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DOE Packaging Certification Program

Safety Evaluation Report for Certificate of Compliance No. 9204 Letter Amendment for the Model 10-160B Package

Docket No. 21-35-9204

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review of the application submitted by the package Certificate Holder, EnergySolutions (ES), for the Oak Ridge Office of Environmental Management (OREM), to authorize use of the 10-160B for a one-time shipment of a Radium-226 Boron (RaB) neutron source from the TRU Waste Processing Center (TWPC) to Nevada National Security Site (NNSS) for disposal.

Summary

By application ^[1] submitted February 4, 2022, as supplemented ^[2] September 23, 2022, the certificate holder, ES, requested a letter of authorization (a.k.a., letter amendment) to amend DOE CoC 9204 Rev. 12 to authorize use of the Model 10-160B for a one-time shipment of a RaB neutron source from the TWPC to NNSS for disposal.

The content configuration consists of a 10 Ci, solid, encapsulated RaB neutron source loaded in an unsealed metal can. The metal can is overpacked in a vented Department of Transportation (DOT) Specification 2R inner containment vessel, with adsorbent (polymer) placed around the metal can, a lead shield plug stacked on top of the can, and a polymer shield plug stacked on top of the lead plug. The source was previously stored in a water pool so adsorbent was subsequently added in the 2R to adsorb any residual water leaking from the can. The 2R is then loaded in a lead-shield insert within a vented DOE Specification 6M 55-gallon drum. The 6M is then loaded in a vented 85-gallon overpack. The 85-gallon drum is secured and centered within the 10-160B containment cavity by a cribbing assembly.

Based on the statements and representations in the application, DOE PCP staff independently confirmed that the package design has been adequately described and evaluated for use of the 10-160B package to ship this RaB source. Therefore, staff has reasonable assurance that the regulatory requirements of Part 71 have been met and recommends a letter amendment to the CoC by the DOE Headquarters Certifying Official (HCO).

Evaluation

This SER documents the independent technical review by DOE PCP staff of the application, *Addendum for Transportation of Radium-226 Boron Source in a 10-160B Packaging*, ESCD-000081, Rev. 1, September 2022, to the requirements of 10 CFR Part 71 and the safety basis document, Consolidated Safety Analysis Report (CSAR) ^[3] to DOE CoC 9204.

Revision 0 of this application (Addendum) was submitted February 4, 2022, and revised by ES in response to questions and comments from the DOE PCP staff on May 23, 2022 and June 28, 2022. The ES responses and proposed implementation to staff's questions and comments were resolved September 6, 2022, and Revision 1 of the Addendum submitted by ES to DOE PCP on September 23, 2022.

1.0 General Information

1.1 Introduction

OREM contracted with the certificate holder of DOE CoC 9204, ES, to prepare an Addendum to the CSAR to authorize use of the 10-160B for a one-time shipment of a legacy, 10 Ci, RaB neutron source from the TWPC to NNSS for disposal.

The Addendum is supported by:

- A legacy (c. 2003) waste characterization document of the source and 6M package configuration,
- Drawings of the cribbing assembly design,
- Calculations to address the structural evaluation of the 10-160B with the new cribbing configuration, and
- Calculations to evaluate hydrogen generation and pressure from the new content configuration.

The source is described in the Addendum as a “sealed source”; however, there is no documentation to confirm the source meets the requirements for special form; consequently, DOE PCP staff's review assumes the source is normal form radioactive material in a metal encapsulation.

The 6M package used in this content configuration was previously authorized by DOT as Type B Specification Packaging. DOT discontinued the authorized use of Type B specification packagings on October 1, 2008, in lieu of performance testing to certify Type B and fissile package designs.

Except for the new cribbing assembly, there were no changes to the 10-160B packaging design or its package analysis for this new content configuration.

1.2 Package Description

The Model 10-160B is a Type B(U)F-96 package certified by DOE for shipment of radioactive waste and material in various solid forms.

The content configuration evaluated in the Addendum is a nested configuration of components for the 10 Ci, solid, encapsulated RaB neutron source, beginning with the source loaded in an unsealed metal can. The metal can is overpacked in a vented DOT Specification 2R inner containment vessel, with adsorbent (loose polymer) placed around the metal can, a lead shield plug is stacked on top of the can, and a polymer shield plug is stacked on top of the lead plug prior to closing the 2R. The 2R is then loaded in a lead-shield insert within a vented DOT Specification 6M 55-gallon drum. The 6M configuration is shown in Addendum Figure 1.2-A. The 6M drum, with the RaB, contents have been stored in a concrete overpack and covered with stainless steel lid pending final disposition. The 6M will be removed from the concrete overpack and loaded in a vented 85-gallon overpack. The 85-gallon drum is secured and centered within the 10-160B containment cavity by a cribbing assembly. The package configuration offered for shipment is shown in Addendum Figure 1.2-B.

1.2.1 Packaging

There were no design changes to the packaging components described in the CSAR and authorized in the CoC.

The important-to-safety packaging components required to ship the RaB source in the 10-160B include the following items:

- Sealed Source Encapsulation,
- Unsealed Metal Can (approximately 2 inches in diameter by 4.5 inches tall),
- CETCO Quik-Solid® polymer absorbent material,
- Vented, DOT 2R container with lead and polymer shield plugs,
- Vented DOT 6M 55-gallon drum with fiberboard insulation and lead and polymer shielding,
- Vented 85-gallon drum, and
- Wooden Cribbing Assembly and web slings (Addendum Drawing No ESCD-000078, Rev 0).

Addendum Table 9.3-D defines these components as Quality Level C items (i.e., Minor to Safety). The primary safety function of these components, except for the source encapsulation, is dunnage to restrain the contents within the 10-160B containment cavity.

The source encapsulation is credited in the applicant's gas generation evaluation by providing a physical barrier between RaB oxide and hydrogenous material in the 2R (e.g., absorbent polymer material and polymer shield plug) to prevent alpha-radiolysis. The 2R

and 55 and 85-gallon drum are vented into the 10-160B containment cavity to ensure gas is not confined within the volume of these packaging components.

The Cribbing Assembly, Addendum Drawing No ESCD-000078, Rev 0, is a two-piece wooden design that fills the void space within the 10-160B package containment cavity, sacrificially protects the interior surfaces of the containment from damage during normal conditions of transport (NCT) and during hypothetical accident conditions (HAC) and restrains the 85-gallon drum in the center of the containment to minimize dose rates at the surface of the package. The bottom cribbing assembly is installed in the 10-160B, then the loaded 85-gallon drum is lowered into the bottom cribbing assembly, and then the top cribbing assembly is installed over the 85-gallon drum. The overall dimensions of the cribbing assembly are approximately 66 inches in diameter and 78-¼ inches in height. Web slings used to lift the cribbing assembly are left in place after the assembly is loaded in the containment cavity to facilitate removal of the cribbing from the package.

1.2.2 Contents

The RaB source is not an authorized content in the CoC.

The RaB source is approximately 10 Ci of ²²⁶RaB oxide encapsulated in metal. It is not known if the source is a single or double encapsulation or the specific material of construction. The source is approximately 1-inch in diameter by 3-inches in length and weighs approximately 100 grams. It was stored under water in an open-top metal can prior to loading in the 6M. Based on the applicant's engineering judgement for storage in a water pool, the metal can is most likely constructed of aluminum or stainless steel and would include a drain hole in the bottom of the can to allow simple submersion in the pool and draining the water after removal from the pool.

The package A₂ value for 10 Ci of ²²⁶Ra is 124 (Addendum Table 3.6-A), the calculated decay heat is 1.8 watts (Addendum Table 5.8-C), and the estimated maximum neutron emission rate is 3.5 x 10⁷ neutrons/sec. (Addendum Table 5.1-C).

The total weight of the RaB content configuration is approximately 1,300 lb. The applicant used the maximum authorized weight for a 6M drum (640 lb. rounded to 700 lb.), plus the weight of an empty 85-gallon drum (80 lb. rounded to 100 lb.), and the estimated weight of the cribbing assembly and web slings (500 lb.) to get to 1,300 lb. for total content weight.

1.3 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff concludes that the package in support of the CoC letter amendment request has been described in sufficient detail to provide an adequate basis for staff to evaluate it for compliance with 10 CFR Part 71.

2.0 Structural Evaluation

The objective of this structural evaluation is to determine that the information presented in the Addendum, including the description of the packaging, design and fabrication criteria, structural material properties, and structural performance of the package design for the tests under NCT and HAC, is complete and meets the requirements of 10 CFR Part 71.

There are no changes to the 10-160B structural design or analysis for the RaB content configuration. The estimated maximum weight of the RaB content configuration is 1,300 lb., which is significantly bounded by the maximum content weight of 14,250 lb. authorized in the CoC.

The applicant's shielding evaluation results in the Addendum Section 5 credits the RaB content configuration structural design under NCT for compliance with §§ 71.47(a) and 71.51(a)(1) by restraining the source in the center of the package during a 1-ft. free drop but is not credited for compliance with § 71.51(a)(2) under HAC. Compliance with § 71.51(a)(2) only requires the 10-160B shielding, without any other packaging or dunnage within the containment cavity. Under the HAC shielding evaluation in the CSAR, the bounding source is evaluated as a point source in contact with the primary lid and against the inner wall of the containment liner adjacent to the location where lead slump could occur from a 30-ft. end drop of the package. CSAR Section 2.7.1.1 identifies this package orientation as the worst-case loading for deformation and lead slump.

The applicant's gas generation and pressure evaluation under NCT in Addendum Section 4.8 credits the RaB source encapsulation as a safety feature to provide a physical barrier between RaB oxide and hydrogenous material within the 2R to prevent alpha-radiolysis to minimize the flammable gas generation rate within the 10-160B containment cavity during transport.

The applicant performed a structural evaluation of the cribbing assembly design with the RaB content configuration under NCT and HAC to demonstrate the cribbing adequately restrains the contents and does not damage the 10-160B containment.

The Addendum is supported by a structural calculation (Addendum Ref 2.3 - *Structural Evaluation of the 10-160B Package and Cribbing for Transportation of ²²⁶RaB Source*, ESCD-000076, Revision 1) that evaluates the 10-160B package and wood cribbing under NCT and HAC drop tests.

Cribbing Assembly Structural Design

The cribbing assembly design is defined in Addendum Drawing No ESCD-000078. The loaded 85-gallon drum is enclosed within the two-piece wooden cribbing assembly which is designed to fit within the 10-160B containment cavity and to meet the CSAR design limits for package contents (i.e., weight, strength, geometry). The cribbing is constructed

mostly from commercial off the shelf (COTS) 2x4 lumber and ½-inch plywood and is assembled with COTS wood screws. The cribbing is used as a compression only component, with the credited wood strength ranging from minimum to maximum expected values for softwood for each load/wood orientation condition being evaluated. This basic design concept has been used by the applicant for previous DOE content configurations in the 10-160B.

The top cribbing assembly is estimated to weigh 115 lb. and the bottom assembly is estimated at 240 lbs. Each crossing 2x4 joint is fastened by a minimum of 4 wood screws. The four-point sling arrangement shown Sheet 1 of ECSD-000078 is more than adequate for lifting each cribbing assembly without further evaluation.

Design Acceptance Criteria

The design acceptance criteria for the RaB content configuration are defined in Section 2.2 of Addendum Ref 2.3, as summarized below:

- For NCT free drops (corner, side, and end from 1-ft.), the wood cribbing assembly shall not experience any permanent deformation due to crushing under the impact forces to ensure that the source remains at the center of the package.
- For HAC free drops (corner, side, and end from 30-ft.), softwood crush lockup does not occur, that is, the maximum crushing strain is less than 75% for the cribbing to protect the package by absorbing impact.
- NCT and HAC drops, the impact forces generated by the RaB content configuration on the 10-160B shall be less than the impact forces evaluated in Sections 2.6.6 and 2.7.1 of the CSAR to ensure the inner shell of the containment is not punctured by radial wood members.

DOE PCP staff concurs that the acceptance criteria for the structural design of the RaB content configuration is sufficient.

Calculation Methodology

The applicant's cribbing evaluation begins by first scaling the decelerations from NCT and HAC free drop tests in the CSAR to account for the difference in weight between the authorized maximum contain weight of 14,250 lb. and the total weight RaB content configuration of 1,300 pounds (Table 2 of Ref 2.3). The NCT and HAC decelerations are applied to the 85-gallon drum and divided by the total cross-sectional area of the supporting wood members credited in the particular drop orientation. This evaluation includes eight radial wood members for an end drop ($n_{end} = 8$) and six radial wood members for a side drop ($n_{side} = 6$) as described in Section A5.0 of Reference 2.3. Using this simplified method and assuming a wood crush strength of 4,800 psi parallel to the grain results in zero crush depth for all NCT and HAC orientations as shown in Section A5.4 of Reference 2.3. The crush strength of 4,800 psi is the maximum strength parallel to the grain for the wood species selected. However, for NCT, the wood strength would

have to be reduced by a factor of 3.8 to 5 for actual crushing to occur given the factors of safety calculated in Section A5.4 of Reference 2.3. DOE PCP staff reviewed and concurred with the applicant's method, evaluation, and results.

For HAC, the factors of safety to crush are a little over 1.0, so it is possible that some wood crush occurs; however, the RaB content configuration packaging components are not required for the package to demonstrate compliance with § 71.51(a)(2) under HAC. Nonetheless, the applicant performed a buckling analysis in Section A5.5 of Reference 2.3 to show a buckling failure mode was not credible for NCT or HAC loadings. DOE PCP staff reviewed and concurred with the applicant's method, evaluation, and results.

Evaluation of the 85 Gallon Overpack Configuration

The 85-gallon drum overpack is an open head drum (1A2) fabricated in accordance the DOT standards for steel drums per 49 CFR 178.504(b). The maximum weight is 882 lb., so it is sufficient for the maximum weight of 640 lb. for the 6M 55-gallon drum. The applicant evaluated the loaded 85-gallon drum at 800 lb. with the RaB contents in the 6M at 700 lb.

The applicant did not perform a structural evaluation of the 85-gallon overpack with 6M, since the 85-gallon overpack and 6M are sacrificial dunnage. However, the 85-gallon overpack is UN1A2/X440/S packaging and the 6M 55-gallon drum is UN1A2/X430/S packaging, so these packaging designs are tested, qualified, and certified to meet or exceed the requirements in 49 CFR 178.600 – 606, and 178.608. The free drop test in § 178.603 for steel drums ranges from 2.6 to 5.9 ft., so these drums tests are bounding for the 1-ft free drop test of the drums nested in the 10-160B. DOE PCP staff agrees that the damage to the loaded 85-gallon overpack in the 10-160B under NCT should be negligible to minimal. Furthermore, any movement or shifting of the source from the center of the package should be marginal and mitigated by the 2-3/4 inches of lead shielding in the 2R, which is not credited in the Addendum shielding evaluation. DOE PCP staff concurs that the applicant's reasoned argument is sufficient in lieu of a structural analysis of the 85-gallon overpack with 6M under NCT and HAC to demonstrate compliance with §§ 71.47 and 71.51.

Evaluation of the Cribbing Assembly Bounding Loads on the 10-160B Containment

The radially loaded 2x4 members of the cribbing assembly may create numerous concentrated loads on the 10-160B containment shell as well as the 85-gallon overpack. Deformation of the loaded 85-gallon overpack under NCT conditions is not a concern given the limited deceleration from the 1-ft free drop and the 85-gallon overpack or 6M drum provide no safety function during HAC. Concentrated loading on the 10-160B containment shell under NCT and HAC is evaluated in Section A6.3 of Ref. 2.3. This evaluation looks at the shear stress on the containment shell from puncture by a 2x4 from the side drop. Assuming a side drop with the radial load equally shared by 6, 2x4 members results in a safety factor of 10.38 with an allowable stress of 29,400 psi (0.42 S_u). From this analysis, the containment shell would not exceed shear criteria if the entire

side load were on a single 2x4. Given these results, DOE PCP staff accepts that the cribbing design will not compromise 10-160B containment shell.

Evaluation of the Source Encapsulation

The Addendum does not evaluate the structural performance of the RaB source encapsulation but will rely on a contamination survey to infer the encapsulation has remained intact after decades of normal handling, use, and storage. DOE PCP staff finds this process acceptable.

Evaluation of the Metal Can

DOE PCP staff generated a model of the metal can which houses the RaB source to confirm the weight of the lead shield and polymer shield plug resting on the can within the 2R would not cause the can to buckle during a bottom NCT free drop and potentially damage the source encapsulation. The model assumed the can was aluminum, with an open top, a 2-inch inner diameter, 4.5 inches tall, and ¼-inch thick. Staff's dynamic explicit analyses of the can model in a bottom-down drop orientation confirmed it would not buckle.

2.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the package structural design continues to meet the requirements of 10 CFR Part 71

3.0 Thermal Evaluation

The objective of this thermal evaluation is to verify that the thermal performance of the package has been adequately evaluated for the tests specified under NCT and HAC and that the package design satisfies the thermal requirements of 10 CFR Part 71.

There are no changes to the 10-160B thermal design or analysis for the RaB content configuration. The estimated maximum RaB content configuration decay heat is 1.8 watts (Ref Addendum Table 5.8-C), which is significantly bounded by the maximum decay heat of 200 watts authorized in the CoC. Given the large margin to the package to decay heat limit, DOE PCP staff concurs that a detailed thermal analysis of the package with the RaB content configuration is not required to demonstrate compliance with 10 CFR Part 71.

The applicant performed a calculation (Addendum Ref 4.2) to evaluate flammable gas generation at the maximum normal operating pressure (MNOP), and to demonstrate the package remains below the design pressure limit under HAC. The applicant's evaluation will be addressed in Section 4.0 of this SER.

3.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the thermal design of the package continues to meet the requirements of 10 CFR Part 71.

4.0 Containment Evaluation

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

There are no changes to the 10-160B containment design for the RaB content configuration. The package A_2 value for the RaB configuration is 124, whereas the A_2 limit for the package is 3,000; consequently, DOE PCP staff concurs that a detailed containment analysis of the RaB content configuration is not required to demonstrate compliance with the Type B package requirements in § 71.51(a).

The Addendum is supported by a calculation (Addendum Ref 4.2 - *Hydrogen Generation and Pressure Calculation during the Transportation of 226RaB Source in 10-160B Package*, ESCD-000077, Revision 1) that evaluates the RaB content configuration for flammable gas generation at the maximum normal operating pressure (MNOP) under NCT, and to demonstrate the package remains below the design pressure limit under HAC.

Flammable Gas Generation

The purpose of the gas generation evaluation is to demonstrate that a flammable mixture of hydrogen and other flammable gases compose less than 5% by volume of the total gas inventory within any confined volume in the package over a period of 1 year at the maximum NCT temperature.

The applicant's flammable gas generation calculation and evaluation requires that all layers of confinement within the 10-160B containment are vented (i.e., 85-gallon overpack, 6M, 2R, and metal can is not sealed) and the RaB source encapsulation is undamaged. Venting ensures the maximum free volume of the containment cavity is the only confined volume where the flammable gas could accumulate, and the undamaged source encapsulation prevents radiolysis from alpha radiation of the polymer material within the 2R.

Based on these conditions for the layers of confinement and source encapsulation, the applicant only considered radiolysis of hydrogenous material (i.e., wood cribbing and web-slings, 6M fiberboard insulation, and polymer shield and adsorbent in the 2R) from gamma radiation. The applicant used the decay heat of the gamma source term, 0.1 watts of the total 1.8 watts (i.e., instead of 1.8 watts) to calculate the hydrogen gas generation rate and pressures in Section 4 of Addendum Ref 4.2. The gas-generation contribution of off-gassing from the package materials by thermal degradation would be negligible given

the large mass of the package, approximately 59,000 lb. for the RaB content configuration, and low total decay heat of the RaB contents (1.8 watts total).

The applicant also used the highest G-value of 4 molecules H₂ per eV of the polymer material (i.e., polyethylene) as the G-value for all hydrogenous materials in the package. This assumption is conservative and simplifies the gas generation calculation by evaluating the worst-case package material for gas-generation by gamma radiolysis.

DOE PCP staff concurs that these assumptions, and others listed in Section 2 of Addendum Ref 4.2 are acceptable to calculate the hydrogen gas generation rate and MNOP, and maximum pressure under HAC for the RaB content configuration.

The applicant calculated a hydrogen gas generation rate of 4.14×10^{-8} H₂ moles/s, in Section 4.1 of Addendum Ref 4.2, and used this rate to determine the time to reach 5% concentration of hydrogen gas in the free volume of the containment cavity. Based on the results in Section 4.5 of Addendum Ref 4.2, the time to reach 5% H₂ gas by volume is 4.21 years. DOE PCP staff reviewed and concurred with these results and notes that the package is vented prior shipment and a shipping window restriction is not required because half the calculated time (2.1 years) to reach the lower flammability limit is greater than one year.

Maximum Normal Operating Pressure and Maximum Pressure under HAC

The applicant calculated the MNOP and pressure under HAC for the RaB content configuration for comparison with the CSAR limits.

The applicant used the CSAR maximum internal temperature of 188°F of the package under NCT loading at sea-level to calculate an MNOP of 8.54 psig, which is bounded by the MNOP in CSAR Table 3.1-1 of 12.22 psig. DOE PCP staff concurs with the applicant's results in Addendum Section 4.8.2.2.1 as calculated in Section 4.6 of Addendum Ref 4.2.

The applicant used the CSAR maximum internal temperature of 290°F of the package under HAC occurring at a higher elevation but loaded at sea-level to calculate a maximum internal pressure of 11.5 psig, which is bounded by the maximum pressure in CSAR Table 3.1-2 of 94.3 psig. DOE PCP staff concurs with the applicant's results in Addendum Section 4.8.2.2.2 as calculated in Section 4.7 of Addendum Ref 4.2.

4.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the containment design of the package continues to meet the requirements of 10 CFR Part 71, subject to the conditions that all layers of confinement are vented and that the source encapsulation is undamaged.

5.0 Shielding Evaluation

The purpose of the shielding review is to confirm that the package (the packaging together with its contents) meet the external radiation requirements in 10 CFR Part 71.

There are no changes to the 10-160B shielding design for the RaB content configuration. The RaB content configuration includes additional lead and polymer shielding within the 2R vessel above the contents and lead shielding outside the 2R in the 6M drum; however, the applicant does not credit these items in their shielding evaluation to reduce estimated neutron or gamma dose rates.

The applicant's method to demonstrate compliance of the RaB content configuration with §§ 71.47 and 71.51 is by comparison to similar contents evaluated in the CSAR and authorized in the CoC. The dose rates in CSAR Table 5.1 are based on a Co-60 source (for gamma) and a PuBe source (for neutrons) as bounding contents for the package. The applicant also performed a simplified shielding model and analysis to confirm the comparison by calculation for neutron dose rates.

The RaB source for the shielding evaluation is decayed for 30 years.

DOE PCP staff notes that the CSAR assumes the NCT dose rate at 1-meter will exceed 10 mrem/h for neutron and gamma dose rates individually, since the maximum dose rates at 2-meters are 9.44 (neutron) and 9.96 (gamma) mrem/h. Therefore, the Transport Index (TI) will exceed 10, per § 71.47(a), so the package must be shipped by exclusive use and must meet the radiation limits of § 71.47(b).

Analysis by Comparison to Determine Neutron Dose Rate

The current CoC authorizes PuBe sources in special form with a maximum neutron emission rate of $1.1E+8$ neutrons/s. The neutron emission rate of the RaB source is $3.5E+7$ neutrons/s, or approximately 32% of Pu-Be source limit.

In Section 5.1, Table 5.1-A of the Addendum, the applicant compared the neutron energy spectrum from the RaB source with the neutron energy spectrum of the PuBe source. The calculated mean neutron energy of the RaB source is 3.45 MeV, as compared with 4.83 MeV calculated for the PuBe. The lower mean neutron energy of the RaB source is accounted for due to its greater fraction of neutrons in the 1.5 to 6.5 MeV energy intervals and essentially zero neutrons in the 6.5 to 10.5 MeV interval, whereas approximately 26% of the neutrons of the PuBe source are in the 6.5 to 10.5 MeV interval. DOE PCP staff concurs with results in Addendum Table 5.1-A and independently verified the neutron spectrum values used in the table are valid.

The applicant also performed a simplified shielding model and analysis of the 10-160B in Addendum Section 5.8.2.4, to compare the neutron source spectra for both sources. Each source was modeled as 5 cm sphere suspended in air in the center of a steel/lead/steel sphere to represent the 10-160B, as shown in Addendum Figure 5.8-A as concentric

circles. The source sphere is located at the center approximately 83.36 cm (34 inches) from innermost steel layer to simulate the approximate distance from the center of the 10-160B to the inner shell wall (34 inches). The dose rate measurement point was modeled as a 1 cm sphere at about 1 cm outside the steel/lead/steel sphere. The input modeling parameters are listed in Addendum Table 5.8-A. The ANSI/ANS 6.1.1-1991, *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors* conversion factors integrated in SCALE software were used to calculate the neutron dose rates. The result of this analysis demonstrates that the neutron dose rate from a unit RaB source is slightly less than that of a unit PuBe source for the same configuration analyzed (RaB/PuBe = 0.94).

DOE PCP staff concurs that the applicant sufficiently demonstrated that the neutron dose rate from the RaB source is bounded by the PuBe source.

Analysis by Comparison to Determine Gamma Dose Rate

For the gamma dose rate from the RaB source, the applicant used the established procedure from CSAR Chapter 7, Attachment 1, *Determination of Acceptable Activity*, to demonstrate the RaB dose rate is bounded by CSAR Table 5.1.

The applicant compared the gamma energy from the RaB source to a Co-60 source (CSAR Section 5.2.2 and Table 5.6) then performed a sum-off-fraction calculation shown in Addendum Table 5.1-C to demonstrate the RaB source is bounded by the maximum gamma dose rates evaluated in the CSAR. The RaB source is approximately 63% of the gamma dose evaluated in the CSAR. DOE PCP staff concurs with the applicant's results.

Summary of Maximum Estimated Dose Rates under NCT and HAC

Based on the applicant's analysis by comparison of the RaB source with the PuBe and Co-60 sources evaluated in the CSAR, the resulting dose rates for the RaB content configuration may be estimated by scaling the CSAR Table 5.1 maximum neutron dose rate to 32% of the PuBe source and maximum gamma dose rate to 63% of the Co-60 source as shown in SER Table 5.1 below.

**SER Table 5.1 – Estimated Dose Rates for RaB Contents
 Scaled from CSAR Table 5.1**

| Condition | | Surface | | @1m | | @2m |
|------------|--------------|------------|------------|-------------|-------------|------------|
| | | Side | Ends | Side | Ends | Side |
| NCT | | | | | | |
| Neutron | Source | 36 | 27 | N/A | N/A | 3.0 |
| Gamma | Source | 79 | 112 | N/A | N/A | 6.3 |
| | Totals | 115 | 140 | N/A | N/A | 9.3 |
| § 71.47(b) | Limit | 200 | 200 | N/A | N/A | 10 |
| HAC | | | | | | |
| Neutron | Source | N/A | N/A | 26 | 13 | N/A |
| Gamma | Source | N/A | N/A | 90 | 63 | N/A |
| | Totals | N/A | N/A | 117 | 75 | N/A |
| § 71.51(a) | Limit | N/A | N/A | 1000 | 1000 | N/A |

The results sufficiently demonstrate the RaB content configuration meets 71.47(b) and 71.51(a) for exclusive use shipment. The additional shielding in the 6M, although not credited in the Addendum, provides additional margin for radiation safety.

5.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the package shielding design continues to meet the requirements of 10 CFR Part 71.

6.0 Criticality Evaluation

The purpose of the criticality review is to confirm that the package together with its contents meet the requirements in 10 CFR Part 71 for nuclear criticality safety (NCS).

The RaB source is non-fissile; consequently, a criticality evaluation is not required for this content configuration.

6.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the package criticality design continues to meet the requirements of 10 CFR Part 71.

7.0 Operating Procedures

The CSAR provides a description of package operations, including package loading and unloading operations, and the preparation of an empty package for shipment. Loading and unloading procedures show a general approach to perform operational activities

because site-specific conditions may require the use of different equipment and loading or unloading steps.

Addendum Chapter 7 address the specific package operations for the RaB content configuration. DOE PCP staff finds the prerequisite steps to loading in Addendum Section 7.1.1., Step (1) consistent with the acceptance criteria in Addendum Section 8.1. Addendum Chapter 7 operation procedures are clearly described in the text and supported with illustrations in Addendum Figures 7.1-A: “Package Loading”, 7.1-B: “Package Loading (Continued)”, and 7.2-A: “Package Unloading”.

7.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff concludes that the combination of the engineered safety features of the package and the operating procedures provide adequate measures and reasonable assurance for safe operation of the package in accordance with 10 CFR Part 71.

8.0 Acceptance Tests and Maintenance Program

The objective of this review is to verify 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.

There are no changes to the 10-160B packaging acceptance tests or maintenance program in the CSAR for use of the 10-160B for shipment of the RaB content configuration.

Addendum Section 8.1, addresses the acceptance tests (i.e., acceptance criteria) for use of the additional packaging components for RaB content configuration and for the RaB source itself, prior to loading, to ensure the components are undamaged, to confirm all layers of confinement are vented (i.e., metal can is not sealed, and the 2R and both drums are vented), and the source encapsulation remains intact as demonstrated by no traces of radium contamination and/or radon gas generation on/around the 2R closure or vent, with the source RaB source loaded.

There are no maintenance program requirements related to the RaB content configuration since it is one-time shipment.

8.1 Evaluation Findings

Based on the review of the statements and representations in the Addendum, DOE PCP 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.

9.0 Quality Assurance

The objective of this review is to verify that the Addendum demonstrates that the applicant's Quality Assurance (QA) program description and package specific QA requirements comply with the requirements of 10 CFR Part 71, Subpart H, Quality Assurance.

The applicant's 10 CFR 71 Subpart H Quality Assurance Program (QAP) is approved by DOE (https://rampac.energy.gov/docs/default-source/qa/approval_0001_r6.pdf).

There were no changes to the applicant's approved QAP. Chapter 9 of the Addendum addressed the new packaging components with respect to quality assurance requirements.

The additional packaging components for this RaB content configuration are listed in Addendum Section 9.3.2.2, *Important to Safety Items*, and classified as Quality Level 3 items (Minor to Safety) in Addendum Table 9.3-D. Their primary safety function is dunnage to restrain the contents within the 10-160B containment cavity. DOE PCP staff concurs with the ES classification of these components and how they are credited for safety in the Addendum.

9.1 Evaluation Findings

Based on review of the statements and representations in the Addendum, DOE PCP staff has reasonable assurance that the package-specific requirements are consistent with their DOE approved QAP, meet the requirements of 10 CFR 71 Subpart H, and are therefore adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

Conditions of Approval

The following conditions are required in the Letter to amend the CoC based on this SER.

1. Authorization is limited to use of the 10-160B package for a one-time exclusive use shipment of the RaB content configuration described in Addendum Chapter 1, by ground transport from DOE Oak Ridge TRU Waste Processing Center to Nevada National Security Site for disposal.
2. The cribbing design for the RaB content configuration shall be fabricated and inspected per the Drawing No ESCD-000078, Rev 0.
3. The package must be prepared for shipment and operated in accordance with the *Operating Procedures* of Addendum Chapter 7.
4. All other conditions of DOE CoC 9204 shall remain the same unless superseded by this Letter.
5. This authorization shall expire on December 31, 2024.

Conclusion

Based on the statements and representations contained in the Addendum and the conditions listed above, DOE PCP staff concludes that the package design has been adequately described and evaluated, and the Model 10-160B package continues to meet the requirements of 10 CFR Part 71. Staff recommends approval of a letter amendment to the CoC by the DOE Headquarters Certifying Official (HCO) to authorize use of the 10-160B for this one-time shipment of the RaB content configuration.

References

- [1] *Addendum for Transportation of Radium-226 Boron Source in a 10-160B Packaging*, ESCD-000081, Revision 0, February 2022.
- [2] *Addendum for Transportation of Radium-226 Boron Source in a 10-160B Packaging*, ESCD-000081, Revision 1, September 2022.
- [3] *Consolidated Safety Analysis Report for Model 10-160B Type B RADWASTE Shipping Cask*, Consolidated SAR, Revision 4, July 2012.