iii) an upper shield lid consisting of 8.625 inches of lead encased with steel.

Shielding is also provided by the 10-160B cask side consisting of a 2- inch thick steel, inner shell, 1-7/8 inches of lead, and a 1-1/2-inch thick steel of an inner containment wall. The inner and outer shells consist of two layers of steel of total 5-1/2-inch thick. The package lid is a 5-1/2-inch thick carbon steel plate with a 31-inch diameter opening equipped with a secondary lid for preventing radiation streaming.

The stainless steel optional cavity liner of the 10-160B cask is not modeled in the shielding evaluation.

5.6.2 Summary Tables of Maximum Radiation Levels

The applicant performed the shielding analysis using the MCNP5 computer code (Reference 2) and calculated NCT and HAC dose rates with ^{60}Co and ^{137}Cs. These values are for maximum allowable source strengths for each isotope. At the top of package, the limit approach regulatory limits. The thermal and A2 values for ^{60}Co and ^{137}Cs are reduced to 96% and 0.2% of the dose rates in tables below.

Table 5-3 of the SAR summarizes the dose rates for NCT for the maximum allowable dose rates for exclusive use according to 10 CFR 71.47(b) and Table 5-4 of the SAR maximum doe rates for HAC in accordance with 10 CFR 71.53.

Peak NCT Dose Rates for the 10-160B Package with Source inside Insert A

NCT	Package Surface mSv/h (mrem/hr)			2 Meters from 8-foot trailer side
Location	Top	Side	Bottom	
Co-60	2.00 (200)	0.028 (2.8)	0.047 (4.7)	0.0013 (0.13)
Cs-137	2.00 (200)	0.025 (2.5)	0.0003 (0.03)	0.0011 (0.11)
10 CFR 71.47(b) Limits	2 (200)	2 (200)	2 (200)	0.1 (10)

Peak HAC Dose Rates

HAC	1 Meter from Package Surface mSv/h (mrem/hr)		
Location	Top	Side	Bottom
Co-60	0.93 (93.0)	0.004 (0.4)	0.022 (2.3)
Cs-137	0.869 (86.9)	0.005 (0.5)	0.0002 (0.02)
10 CFR 71.51(b) Limit	10 (1000)	10 (1000)	10 (1000)

The staff reviewed Tables 5-3 and 5-4 of the application to ensure that the package meets the requirements in 10 CFR 71.47 and 10 CFR 71.51.

5.6.3 Radiation Source

5.6.3.1 Gamma Source

The analyses are performed for gamma energies from 0.5 MeV to 4.0 MeV and for ^{60}Co and ^{137}Cs. The ^{137}Cs source was modeled in equilibrium with ^{137}Ba. The unit of 1 gamma/sec is modeled in the shielding analyses. The maximum peak unit dose rates are compared to 10 CFR Part 71 limits to determine the maximum gamma source strengths

The gamma source is modeled as 1 cm diameter sphere in the worst Shield Insert B location. The modeling places the source close to the cask exterior surfaces.

5.6.3.2 Neutron Source

Pu-Be neutron source was approved for the 10-160B cask. No credit is taken for Insert B in neutron shielding.

5.6.4 Shielding Model

The staff finds that the shielding model is consistent with the effects of the tests performed in compliance with 10 CFR 71.71 and 10 CFR 71.73. The staff finds that the package has been adequately described and evaluated against NCT and HAC, as specified in 10 CFR 71.71 and 10 CFR 71.73.

5.6.4.1 NCT Model

Figure 5-5 of SAR shows a detail of the Shield Insert B shielding model which is centered, axially and radially, within the 10-160B cask cavity. There are no penetrations or discontinuities in either the 10-160B cask or Insert B designs, therefore all models have the Insert B centered within the cask cavity. Figure 5-4 of SAR shows the 10-160B cask and Shield Insert B configuration. Figure 5-1 and Figure 5-4, of SAR shows respectively all dimensions of the 10-160B cask and Shield Insert B, as well as in Tables 5-1 and 5-which also illustrate component materials.

Two analyses is performed for each gamma energy, one with point source in the insert cavity top corner and one bottom corner, which used to determine bottom and top corners dose rates. The same model is used also for HAC cases.

5.6.4.2 HAC Model

As noted in Chapter 2 of addendum of the SAR, under HAC conditions cribbing remain stable and no significant deformation of the cask and Insert B. Test results show there are not any significant deformation of cask and insert components and no significant slumping of lead. Since the radial lead shield is well above the top source cavity, no radiation streaming through lead slump gap to onside casks is expected and no lead slump gap required. The only significant difference between NCT and HAC is lead slump, so the same model is used for both conditions. The dose rates are calculated one meter from the 10-160B cask side, top, and bottom ends.

5.6.4.3 Configuration of Source and Shielding

The staff examined Figures 5-1 through 5-4 of the application and also in Figures 5-1 through 5-6 of shielding evaluation of 10-160B Shield Insert B, which describe of the modeling, and the MCNP input decks to determine how the shielding is modeled. The staff verified that the Shield insert B dimensions are consistent with the licensing drawings.

For all HAC cases, the ^{60}Co source term was tallied on surfaces one meter from the 10-1 60B Cask body side, top, and bottom ends. The one meter surface tallies are modeled for both primary and drain line evaluation.

The staff verified that the applicant has a dose rate at 1 meter from the surface of the package for HAC which is less than the limit as specified by 10 CFR 71.51(a)(2).

5.6.4.4 Results

The MCNP5 output files in unit of dose rates per gamma/sec are presented at the cask exterior surface are presented in Table 6-1 for NCT and in Table 6-2 for HAC of the shielding evaluation of 10-160B Shield Insert B of CALC-CSK-145103-EG-001.

The NCT top and package bottom surfaces are presented in Table 6-1 which corresponds to the top and bottom end surfaces of the top and bottom impact limiters, respectively. The side surface in the Table 6-1 corresponds to the side surfaces of both the top and bottom impact limiters, as well as the section of the cask body side surface that lies between the impact limiters.

Table 6-1 shows the 2-meter surface is the vertical surface 322 cm from the cask system centerline which corresponds to a vertical surface two meters from an 8-foot-wide trailer side plus cask radius. The side, top, and bottom HAC surfaces presented in Table 6-2 of CALC-CSK-145103-EG-001 are the surfaces that lie one meter from the cask body side, top, and bottom surfaces.

5.6.5 Shielding Evaluation

5.6.5.1 Methods

For the shielding analysis the applicant used the MCNP5 computer code with photon and neutron cross-section sets designated ".04p," obtained from the ENDF/B-VIII photon data library and materials/cross section (ZAID) provided with MCNP5.

The peak unit-source dose rates are taken directly from the MCNP5 output files. The dose rate surfaces for which the top corner and bottom corner source point cases used are discussed in Section 4 of CALC-CSK-145103-EG-001. The dose rate limits for each cask exterior surface are divided by the peak unit-source gamma dose rates from Tables 6-1 and 6-2 to yield maximum allowable gamma source strengths (in gammas/sec) that would produce the maximum allowable dose rate on each surface. The lowest of the calculated allowable source terms is designated, as the maximum allowable gamma source strength (in gammas/sec) for each gamma energy level and for Co-60 and Cs-137. For each gamma energy, the peak unit-source gamma dose rates from Tables 6-1 and 6-2 is multiplied by the maximum allowable gamma source strengths to yield the peak absolute gamma dose rates in unit of mrem/hr. These maximum gamma dose rates are shown in Table 6-3 and Table 6-4, for NCT and HAC respectively. These are the maximum allowable gamma source strengths, for different gamma energies.

5.6.5.2 Key Input and Output Data

The staff performed a review of the MCNP input decks provided by the applicant to ensure that the geometry and materials were appropriately specified. The staff also reviewed the output files provided by the applicant and determined that the results were properly represented in the application.

The staff confirmed that the applicant's calculated radiation levels under both NCT and HAC are in agreement with the summary tables and that they satisfy the limits in 10 CFR 71.47(b) and 10 CFR 71.51(a)(2).

5.6.5.3 Flux-to-Dose-Rate Conversion

The staff confirmed that the applicant used the ANSI/ANS 6.1.1-1977 (Reference 3) standard and finds this acceptable. The applicant performed the gamma flux-to-dose-rate conversion using the MCNP code and Table 3 from the standard.

5.6.5.4 Treatment of Beta Sources

Pure beta emitters such as ^{14}C, ^{35}S, ^{32}p, 3H, and ^{90}S/ ^{90}Y can be shipped in the 10-160B cask Shield Insert B. These contents are limited to 3000 A2 or less than 3000A2, when the package dose rates or thermal input are governing. This method for qualifying payloads where Bremsstrahlung is a significant contributor to package dose rates is discussed here.

Beta particles lose energy when pass through material and emitting photons (Bremsstrahlung) over their range. The beta range for steel is about 0.1 cm. The Bremsstrahlung can be a significant contributor to dose rate of the package. The Bremsstrahlung photons have continues energy distribution that ranges downward from a theoretical maximum equal to the kinetic energy of the beta particle. The beta source can be converted to the equivalent photon source.

S_γ = S_β * fraction of energy converted to photons* beta average energy/photon energy
S_γ =gamma source at maximum beta energy (E_{max}) in γ/sec

S_β = beta source β/sec

It is always assumed that all photons are emitted at maximum beta energy (E_{max})

$$\frac{S_\gamma}{S_\beta} = f * \frac{E_{avg}}{E_{max}}$$

The fraction of beta converted to photon is

$$f \cong 3.5x10^{-4} Z E_{max}$$

$$S_\gamma = S_\beta (3.510^{-4} Z E_{avg})$$

Z is atomic number of the absorber, for compounds mixtures:

$$Z_W = \sum_{i=1}^{n} (\frac{m_i}{m_{total}} Z_i)$$

This method is for qualifying pure beta emitting isotopes which convert the beta emitter as an equivalent photon emitter. Beta from gamma emitter can be neglected, since its contribution with respect to gamma is negligible. If the maximum beta energy is more than 4.0 MeV, it is not allowed to ship with this cask, 4.0 MeV is the maximum gamma energy allowed to be ship with this cask.

5.6.5.5 Multi-Energy Gamma Sources or Radiation Types

The maximum allowable gamma source strengths are given, for Co-60, Cs- 137, and for multiple gamma energies, in Table 6-3. Cask and Insert B payloads may contain multiple isotopes and/or may emit multiple radiation types such as beta, gamma, and neutron, or emit multiple gamma energies.

Gamma Sources

If the sources emit several gamma energies, the source equivalent is evaluated using a "sum of fractions" approach. If the sources contain several gamma sources, each gamma source at a given energy is divided by the corresponding limit for Table 6-3 to yield a fraction. The same procedure is applied for all other gamma energies, and then the fractions are summed. If these fractions are not exceeding one, these sources can be shipped by this cask.

The multi-energy gamma sources are treated using the following steps:

1) For gamma energies between 0.3 and 4.0 MeV, round the energy up to the nearest gamma energy presented in Table 6-3.
2) Select the equivalent gamma source strength limit from Table 6-3.
3) Divide the payload's gamma source strength at that energy by the equivalent Table 6-3 limit to yield a fraction value for that energy.
4) Repeat the above process for all gamma energies emitted by the payload.
5) Add the fractions.
6) If the total of fractions is less than 1.0, the cask exterior dose rate limits will not exceed regulatory limit.

Beta Sources

Convert beta sources to photons equivalent and use the same procedure as above to obtain the sum of fractions.

Neutron Sources

Neutron is not analyzed in this addendum. The 10-160B cask is currently qualified for shipment of $1.1x10^8$ neutron/sec Pu-Be neutron source. Any special form neutron sources that bounded with this value can be shipped with this cask. No credit is taken for Insert B for neutron shielding. The fraction method discussed above also can be used for multiple neutron sources.

The allowable maximum activities for isotopes ^{60}Co, ^{137}Cs, ^{192}Ir, ^{90}Se, and ^{90}Sr are presented in Table 9.1 of this addendum. Table 9.2 represents the fraction rate for these five isotopes and Table 9-3 the dose rate fraction, heat generation and A2 values for these five isotopes. Table 9-4 is for the final isotopes activity limit for each of these five isotopes.

5.6.5.6 Confirmatory Analysis

The staff performed independent confirmatory analyses using the MCNP5 to model gamma radiation and also hands calculation. The results of the staff's confirmatory analyses show reasonable agreement with the applicant's shielding analysis for the limiting point source case.

5.6.6 Evaluation Findings

The staff reviewed the description of the package design features related to shielding and the source term for the insert and found them acceptable. The methods used 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 limits in 10 CFR 71.47 and 10 CFR 71.51 for an exclusive use package.

Beta emitting payloads are discussed in Section 9.1 of .CALC-CSK-145103-EG-001. Payloads that emit multiple gamma energies, or emit multiple types of radiation such as beta, gamma, and neutron are discussed in Section 9.2. Activity limits in Ci payload for isotopes Co-60, Cs-137, Ir-192, Se-75, and Sr-90 in Section 9.3 are presented in Section 9.3. These activity limits consider the cask's 200 watt thermal limit and 3000 A2 containment limit.

5.7 References

1. U.S. Nuclear Regulatory Commission, Safety Evaluation Report, Model No. 10-160B Package, Certificate of Compliance No. 9204, Revision No. 20, August 23, 2012, ADAMS Accession No. ML12235A236.

2. MCNP5 – A General Monte Carlo N-Particle Transport Code Version 5, X-3 Monte Carlo Codes Applied Physics Division, Los Alamos National Laboratory, April 24, 2003 (Revised 2/1/2008).

3. American Nuclear Society, ANSI/ANS 6.1.1 1977, Neutron and Gamma-Ray Flux-to-Dose-Rate Factors, La Grange Park, Illinois.

6.0 CRITICALITY EVALUATION

The applicant proposed no changes to the Model No. 10-160B package that require a criticality evaluation.

7.0 PACKAGE OPERATIONS

The applicant proposed minor changes to the operating procedures of the package to add a new step to perform drop leak test and a note to clarify when it is required, deleting the option to not remove the impact limiter to perform the pressure drop leak test of primary lid O-rings, and minor editorial changes.

The staff reviewed the changes and determined they were acceptable.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The applicant proposed changes to allow reuse of Shield Insert A, and allow threaded inserts to be used to repair bolt holes on the 10-160B cask. These changes are discussed in Section 2.1, "Structural Evaluation," of this safety evaluation report.

The staff reviewed the changes and determined they were acceptable.

CONDITIONS

The conditions specified in the certificate of compliance have been revised to incorporate several changes as indicated below:

Condition 5.(a)(2) has been updated to delete an optional carbon steel shield insert, to reflect changes to the previous shield insert (now named Shield Insert A) and to describe and authorize use of Shield Insert B.

Condition 5.(a)(3) has been updated to reflect the new drawing designations for Shield Inserts A and B. These drawings also contain the source insert assembly information previously contained in Energy*Solutions* Drawing No. C-038-145083-004, Rev. 0, so this drawing has been deleted. The condition also updates Energy*Solutions* Drawing No. C-038-145083-005 from Rev. 0 to Rev. 1.

Condition 5.(b)(1)(vi) has been revised to specify use of a shield insert for Co-60, previously a source insert.

Condition 5.(b)(2)(vi) has been updated to reflect the correct maximum weight of contents (14,250 pounds including shoring, secondary containers, and either optional or mandatory shield insert).

Condition 6.(a) has been updated to add operating procedure requirements for the shield inserts.

Condition 6.(b) has been updated to add acceptance test and maintenance requirements for the shield inserts.

Condition 13 (expiration date) has been renumbered as Condition 14. The new Condition 13 has been added to restrict the use of Shield Insert B to dry-loaded contents.

Condition 14 (previously Condition 13) states the expiration date, which was not changed.

The References section was updated to include the supplements dated July 18, 2013, September 20, 2013, and November 4, 2013.

CONCLUSION

Based on the statements and representations in the application, as supplemented, and the conditions listed above, the staff concludes that the Model No. 10-160B package design has been adequately described and evaluated and that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9204, Revision No. 21,
on December 27, 2013.