Environmental Management

safety ❖ performance ❖ cleanup ❖ closure

DOE Packaging Certification Program

Safety Evaluation Report for Certificate of Compliance No. 9516 Amendment for the Model 9516 Package

Docket No. 22-36-9516

Prepared by: James M. Shuler Digitally signed by James M. Shuler Date: 2023.06.20 17:07:48 -04'00'

Dr. James M. Shuler
Manager, DOE Packaging Certification Program
Office of Packaging and Transportation

Approved by: JULIA SHENK Digitally signed by JULIA SHENK Date: 2023.07.24 09:38:33 -04'00'

Julia C. Shenk
Headquarters Certifying Official
Director
Office of Packaging and Transportation

This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review of the application and supplements submitted for the DOE Idaho Operations Office (ID) for amendment of DOE Certificate of Compliance (CoC) Number 9516 for the Model 9516 package design. This package is needed to support the mission of the Idaho National Laboratory (INL), Space Nuclear Power & Isotope Technologies Division.

Summary

By email [1] dated June 9, 2022, the certificate holder, ID, requested an amendment of DOE CoC 9516 for the Model 9516 package design to add Shipping Configuration 12 (SC-12) to authorize use of the package for shipment of Advanced Long Term Battery Fueled Capsule Assemblies (ALTB-FCA). The ALTB-FCA is a double encapsulated weldment for granular PuO_2 fuel and meets CoC Table 1, *Plutonium Initial Isotopic Limits* for Shipping Configurations 1 through 6, with an additional limit that ^{234}U does not exceed 10 wt.%.

The SC-12 content configuration in the package Containment Vessel (CV) is shown in Figure 1-4 of Addendum 3 to the 9516 Safety Analysis Report for Packaging (SARP), and consists of one-to-three ALTB-FCA inserted in a Graphite Support Block (GSB), a vented Liner weldment (vent is a 1/4 inch through hole in the Liner side wall) containing the GSB with ALTB-FCA, and the CV weldment with the Liner inserted first and a Graphite Filler Block (GFB) placed on top of the Liner. The configuration includes an option to use a ½ in. thick pieces of graphite felt above and below the GSB for additional dunnage in the Liner.

The initial application [2] for package approval in support of the ID request was *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3*, Revision 0a, dated June 2022. This application, and subsequent supplements, were prepared for ID and INL by the Pacific Northwest National Laboratory (PNNL) and uploaded to a secure server by INL for ID to DOE PCP for review.

On September 9, 2022, the DOE PCP Manager notified ID by memorandum [3] that DOE PCP staff completed their independent technical review and confirmatory analysis of the application and had no regulatory compliance questions, but did identify errors in SARP Addendum 3, Chapter 7 *Package Operations* in need of correction and several other procedure steps in the chapter in need of correction or clarification.

On October 5, 2022, ID submitted a response and proposed implementation [4] to the errors identified by DOE PCP staff and noted, based on an "extent of condition" review, that these errors also affected Chapter 1 and Chapter 7 *Package Operations* of the SARP, and SARP Addendums 1 and 2. The submittal also included SARP Addendum 3, Rev 0b, and errata pages to the SARP (Rev 4), SARP Addendum 1 (Rev 2), and SARP Addendum 2 (Rev 0).[5-8]

On October 18, 2022, DOE PCP issued [9] one additional comment regarding the Addendum Chapter 3, *Thermal Evaluation*.

On February 9, 2023, ID submitted a response and proposed implementation [10] to resolve staff's thermal evaluation comment. The submittal also included SARP Addendum 3, Rev 0c.[11] Staff accepted the responses and proposed implementation to resolve the final comment, and the DOE PCP Manager notified ID by memorandum [12] on February 9, 2023, that the staff's review was complete pending implementation in final revisions of the SARP and SARP Addendums.

On March 14, 2023, ID submitted the final application [13] to DOE PCP. The application consists of:

- *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 5, dated February 2023 [14]
- *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 1*, R1033-0065-ES, Rev. 3, dated February 2023 [15]
- *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 2*, R1033-0067-ES, Rev. 1, dated February 2023 [16]
- *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3*, R1033-0066-ES, Rev. 0, dated February 2023 [17]

Based on the statements and representations in the final SARP Addendum No. 3, Revision 0, and minor changes in SARP Rev. 5, SARP Addendum 1 Rev. 3, and SARP Addendum 2, Rev.1, DOE PCP staff independently confirmed that the package design has been adequately described and evaluated for shipment of SC-12 – ALTB-FCA. Therefore, staff has reasonable assurance that the regulatory requirements of Part 71 have been met and recommends amendment of the CoC by the DOE Headquarters Certifying Official (HCO).

Evaluation

This SER documents the independent technical review by DOE PCP staff of SARP Addendum No. 3, Revision 0 (hereinafter referred to as the "Addendum 3" unless otherwise specified), and pages changes to SARP Rev 5, and SARP Addendums 1 (Rev 3) and 2 (Rev 1) to the requirements of 10 CFR Part 71.

1.0 General Information

1.1 Introduction

The certificate holder requested an amendment to DOE CoC 9516 to add SC-12 - ALTB-FCA as authorized contents. The ALTB-FCA was previously an authorized content in the "-85" version of the package under CoC 9516 Rev. 13 and 14 but omitted in the SARP and CoC when the package was certified to the "-96" requirements in accordance with § 71.19(d).

The ALTB-FCA is a double encapsulated weldment for granular PuO_2 fuel and meets CoC Table 1, *Plutonium Initial Isotopic Limits* for Shipping Configurations 1 through 6, with an additional limit that ^{234}U does not exceed 10 wt.%.

The SC-12 content configuration in the package CV is shown in Addendum 3, Figure 1-4. For content preparation, one-to-three ALTB-FCA are inserted in a GSB, with the option to use of ½ in. thick pieces of graphite felt above and below the GSB for additional dunnage in the vented Liner (vent is a 1/4 inch through hole in the Liner side wall). Next, the GSB is loaded in the Liner and the Liner Lid welded shut. Next, the Liner weldment is loaded in the CV followed by the GFB and the CV Lid is welded shut. These operations are performed in an argon gas rich environment.

1.2 Package Description

There were no changes to the previously approved package description in the SARP.

The Model 9516 is a Type B(U)F package that is designed for transport of up to 500 watts of PuO_2 heat source material in any solid form (e.g., powder, pellets, granules, etc.).

The package has a maximum gross weight of 900 lb. (408 kg) and consists of a cylindrical Cask that is housed within a Personnel Shield (frame and skid). The package containment is a one-time use leak-tight CV weldment. The package contents consist of various quantities of plutonium heat source material (primarily ^{238}Pu) and fissile material that may exceed 3,000 A_2. Since the package contains Pu in excess of 0.74 TBq (20 Ci) its contents must be in any solid form to meet the requirements § 71.63.

The package as offered for consignment is shown in Figure 1 of the CoC.

1.2.1 Packaging

There are no design changes to the primary packaging components for SC-12. The Model 9516 packaging consists of three basic components: Cask, a one-time use CV, and Personnel Shield. These components are classified in SARP Table 9.1 as Quality Level A items (Quality Category A), which are critical-to-safe operation of the package.

New packaging components internal to the CV for SC-12 include:

- INL Drawing 805406, Rev. 1, *Liner (11.16 in. high)*
- INL Drawing 805408, Rev. 1, *Graphite Support Block*
- INL 805407, Rev. 0, *Graphite Support Block*

These components and materials of construction are described in the Addendum 3 Section 1.2.2.1.1 and shown in Addendum Figures 1-2, and 1-4. Figure 1-4 shows the *Loading Configuration for Three ALTB Fueled Capsule Assemblies*, which include the option to use ½ in. thick pieces of graphite felt above and below the GSB in the Liner for additional dunnage.

The safety function of these internal components is to restrain the contents from movement in the CV. These components are classified in Addendum 3, Table 9-1, *Q-List for the ALTB Fueled Capsule Assembly Payload*, as Quality Level C items (Quality Category C), which are minor to the safe operation of the package.

The list and drawings of all packaging components required for SC-12, including the ALTB-FCA drawing, are defined in Addendum 3, Table 1-2, *9516 Package Content Shipping Configurations.*

1.2.2 Contents

There are no changes to the exiting authorized radioactive contents or their loading configurations.

The radioactive contents for SC-12 consist of granular PuO_2 fuel packaged with a hollow spacer in a cylindrical double encapsulated weldment defined as the ALTB-FCA, as shown in Addendum Figure 1-3 and Appendix 1.3.2, Drawing R1034-0011-EB. The plutonium initial isotopic limits for SC-12 are shown in Addendum Table 1-1 and are identical as Shipping Configurations 1 through 6 (See CoC Table 1), except an additional limit for ^{234}U to less than 10 wt.% is required for SC-12. The principal isotope in the ALTB-FCA PuO_2 is ^{238}Pu, which has an initial composition of 74-90 wt.% of the total plutonium in the mixture. As the initial ^{238}Pu weight percent is increased in a mixture of PuO_2, the ^{239}Pu and ^{241}Pu weight percents are reduced from their initial wt.% of 23.9 and 7.9, respectively.

Each ALTB-FCA is cylindrical double encapsulated weldment fabricated from Haynes® Alloy 25 (nickel-chromium-tungsten-molybdenum alloy). Approximate external capsule dimensions are 8.58 in. in length with an outside diameter of 1.67 in. and a wall thickness of 0.127 inch. The radioactive contents are sintered PuO_2 granules with a hollow spacer for dunnage. The spacer is also fabricated from Haynes® Alloy 25. The maximum weight of an ALTB-FCA is 1800 g (3.97 lb.) with a maximum PuO_2 weight of 371.5 g (0.82 lb.). The decay heat limit is 133.3 W per ALTB-FCA or 399.9 W per CV for three ALTB-FCAs.

Note – the Structural, Thermal, and Shielding Evaluations in Addendum 3 evaluated the contents at 450.1 g of PuO_2 per ALTB-FCA for the bounding package decay heat limit of the 500 W, whereas the maximum fuel age calculation in Addendum Section 3.3.2.2, *CV MNOP*, uses the actual SC-12 decay limit of 399.9 W.

1.3 Evaluation Findings

Based on review of the statements and representations in Addendum 3, DOE PCP staff concludes that this addendum in support of the CoC amendment request has been described in sufficient detail to provide an adequate basis for the package evaluation under 10 CFR Part 71.

2.0 Structural Evaluation

The objective of this structural review is to determine that the information presented in the SARP, including the description of the packaging, design and fabrication criteria, structural material properties, and structural performance of the package design for the tests under Normal condition of Transport (NCT) and Hypothetical Accident Conditions (HAC), is complete and meets the requirements of 10 CFR Part 71.

There are no design changes to the primary packaging components (i.e., Cask, a one-time use CV, and Personnel Shield) or maximum loaded CV weight of 72.2 lb. The additional packaging components required for SC-12 consists of three one-time use components: Liner, GSB, and GFB.

DOE PCP staff confirmed that the package and its structural evaluation for SC-12 is consistent with the package description in Addendum 3, Section 1.2.

DOE PCP staff reviewed SARP Addendum 3, Chapter 2, *Structural Evaluation*, for the effect of SC-12 on the structural performance of the package relative to the structural evaluation in Chapter 2 of the SARP. Staff also evaluated material compatibility between the SC-12 materials, contents, and the existing packaging components materials.

<u>Weight and Center of Gravity</u>
For SC-12, the maximum weight of the loaded CV with three ALTB-FCA is 60 lb. and is bounded by the existing CV weights ranging from 65.4 to 72.2 lb. (SARP Table 2-3, *CV Assembly Weights*) for other shipping configurations authorized in the CoC. The center of gravity (CG) of the package for SC-12, is approximately 13.1 in. from the bottom of

the cask, which is also bounded by the existing CG range of 13.9 - 14.3 inches for other authorized configurations.

Materials of Construction, Temperature, and Pressure
There materials used to fabricate the packaging components for SC-12 are common to other authorized packaging component materials. The Liner and its lid are weldments fabricated from 304L stainless steel, which is the same material as the CV, and the GSB and GFB (and optional graphite felt) are fabricated from GrafTech ATJ ™, Poco TM, or Poco PLS-1, which is the same graphite material used for the blocks in Shipping Configurations 1 through 6 and 8.

During loading, the contents, Liner, and CV are prepared in an inert atmosphere and protected from moisture. There are no dissimilar metals in direct contact for SC-12 so galvanic corrosion is unlikely to occur. No corrosive agents or volatile substances are used in the package; therefore, chemical, or galvanic reactions between the ALTB-FCAs and the packaging, or between packaging items are unlikely to occur.

Addendum 3, Chapter 3, *Thermal Evaluation*, demonstrates for SC-12, that the maximum content decay heat, the maximum temperatures of the packaging components and the maximum internal pressures of the cask and the CV under NCT and HAC are bounded by the SARP for other shipping configurations.

Due to an increase in the bounding maximum normal operating pressure (MNOP) in the CV from 50.3 psig (65.0 psia) to 98.3 psig (113.0 psia) for SC-12, the applicant performed a structural evaluation and calculations of the CV under NCT load combination in Addendum 3, Section 2.12.2, *Containment Vessel NCT Load Combination Evaluation*. The calculations conservatively combine the NCT free drop stress intensity reported in SARP Chapter 2 with the calculated maximum stress intensities from pressure at key locations on the CV. The results demonstrate that the CV has sufficient structural integrity to satisfy the Design Loading stress intensity limits stipulated in paragraph NB-3221 of the ASME BPVC, Section III, Division 1, Subsection NB form the increased bounding MNOP to 98.3psig. Therefore, the CV has sufficient structural integrity to sustain the combined loadings from MNOP, reduced external pressure, and the NCT free drop at a maximum metal temperature of 500 °F.

Likewise, the applicant performed a structural evaluation and calculations of the CV under HAC load combination in Addendum 3, Section 2.12.3 *Containment Vessel HAC Load Combination Evaluation*, to demonstrate that the CV has sufficient structural integrity to satisfy the Level D stress intensity limits stipulated in paragraph NB-3225 of ASME BPVC, Section III, Division 1, Subsection NB due to the increased bounding MNOP.

Therefore, the CV has sufficient structural integrity to sustain the combined loadings from MNOP, reduced external pressure, and the HAC free drop, crush, and puncture at a maximum metal temperature of 500 °F.

2.1 Evaluation Findings

Based on review of the statements and representations in Addendum 3, 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 review 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 design changes to the primary packaging components (i.e., Cask, a one-time use CV, and Personnel Shield) or the maximum decay heat limit of 500 W for the package. The additional packaging components required for SC-12 consists of three one-time use components: Liner, GSB, and GFB. The applicant analytically evaluated the package's thermal performance under NCT and HAC for the Shipping 12 Configuration.

DOE PCP staff's thermal review and evaluation focused on the package's accessible surface temperature, the maximum temperatures of packaging components, the maximum internal pressures under NCT and HAC, and maximum allowable fuel age of the ALTB-FCA. Staff also performed a confirmatory thermal analysis with ANSYS/APDL code to verify the applicant's temperature and the pressure results.

<u>Thermal Modeling</u>
The model for the thermal analysis of SC-12 includes the Cask, CV, and the Liner loaded with three ALTB-FCAs in the GSB. The GFB is placed on top of the Liner to provide dunnage in the CV and prevent movement of the Liner. Both graphite blocks have additional holes milled axially and radially to minimize weight, increase the free volume inside the Liner and CV, and provide an air passage between the ALTB-FCA in the support block. However, for modeling simplicity, these holes are neglected.

The maximum weight of an ALTB-FCA is 1800 g (3.97 lb.), with 371.5 g PuO_2 granules, which results in a nominal decay heat of 133.3 W, or 399.9 W per package. For conservatism, the thermal model will use the bounding package decay heat of 500 W per package and 166.66 W per ALTB-FCA. Note – the applicant's maximum allowable fuel age calculations in Addendum 3, Appendix 3.5.3 use the nominal decay heat values.

The package free volumes are room air in the Cask, argon gas in the CV and Liner, and helium gas with a small of argon weld torch gas in the ALTB-FCA. The primary heat transfer mechanisms are conduction and radiation within the package, and convection and radiation between the exterior of the package and the surrounding environment. The package thermal loading is from the bounding content decay heat of 500 W, solar insolation in accordance with § 71.71(c)(1), and a 30-minute fire under HAC in accordance with § 71.73(c)(4). The effects of ambient temperature, decay heat, and solar heating on the packaging temperatures were determined by using the finite element computer code ANSYS/Mechanical (APDL).

DOE PCP staff concurs that neglecting the holes in the graphite blocks, which would otherwise be filled with argon gas, is non-conservative under NCT and conservative under HAC due to the much higher thermal conductivity of graphite than helium (See Addendum 3, Tables 3-4 and 3-5) resulting in higher heat transfer rates in the thermal model. Under NCT, the model will result in lower calculated ALTB-FCA and Liner temperatures since more internal heat is being dissipated through the graphite as would otherwise be dissipated through helium. This non-conservatism modeling assumption is acceptable given the large safety margins to the allowable temperature limits shown in Addendum 3, Table 3-9, *Temperatures for NCT with Three ALTB Fueled Capsule Assemblies*, and using the bounding 500 W decay heat instead of 399 W. Under HAC, the model will result in higher heat input to the Liner and ALTB-FCA but these and all other packaging components/items are still within their allowable temperature limits shown in Addendum 3, Table 3-12. *Maximum HAC Temperatures with Three ALTB Fueled Capsule Assemblies*.

<u>NCT Thermal Analysis</u>
The allowable temperature limits for packaging components under NCT are established in SARP Section 3.2.2 for the Cask and CV, and Addendum 3, Section 3.2.3, for the SC-12 components. DOE PCP staff reviewed the temperature limits and verified the references and found them acceptable. The calculated maximum temperatures of the packaging components under NCT are based on a total bounding decay heat loading of 500 W and are well below the corresponding allowable temperature limits.

DOE PCP staff examined the applicant's input/output files for conducting thermal analysis using ANSYS/APDL with the 3-D package full geometry. Staff confirmed the applicant's NCT analyses was performed for an ambient temperature of 38°C (100 °F), with solar insolation as specified in § 71.71(c)(1). Staff's confirmatory calculations are in good agreement with the applicant's results shown in Addendum 3, Table 3-9, which demonstrate that the packaging component temperatures are all below their corresponding allowable temperatures.

The Cask surface temperature is calculated to reach a maximum temperature of 372 °F under NCT; therefore, the Personnel Shield is required to meet the exclusive-use requirement of § 71.43(g). SARP Section 3.5.4.4 demonstrates that the accessible surface temperatures of the Personnel Shield will remain below 185 °F with a 1000 W package decay heat thus meeting the exclusive-use conditions in § 71.43(g).

<u>Cask Pressure and Maximum Normal Operating Pressure (MNOP)</u>
The Cask cavity is pressurized due to expansion of air during NCT. The applicant's calculations in Addendum 3, Section 3.3.2.1 show that the peak internal pressure inside the Cask cavity is 8.9 psig (23.6 psia) based on a maximum cask gas temperature of

392°F under NCT hot condition. This cavity pressure is far below the Cask design pressure limit of 300 psig (SARP Section 2.7.6).

The MNOP results from expansion of the argon cover gas originally inside the CV and the Liner cavities, and the potential release of helium gas from the PuO_2 in the ALTB-FCAs. The applicant's calculated MNOP is 98.3 psig (113.0 psia), which remains below the CV design pressure limit of 200 psig (Ref SARP Appendix 2.12.10, Section 2.1). Since the MNOP is a function of the PuO_2 fuel age and wattage of the contents (i.e., the gas temperature in the CV cavity), the applicant used an MNOP 113.0 psia with a 399.9 W content decay heat to determine the maximum allowable fuel age at the end of shipment for one, two, and three ALTB-FCA per package as 84.5, 32.6, and 19.2 years respectively. DOE PCP staff confirmed that the administrative controls are included to verify the fuel age restrictions in the Operations Procedures (Addendum 3, Section 7.1.3 *Preparation for Transport*, Step 14) and must be added as a condition in the CoC, such that a 100% release of decay generated helium from the ALTB-FCAs will not result in the CV pressure exceeding the MNOP.

<u>HAC Thermal Analysis</u>
The same package thermal model for NCT analysis, with three ALTB-FCAs outputting 500 W of decay, was used by the applicant to evaluate the performance of the package under HAC, except the Personnel Shield was omitted from the model. The structural evaluation under HAC assumes the Personnel Shield is destroyed to the point where it can no longer be a credited as important-to-safety component following the free-drop, crush, and puncture tests of §71.73(c). DOE PCP staff confirmed the initial temperatures of packaging components prior to the HAC thermal test are based on the thermal analysis under NCT heat condition of § 71.71(c)(1) with a heat loading of 500 W. The surface absorptivity of all external surfaces of the Cask is 0.8, and convective heat transfer coefficients are computed based on the forced convection correlations with gas velocities of 32 ft./s during the 30-minute thermal test at 1475 ºF in accordance with§ 71.73(c)(4).

The results of the applicant's HAC thermal analyses are summarized in Addendum 3, Table 3-12, *Maximum HAC Temperatures with Three ALTB Fueled Capsule Assemblies*, along with the allowable temperature limits which were established in Addendum 3, Section 3.2, *Material Properties and Component Specifications*. DOE PCP reviewed the applicant's thermal analysis and conducted a confirmatory analysis using ANSYS/APDL. Staff concluded that the maximum temperatures of all packaging components listed in Addendum 3, Table 3-12 are in good agreement with staff's confirmatory analysis results and sufficiently demonstrate that the calculated maximum temperatures of all packaging components under HAC are within their corresponding allowable temperature limits.

<u>Maximum Pressure under HAC</u>
The maximum pressure in the Cask cavity due to gas expansion under HAC is calculated to be 33.2 psig (47.9 psia) based on a Cask gas temperature of 1,265 °F (See Addendum 3, Table 3-2), which is below the Cask design pressure limit of 300 psig.

The estimated maximum pressure in the CV due to gas expansion under HAC is 143.1 psig (157.8 psia) based on a CV bulk average gas temperature of 1,155 °F (See Addendum 3, Table 3-2), which is lower than the CV design pressure limit of 200 psig.

DOE PCP staff conducted confirmative calculations of the maximum pressures in the Cask cavity and in the CV and staff's results are in good agreement with Addendum 3, Table 3-2.

Gas Generation and Maximum Fuel Age

The ALTB-FCA do not contain any materials (e.g., elastomeric seals) which would decompose and generate hydrogen or other gases. The granular PuO_2 fuel is sintered at 1600 °C for six hours prior to encapsulation. Encapsulation and welding of the primary and secondary capsule assemblies are performed in an inert gas glovebox that consists primarily of helium. The weld torch gas is argon; consequently, the final gas mixture inside the capsule will be a helium/argon mixture. The moisture levels in the glovebox are maintained at less than 20 ppm and oxygen levels are maintained at less than 15 ppm during encapsulation and welding to ensure the ALTB-FCA contents are free from impurities and moisture that generate hydrogen or other gases resulting from radiolysis.

At the time of encapsulation, additional helium gas generated by alpha decay of ^{238}Pu oxide (PuO_2) continuously accumulates in the capsule. The additional pressure contribution from generation of helium gas by alpha decay is accounted for in Addendum 3, Section 3.3.2.2, *CV MNOP*, by determining a maximum fuel age required to keep the MNOP at 98.3 psig (113.0 psia) and assuming all the helium is released from the ALTB-FCA and Liner into the CV. For fuel age related calculations, the applicant used the nominal decay heat of 133.3 W per ALTB-FCA, or 399.9 W total per package for three ALTB-FCAs assemblies. Pressure calculation results in Addendum 3, Table 3-11, *Maximum Allowable Age of Fuel* show the maximum allowable fuel age by the end of the shipment period is 19.2 years for three ALTB-FCAs, 32.6 years for two ALTB-FCAs, and 84.5 years for one ALTB-FCA. DOE PCP staff reviewed the fuel age calculations in SARP Section 3.3.2.2, *CV MNOP*, and verified by document review and confirmatory calculations that the method used, calculations, and results in Addendum 3 for the fuel age calculations for SC-12 were correct.

3.1 Evaluation Findings

Based on review of the statements and representations in Addendum 3, DOE PCP staff has reasonable assurance that the thermal design of the package continues to meet the requirements of 10 CFR Part 71, subject to use of the Personnel Shield for exclusive-use shipment of the package and the fuel age limits from Addendum Table 3-11.

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 design changes to the primary packaging components (i.e., Cask, a one-time use CV, and Personnel Shield) or leakage rate criterion (ANSI N14.5 "leaktight") for the package. The additional packaging components required for SC-12 are internal to the containment boundary and therefore are not important-to-safety items for package containment.

There were no changes to containment performance features of the package design (i.e., CV) for transport of SC-12.

The package containment system is a one-time use CV, which is a cylindrical stainless steel weldment that is loaded and welded shut in an atmosphere of helium gas (i.e., inerted). The closure weld is subsequently visually inspected and radiographed prior to leakage testing the CV. The CV provides a tested leaktight containment boundary for the contents of the package under NCT and HAC to meet the release rate limits of §71.51(a)(1) and (a)(2).

DOE PCP staff confirmed in Chapter 2 and 3 of this SER that the CV MNOP and maximum pressure under HAC evaluated in Addendum 3 are below the design pressure limits of the CV. The fuel age restrictions based on the number of ALTB-FCA loaded in CV ensures the MNOP for Shipping Configure 12 does not exceed 98.3 psig (113.0 psia).

Therefore, the existing containment evaluation in Chapter 4 of the SARP remains bounding under NCT and HAC for SC-12.

4.1 Evaluation Findings

Based on review of the statements and representations in Addendum 3, DOE PCP staff has reasonable assurance that the containment design of the package continues to meet the requirements of 10 CFR Part 71.

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.

The applicant demonstrated compliance with §§ 71.47 and 71.51 for exclusive use shipments by analysis.

DOE PCP staff reviewed the shielding evaluation described in Addendum 3, Chapter 5 for SC-12, with three ALTB-FCA per package and six packages in the conveyance. Staff subsequently performed an independent Monte Carlo confirmatory analysis to confirm compliance with the dose rate requirements in §§ 71.47 and 71.51 for exclusive use shipment. Staff calculated the neutron and photon source terms using the ORIGEN code of SCALE 6.2.4 Code System and performed Monte Carlo analyses using MCNP6.2 to independently confirm the shielding calculations for both NCT and HAC.

5.2 Shielding Design

A detailed description of the package is provided in Section 1.2.1 of the SARP and Addendum 3. The dimensions and the material specifications of the packaging components are provided in Chapters 1 and 2 of the SARP and Addendum 3, respectively. The package does not contain materials specifically intended for radiation shielding (e.g., lead or tungsten); however, the stainless steel cask body, the stainless steel CV, the Liner, and the graphite packing materials do provide some radiation attenuation. The external radiation level requirements/limits of § 71.47, for a single package are met by (1) restricting the isotopic content of the PuO_2 source material, (2) maintaining the distance between the source material and the external surface of the package, and (3) properly spacing multiple packages on the transport vehicle. For conservatism, the applicant does not credit the effect of radiation attenuation by the personnel shield (cage) material. The personnel shield is credited in the applicant's structural evaluation under NCT but is damaged under HAC to the extent that it not credited as a safety feature under HAC. Consequently, the external radiation levels under NCT are measured at the external surfaces of the personnel shield and the external radiation levels under HAC are measured at the external surface of the cask.

5.3 Source Specification

Although the bounding mass of PuO_2 in each ALTB-FCA is 371.5 g, for conservatism, the applicant used 450.1g PuO_2 per ALTB-FCA as the bounding mass loading for SC-12 with three ALTB-FCAs per package, which would yield 500-W of total decay heat per package. Table 5-1 below (Table 5-5 in Addendum 3) below shows the initial compositions of the PuO_2 fuel in three ALTB assemblies with 74 and 90 wt. % ^{238}Pu enrichments, which are used for neutron and photon source terms calculations. The actinide impurities (^{241}Am, ^{237}Np, ^{234}U, and ^{232}Th), at average concentrations (based on historic assay data) are not major contributors to the neutron or photon source terms. Up to 10 wt.% of ^{234}U does not increase the dose rates outside the package. Therefore, the individual actinide impurities may be as high as 1 wt.% of the total plutonium content, and ^{234}U could be as high as 10 wt.%, with negligible impact on the overall dose rates.

Table 5-1. PuO_2 Fuel Composition with 74 and 90 wt.% 238Pu enrichment for Three ALTB Fueled Capsule Assemblies in a Single 9516 Package

Isotope	Mass (g)	
	74 wt.%	90 wt.%
^{236}Pu	0.00238	0.00196
^{238}Pu	879.24	879.98
^{239}Pu	278.53	72.76
^{240}Pu	23.89	19.66
^{241}Pu	4.76	3.92
^{242}Pu	1.75	1.44
^{241}Am	0.12	0.10
^{237}Np	0.77	0.64
^{234}U	0.65	0.54
^{232}Th	1.24	1.02
O_2	159.2	131.0

The photon source term was calculated for PuO_2 decayed for 17.5 years. This decay period conservatively bounds fresh PuO_2 because it results in a larger photon source in the energy intervals of 0.25 – 2.75 MeV that contribute more to personnel dose. The emission of higher-energy photons is primarily due to the decay of ^{236}Pu: 17.5-years of decay time was found to be bounding for all periods within and beyond 17.5 years.

The fuel density used in the applicant's shielding evaluation is derived based on the maximum fuel mass for 74 wt.% ^{238}Pu (450.1 g) and the fuel volume (97.7167 cm^3) calculated using the inner diameter of the primary capsule (1.112 in.) and length of the fuel (6.14 in.), resulting in a calculated fuel granule density of 4.606 g/cm^3.

An enrichment of 74 wt.% ^{238}Pu yields the largest source in terms of neutrons/second due to the higher induced fission neutron source from the larger quantity of ^{239}Pu. Because the neutron flux and, therefore, the neutron dose rate, is proportional to the source (as measured in neutrons/s), the 74 wt.% ^{238}Pu mixture yields the largest dose rate.

The total neutron source strength based on the specific neutron emission rate limit (SNER) of 11,000 n/s/g-^{238}Pu corresponds to 9.672×10^6 neutrons/s for three ALTB fueled capsule assemblies at 74 wt.% ^{238}Pu (=11,000 n/s/g-^{238}Pu × 879.24 g-^{238}Pu). The total neutron source calculated after a 10-day and 17.5-year decay are both above the allowable SNER. This exceedance is due to the amount of ^{17}O and ^{18}O present in natural oxygen and the greater (α, n) yield than ^{16}O. The actual ^{17}O and ^{18}O concentrations used in the PuO_2 powder production are controlled to lower values. Therefore, the neutron dose rate calculations in MCNP will use the total neutron source strength of 9.672×10^6 neutrons/s and the neutron spectra at 10-day decay.

The ANSI/ANS-6.1.1-1977, Neutron and Gamma-ray Flux-to-dose Rate Factors conversion factors were used to convert the calculated photon and neutron fluxes to dose rates. The staff used the ORIGEN module of SCALE Version 6.2.4 and the ENDF/B-VII.1 decay data for the confirmatory evaluations.

5.4 Shielding Model

The package configuration containing three ALTB-FCAs consists of the following items:

1. Type 304 stainless steel Cask.
2. Type 304L stainless steel CV.
3. Type 304L stainless steel Liner.
4. Graphite Filler Block (GFB).
5. Graphite Support Block (GSB) containing three ALTB-FCAs, and
6. Optional graphite felt, which is ignored for this shielding analysis.

Each ALTB-FCA is placed into symmetrically spaced holes bored axially into the GSB. The loaded GSB is overpacked inside the Liner, which is welded shut and then overpacked in the CV. The GFB is placed on top of the Liner and then the CV is welded shut. The CV is loaded in the Shipping Cask.

DOE PCP staff created MCNP models for each source configuration shown in Addendum 3, Figures 5-2 to 5-4. Dose rates were calculated at the positions (dose points) shown in Addendum 3 Figure 5-1 using flux tallies (F4).

5.5 Shielding Analysis Results

Dose rate results in the section of the SER are based on 450.1g PuO_2 per ALTB-FCA containing 2.0 ppm ^{236}Pu and decayed for 17.5 years, with a specific neutron emission rate (SNER) of 11,000 n/s/g-^{238}Pu, which is the bounding case for photon and neutron doses, respectively.

The package radiation level under NCT is estimated to 200 mrem/h at a point on the external surface of the package; consequently, the applicant's shielding evaluation is based on § 71.47(b) for transport by exclusive use.

Table 5-2 below compares the DOE PCP staff's calculated maximum dose rates for a single 9516 package loaded with three ALTB-FCA under NCT and HAC with the applicant's the dose rates listed in Addendum 3, Table 5-1.

Table 5-2. Staff's Calculated Maximum Dose Rates for Exclusive Use Shipment of a Single 9516 Package, in Comparison with the Dose Rates in Addendum 3

Normal Conditions of Transport (NCT)								
	Personnel Shield Surface(mrem/h)		Outer Surface of vehicle - bottom of the trailer bed (mrem/h)		2m from vehicle external Surface - trailer sidewall (mrem/h)		Normally occupied position in vehicle (mrem/h)	
	Add. 3	Staff	Add. 3	Staff	Add. 3	Staff	Add. 3	Staff
Photon	39.9	40.6	28.9	31.7	0.62	0.63	0.89	0.89
Neutron	150.8	151.7	109.1	103.0	1.24	1.27	1.75	1.78
Total	190.7	192.3	138.0	134.7	1.86	1.91	2.64	2.66
§71.47(b) limit	1000		200		10		2	

Hypothetical Accident Conditions (HAC), at 1m from package surface						
	Side (mrem/h)		Top (mrem/h)		Bottom (mrem/h)	
	Add. 3	Staff	Add. 3	Staff	Add. 3	Staff
Photon	6.12	6.1	7.38	7.3	5.04	5.2
Neutron	11.82	12.3	13.71	13.9	12.54	12.9
Total	17.94	18.4	21.09	21.2	17.58	18.0
§71.51 limit	1000		1000		1000	

Note - The bounding calculated dose rate under NCT at the "Normally occupied position in vehicle" exceeds 2 mrem/h, so dosimetry may be required per § 71.47(b)(4) if the measured dose rate exceeds 2 mrem/h at this location.

Table 5-3 below compares the DOE PCP staff's calculated maximum dose rates for a consignment of six 9516 packages loaded with three ALTB-FCA under NCT and HAC with the applicant's the dose rates listed in Addendum 3, Table 5-2.

Table 5-3. Staff Calculated Maximum Dose Rates for Exclusive Use Shipment of Six 9516 Packages, in Comparison with the Dose Rates in Addendum 3

Normal Conditions of Transport (NCT)						
	Outer surface of vehicle [a] (mrem/h)		2m from vehicle external surface [b] (mrem/h)		Normally occupied position in vehicle (mrem/h)	
	Add. 3	Staff	Add. 3	Staff	Add. 3	Staff
Photon	33.1	32.9	2.23	2.42	0.93	0.92
Neutron	109.4	112.8	4.33	4.42	1.89	1.94
Total	142.5	145.8	6.56	6.84	2.82	2.87
§71.47(b) limit	200		10		2	

Note - The calculated dose rate under NCT at the "Normally occupied position in vehicle" exceeds 2 mrem/h, so dosimetry may be required per § 71.47(b)(4) if the measured dose rate exceeds 2 mrem/h.

DOE PCP staff independently confirmed that the calculated dose rates for the bounding configurations are within the limits of §§ 71.47 and 71.51, except for the nearest normally occupied position (i.e., the truck cab), which exceeds the 2 mrem/h limit, so dosimetry may be required per § 71.47(b)(4) if the measured dose rate exceeds 2 mrem/h.

5.2 Evaluation Findings

Based on review of the statements and representations in Addendum 3, DOE PCP staff has reasonable assurance that the package shielding design continues to meet the requirements of 10 CFR Part 71, subject to transport by exclusive use only per § 71.47(b).

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 applicant performed an analysis-by-comparison of SC-12 with the three General Purpose Heat Source (GPHS) modules and eight product loading cans containing the GPHS fuel pellets or powder, with a limited number of sensitivity cases run to account for the differences in the geometry of the ALTB-FCA and GPHS modules, to demonstrate the SC-12 is bounded by the SARP.

DOE PCP staff reviewed the criticality safety evaluation described in Chapter 6 of the SARP and Addendum 3 for SC-12. Staff subsequently performed Monte Carlo analyses using the computer code MCNP6 Version 6.2 to independently confirm NCS under the most reactive conditions of the fissile material loading of up to three ALTB-FCA per package to confirm compliance with the requirements in §§ 71.55 and 71.59, under NCT and HAC.

6.1 Criticality Safety Design

The import-to-safety packaging components for criticality control are the Cask and CV: both items are Quality Category A (Ref SARP Table 9-1). The Cask provides confinement of the CV and fissile contents under NCT and HAC. The CV provides leaktight containment of the contents. There were no changes to Cask and CV designs for SC-12. The Liner, GSB, and GFB Block for SC-12 are Quality Category C items (Ref Addendum 3, Table 9-1): the Liner is credited with minimizing movement of the contents within the CV, the GSB is credited with minimizing movement of the ALTB-FCA within Liner, and the GFB is credited with minimizing movement of the Liner within the CV. The Cask, CV, and Liner are credited in the criticality evaluation with maintaining the geometry of the PuO_2 and preventing the PuO_2 content from combining into a more reactive configuration.

The ALTB-FCA consists of a primary (inner) capsule and a secondary (outer capsule). The inner capsule is 8.263 in. in length with a 1.366 in. outer diameter and a 0.127 in. wall thickness. The PuO_2 fuel length inside the primary capsule is approximately 6.14 in.

with a density approximately 4.6 g/cm^3. The outer capsule is 8.581 in. in length with a 1.67 in. outer diameter and a 0.127 in. wall thickness.

Up to three ALTB-FCA can be placed in a GSB, which is a 7.9 in. high, 5.62 in. diameter cylinder with chamfered edges. The GSB has three, 1.73 in. diameter holes, which are centered on a 1.59 in. radius, to house the ALTB-FCA. The GSB with ALTB-FCA is placed in a Liner and welded shut. The Liner is then loaded in the CV with a GFB (cylinder 3.38 in. height and 5.6 in. diameter) placed on top of the Liner, after which the CV is welded shut.

6.2 Fissile Contents

Each ALTB-FCA has up to 371.5 g of PuO_2 and fissile radioisotopes, Pu-239 and Pu-241, ranging from 7.9 to 23.9 wt. percent of the mass (Addendum 3, Table 1-1). The maximum fissile is 88.8 g per ALTB-FCA based on 23.9 wt. percent. Since up to three ALTB-FCA may be shipped in a single package, the maximum fissile mass is 266.4 g per package.

Although the bounding mass of PuO_2 in each ALTB-FCA is 371.5 g, for conservatism, the applicant used 450.1 g per ALTB-FCA (1350.3 g per package) as the bounding mass to evaluate SC-12. The fissile mass limit per ALTB-FCA used in the applicant's evaluation is therefore 107.6 g or 322.7 g per package.

6.3 Criticality Analysis Model

The criticality safety calculations performed in Addendum 3 were based on a semi-qualitative argument that the criticality evaluation for the bounding configuration in SARP conservatively bounds three ALTB-FCA for a single package and an array of packages.

The applicant used KENO V.a of the SCALE computer code package to model the geometry of the package, which includes the Cask, CV, Liner(s), and the PuO_2. The original KENO input files for the SARP calculations were used as the starting point for SC-12 and all cases use the SCALE 238-group ENDF-B-V cross section library for consistency with the original evaluation.

Single Package

The bounding configuration in the SARP criticality evaluation for a single package is for three General Purpose Heat Source (GPHS) modules consisting of 2215 g of PuO_2. The maximum k_{eff} value of 0.30312 occurs for 74 wt. percent Pu-238 with fully flooded package condition. For a single package with eight product cans containing 2100 g of PuO_2 powder at 74 wt. percent, the maximum k_{eff} value of 0.24450 also occurs with fully flooded package condition.

Although the ALTB-FCA PuO_2 mass of 1350 g per package is significantly lower than the masses of the GPHS modules (2215 g) and the eight product cans (2100 g) package configurations, the geometries are slightly different, so a simple comparison of fuel masses is not sufficient to demonstrate compliance with the regulatory limits. Therefore, the applicant performed a limited number of sensitivity cases to support the NCS basis for the ALTB-FCA configuration and to demonstrate the ALTB-FCA configuration is bounded by the SARP for original eight powder can model.

For the first case, the density of the PuO_2 powder in the configuration of eight powder cans was decreased from 5.7 g/cm^3 to 4.6 g/cm^3, while maintaining the same total mass of fuel (i.e., 2100 g) by increasing the height of the powder in the can.

For the second case, using the 4.6 g/cm^3 powder density, the fuel mass in the bottom four cans was increased to 1350 g to match the total ALTB-FCA mass, and the powder in the top four cans was replaced with water. Furthermore, the radius of the powder in the can was reduced to nearly the same as that for the ALTB-FCA and the height of the powder was increased to get a total mass of 1350 g.

Infinite Array
The infinite array of packages under HAC is the bounding configuration in the SARP criticality evaluation for three GPHS modules consisting of 2215 g of PuO_2. No NCT array cases were run because an infinite array of packages under HAC bounds NCT.

The applicant used a similar approach to the single package evaluation by running two sensitivity cases using the original powder can model from the SARP to demonstrate that the ALTB-FCA configuration is bounded by the GPHS configuration to demonstrate that the GPHS results bound those for the original powder can model after it has been slightly modified to simulate the ALTB-FCA configuration.

6.4 Summary of Results

DOE PCP staff confirmed by document review and analysis that SC-12, with three ALTB-FCA is bounded by the SARP criticality evaluation.

Table 6-1 below shows a comparison of Addendum 3 results for a single package analysis with DOE PCP staff's independent criticality safety analyses results.

Table 6-1 Criticality Safety Analyses Results for Single Package Evaluation

Configuration	k_{eff}	
	Addendum 3	**Staff**
Three GPHS modules [a]	0.30550	[e]
Eight powder cans [b]	0.24557	[e]
Eight powder cans [c]	0.23049	0.20970
Four powder cans [d]	0.24844	0.23012

[a] Original SCALE5 results from SARP Tables 6-8 (dry CV) and 6-9 (flooded CV).
[b] Original SCALE5 results from SARP Tables 6-10 (dry CV) and 6-11 (flooded CV). These cases use a 5.73 g/cc powder density.
[c] Sensitivity case for 4.6 g/cm^3 powder density to match the ALTB-FCA.
[d] Sensitivity case for 4.6 g/cm^3 powder density and 1350.2 g PuO_2 in the bottom four powder cans to match the total ALTB-FCA mass. The top four cans are filled with water, and the radius and height of the powder are nearly the same as that for the ALTB-FCA.
[e] Not calculated

Table 6-2 below shows comparison of Addendum 3 results for an infinite array of packages under HAC with DOE PCP staff's independent criticality safety analyses results.

Table 6-2 Criticality Safety Analyses Results for an Infinite Array under HAC

Configuration	PuO_2 mass (g)	k_{eff}	
		Addendum 3	**Staff**
Three GPHS modules [a]	2215.7	0.54340	[e]
Eight powder cans [b]	2100.0	0.52150	[e]
Eight powder cans [c]	2100.0	0.51051	0.45264
Four powder cans [d]	1350.2	0.42340	0.39225

[a] Original SCALE5 results from SARP Tables 6-12 (dry CV) and 6-13 (flooded CV)
[b] Original SCALE5 results from SARP Tables 6-14 (dry CV) and 6-15 (flooded CV). These cases use a 5.73 g/cc powder density.
[c] Sensitivity case for 4.6 g/cm^3 powder density to match the ALTB-FCA.
[d] Sensitivity case for 4.6 g/cm^3 powder density and 1350.2 g PuO_2 in the bottom four powder cans to match the total ALTB-FCA mass. The top four cans are filled with water, and the radius and height of the powder are nearly the same as that for the ALTB-FCA.
[e] Not calculated

6.5 Evaluation Findings

Based on review of the statements and representations in Addendum 3, DOE PCP staff has reasonable assurance that the package criticality safety design continues to meet the requirements of 10 CFR Part 71.

7.0 Operating Procedures

The SARP, as supplemented by Addendum 3, 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.

DOE PCP staff confirmed by document review of Addendum 3, Chapter 7, that operating procedures for SC-12 are clear and sufficient to assure that the package will be operated in a manner consistent with its evaluation for approval for compliance with 10 CFR 71.

The operating procedures include a step in Addendum 3, Section 7.1.3, Step 14 for independent verification that the maximum age of the PuO_2 content at the end of the shipment for SC-12 will not exceed 19.2 years for three ALTB-FCA, 32.6 years for two ALTB-FCA, and 84.5 years for one ALTB-FCA. DOE PCP staff confirmed this requirement is consistent with the thermal evaluation in Chapter 3 of Addendum 3.

The applicant also revised the operating procedures in the SARP and Addendum 1 to move the step(s) in Section 7.1.2 *Loading of Contents* to independently verify the identity and location of the contents loaded in a liner or FSO container(s) to an earlier step in the procedure. The SARP, Addendum 1, and Addendum 2 were also revised to correct the package surface temperature limit reference in Section 7.1.3, Step 6, to § 173.442 *Thermal limitations* and to remove a superfluous step in 7.2.1 *Receipt of Package from Carrier*, Step 8. Finally, the applicant revised the SARP and Addendum 2, Section 7.2.1, Step 11 to clarify that the spacing to the normally occupied space in the truck cab is measured from the external surface of the package instead of from the cargo container. DOE PCP staff reviewed and concurred with these improvements, corrections, and clarification.

7.1 Evaluation Findings

Based on review of the statements and representations in SARP Rev 5, Addendums 1 Rev 3, Addendum 2 Rev 1, and Addendum 3, 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, subject to the maximum age limits of the PuO_2 content at the end of the shipment for SC-12 as a condition in the CoC.

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 were no changes to the acceptance tests and maintenance for the basic components of the 9516 packaging for SC-12. The increased MNOP from 37.6 psig (SARP Table 3-2) to 98.3 psig (Addendum 3, Table 3-2) for SC-12 remains bounded by the 200 psig design pressure limit acceptance criteria for the CV.

The packaging components internal to the CV for SC-12: ALTB-FCA, Liner, GSB, and GFB are listed in Addendum 3, Table 1-2. The Liner and graphite blocks are classified in Addendum 3, Table 9-1 as minor-to-safety items (Q-Category C) and their safety functions are to restrain the ALTB-FCA within the Liner, and to restrain the Liner within the CV. The acceptance criteria for these items consist of visual and dimensional inspections, and material verification per the drawings listed Addendum 3, Appendix 1.3.2. The Liner, Graphite Support Block, and Graphite Filler Block are one-time-use items so there are no maintenance requirements for these components.

8.1 Evaluation Findings

Based on the review of the statements and representations in Addendum 3, 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 SARP, as supplemented by 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_0010_r1.pdf).

The new design drawings of the ALTB-FCA, Liner (11.16 in. high), GSB, and GFB (3.38 in. high) for SC-12 did not affect the existing QA Program of the packaging. The Quality Level for the components internal to the CV for this shipping configuration are all classified as Quality Level C items (Q-Cat C), as shown in Addendum 3, Table 9-1. The primary safety function of these components is to "restrict movement" of the ALTB-FCA or Liner within the CV under NCT. These components are credited in the shielding model to evaluate package dose rates under NCT but omitted from shielding model to evaluate package dose rates under HAC. DOE PCP staff finds the shielding model assumptions consistent with the applicant's Q-Cat-C classification of these components.

9.1 Evaluation Findings

Based on review of the statements and representations in Addendum 3, 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 changes to the CoC are required to implement Addendum 3 changes evaluated in this SER in CoC Rev.11.

- Packaging Description 5(a)(2)
  - Revise to "… The base plate of the cask is 14 inches by 12 inches by 1.5 inches that is welded to the cask body." (CoC page 2, 4th paragraph – editorial change)
  - Revise MNOP from "37.6 psig" to "98.3 psig (SARP Addendum 3)" (CoC page 3 3rd paragraph)
  - Revise as follows (CoC page 3, 4th paragraph)
    - Revise shipping configuration descriptions 1 through 6 and 8 to include 12.
    - Revise "… The various lengths of liners are shown in Figure 1-5 of the SARP" to "… The liner overall lengths vary from 5.00 inches to 11.16 inches depending on the authorized shipping configuration."
    - Revise "… The dimensions of the graphite filler blocks are shown in Figure 1-6 of the SARP" to "… The dimensions of the graphite support and filler blocks vary depending on the authorized shipping configuration."
  - Add packaging description for Shipping Configuration 12 (CoC page 3, after last paragraph):
    - Contents for Shipping Configuration 12 are packaged in a liner weldment (Drawing 805406) constructed of Type 304L stainless steel pipe. It has an outside diameter of 6 in. and a minimum wall thickness of 0.12 in. The liner top and bottom lids are both constructed of Type 304L material and are 0.5 in. thick each. The liner also has a ¼ in. diameter through-hole in the side wall to ensure the gas volume inside the liner communicates with the gas volume in the CV and prevents any pressure buildup in the liner. This configuration requires a graphite support block (Drawing 805408) that will hold up to three Advanced Long Term Battery (ALTB) fueled capsule assemblies (FCA) and a graphite filler block (Drawing 805407) that rests on top of the liner in the CV, and the option to use ½ in. thick

pieces of graphite felt above and below the graphite support block for additional dunnage in the liner. The internal component arrangement in the CV for Shipping Configuration 12 is shown in Figure 1-4 of SARP Addendum 3.

- Drawings 5(a)(3) add the following drawings:
    - Add R1034-0011-EB, Rev. 2, *ALTB Fueled Capsule Assembly* (1 Sheet)
    - Add 805406, Rev. 1, *Liner, 11.16 in. high* (2 Sheets)
    - Add 805407, Rev. 0, *Graphite Filler Block, 3.38 in. high* (1 Sheet)
    - Add 805408, Rev. 1, *Graphite Support Block* (1 Sheet)
- Contents, Type and Form of Material 5(b)(1), (CoC page 5)
    - Revise Shipping Configuration descriptions 1 through 6 to include 12 in the heading and first and second paragraphs (3 places):
        - "Shipping Configurations 1 through 6 and 12:"
        - "The contents for Shipping Configurations 1 through 6 and 12 …"
        - "… The composition of the plutonium shipped in the package for Configuration 1 through 6 and 12 are shown in Table 1."
    - Add "… For Shipping Configuration 12, there is an additional limit for ^{234}U not to exceed 10 wt.% and decay heat limit of 133.3 W per ALTB-FCA and 399.9 W per CV for three ALTB-FCA." to the 1st paragraph.
- Contents, Type and Form of Material 5(b)(1), (CoC page 7)
    - Revise Table 1 to include Shipping Configuration 12 and Table Note 6.
        - "Shipping Configurations 1-6 & 12 [6]" (first row)
        - Add "… and the limits in Table 1-1 of Addendum 3 apply to the initial composition for Shipping Configuration 12 conversion to oxide." (NOTE)
        - Add Table Note "6. Shipping Configuration 12 is also limited ≤ 10 wt.% of ^{234}U."
- Contents, Maximum Quantity of Material per Package 5(b)(2), (CoC Page 7)
    - Revise 1st paragraph to "… Descriptions of the 12 shipping configurations from the SARP and SARP Addendums 1, 2, and 3 are summarized below: "
- Contents, Maximum Quantity of Material per Package 5(b)(2), (CoC Page 10)
    - Add Shipping Configuration 12: "**Shipping Configuration 12— ALTB Fueled Capsule Assembly (FCA)**. An ALTB-FCA consists of granular PuO_2 fuel and a hollow spacer in a double encapsulated weldment as shown in Figure 1-3 of SARP Addendum 3 and Drawing R1034-0011-EB. All capsule material is fabricated from Haynes® Alloy 25 (L 605). The maximum weight of an ALTB-FCA is 1800 g (3.97 lb.) where the bounding fuel is 371.5 g of

PuO_2 granules. Up to three ALTB-FCA are inserted in a Graphite Support Block (Drawing 805408), which in-turn is loaded in a vented, stainless steel Liner (Drawing 805406) weldment. Note – it is optional to install ½ inch of graphite felt above and below the graphite support block in the Liner. The Liner is then loaded in the bottom of the 9516 CV with a Graphite Filler Block (Drawing 805407) placed on top of the Liner prior to welding the CV closure. The nominal decay heat is 133.3 W per ALTB fueled capsule assembly, or 399.9 W total per package for three ALTB fueled capsule assemblies."

- "Conditions 5(d) (CoC page 11):
    - (2) revise to add fuel age limits "… The maximum allowable age of processed PuO_2 at the end of the shipping period for Shipping Configuration 12 is 84.5 years for one ALTB-FCA, 32.6 years for two ALTB FCA, and 19.2 years for three ALTB-FCA per CV (SARP Addendum 3)."
    - (3) revise to add SARP Addendum 3 "… under the conditions provided in Chapter 7 of the SARP and SARP Addendums 1, 2, or 3,"
    - (8) revise to add SARP Addendum 3 "… as supplemented by SARP Addendums 1, 2, and 3."
    - (10) revise to "Revision 10 of this certificate may be used until July 31, 2024."
- Supplements 5(e) (CoC page 12):
    - (6) revise to update SARP revision "Safety Analysis Report for Packaging (SARP) for the 9516 Package, R1033-0062-ES, Revision 5, February 2023."
    - (7) revise to update SARP Addendum 1 revision "Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 1, R1033 0065 ES, Revision 3, February 2023"
    - (8) revise to update SARP Addendum 2 revision "Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 2, R1033 0067 ES, Revision 1, February 2023
    - (9) add SARP Addendum 3 "Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3, R1033 0066 ES, Revision 0, February 2023"

Conclusion

Based on the statements and representations contained in SARP Addendum 3, Rev. 0 and minor revisions in SARP Rev. 5, SARP Addendum 1, Rev. 3, and SARP Addendum 2, Rev 1, and the conditions listed above, DOE PCP staff concludes that the package design has been adequately described and evaluated, and the Model 9516 package continues to meet the requirements of 10 CFR Part 71.

References

[1] *CCN 251733 9516 SARP Addendum 3 Trans Ltr.pdf*, Email Carl Friesen to Shuler, June 9, 2022.

[2] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3,* R1033-0066-ES, Rev. 0a, dated June 2022 (uploaded June 9, 2022)

[3] *Docket 22-36-9516 Technical Review Complete*, Memorandum Shuler to Friesen, September 9, 2022.

[4] *FW: CCN 252371 9516 SARP Addendum 3 Q1*, Email Carl Friesen to Shuler, October 5, 2022.

[5] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3,* R1033-0066-ES, Rev. 0b, dated September 2022 (uploaded October 5, 2022).

[6] *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 4, dated May 2021, Errata (uploaded October 5, 2022).

[7] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 1*, R1033-0065-ES, Rev. 2, dated October 2021, Errata (uploaded October 5, 2022).

[8] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 2*, R1033-0067-ES, Rev. 1, dated April 2021, Errata (uploaded October 5, 2022).

[9] *Docket 22-36-9516 Additional Comment*, Memorandum Shuler to Friesen, October 18, 2022.

[10] *FW: CCN 253014 9516 SARP Addendum 3 Q3*, Email Carl Friesen to Shuler, February 9, 2023.

[11] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3,* R1033-0066-ES, Rev. 0c, dated January 2023 (uploaded February 9, 2023).

[12] Docket 22-36-9516 Technical Review Complete, Memorandum Shuler to Friesen, February 9, 2023.

[13] *FW: CCN 253372 9516 SARP Trans Ltr Addendum 3 ect*, Email Carl Friesen to Shuler, March 12, 2023.

[14] *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 5, dated February 2023.

[15] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 1*, R1033-0065-ES, Rev. 3, dated February 2023.

[16] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 2*, R1033-0067-ES, Rev. 1, dated February 2023.

[17] *Safety Analysis Report for Packaging (SARP) for the 9516 Package, Addendum No. 3*, R1033-0066-ES, Rev. 0, dated February 2023.