U.S. DEPARTMENT *of* ENERGY

Office of Environmental Management

*DOE Packaging Certification Program*

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

## Docket No. 25-05-9516

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review and confirmatory analysis of the application submitted for the DOE Idaho Operations Office (ID) for amendment and renewal 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 October 17, 2024, DOE-ID requested amendment and renewal of DOE CoC No. 9516 Revision 13. The request was supported by an application which consisted of a consolidated Safety Analysis Report for Packaging (SARP) for the 9516 Package, Rev. 6a. [2]

The changes in the consolidated SARP are described in detail in SARP Appendix 1.3.5, *Assessment of Changes to the 9516 Package Safety Analysis Report for Packaging for Recertification*. The appendix addresses thirteen items for change in the SARP, the reason for each change, and the basis for demonstrating how each change continues to meet the applicable requirements in 10 CFR Part 71. The major changes included:

- Incorporation of three SARP Addendums (that is, the CoC Rev 13 supplements),
- Minor revisions to the currently approved Shipping Configurations 2, 3, and 7 through 11,
- Addition of two new shipping configurations for Lightweight Radioisotope Heater Unit (LWRHU) materials - Clad Pellets (Shipping Configuration 13) and Assemblies (Shipping Configuration 14),
- Update to the maximum normal operating pressure (MNOP), shielding, and criticality calculations, and
- A new tie-down analysis for transport via a commercial trailer.

DOE PCP staff reviewed the initial SARP Rev. 6a submittal and issued three technical review questions (Q1s) on April 29, 2025, to the revised shielding evaluation.[3] The applicant responded to the Q1s on May 29, 2025, with SARP Revision 6b page-changes [4-5] and the staff reviewed and accepted the responses pending implementation in the final SARP. On June 9, 2025, the applicant submitted the final consolidated SARP Revision 6 [6], and the staff reviewed and confirmed that the proposed changes, with some editorial corrections, were properly implemented in the SARP.

Based on the statements and representations in SARP Revision 6, and DOE PCP staff's independent confirmatory review and evaluation described in this SER, the staff finds this amendment and renewal request acceptable and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met subject to the Conditions in the CoC.

## EVALUATION

The following sections in this SER document DOE PCP staff's chapter-by-chapter independent review and evaluation of the design and performance of the package for safety and regulatory compliance in general information and drawings, structural, thermal, containment, shielding, criticality safety, operating procedures, acceptance tests and maintenance program, and quality assurance (QA) as demonstrated in the final consolidated SARP Rev. 6, to confirm it contains a sufficient safety basis for approval of the package design to the requirements of 10 CFR Part 71.

Subsequent references to "SARP" in this SER are to the final consolidated SARP Rev. 6 [6], unless stated otherwise.

## 1.0 General Information

The objective of this review is to verify that the package design has been described in sufficient detail to provide an adequate basis for its evaluation under 10 CFR Part 71. The design must be shown on engineering drawings that can be referenced in the certificate of compliance.

### 1.1 Introduction

The Model 9516 package is a Type B fissile package used by DOE for shipment of numerous configurations of plutonium dioxide heat source material in any solid form. The package design is currently certified by DOE CoC No. 9516, Rev. 13, which expired January 31, 2025, but is under timely renewal per § 71.38(b). The applicant submitted a consolidated SARP per § 71.38(c) for amendment and renewal of the CoC.

The Criticality Safety Index (CSI) for the package remains 0.0 as demonstrated in SARP Chapter 6.

SARP Appendix 1.3.5, *Assessment of Changes to the 9516 Package Safety Analysis Report for Packaging for Recertification*, addresses thirteen items for change in the SARP, the reason for each change, and the basis for demonstrating how each change continues to meet the applicable requirements in 10 CFR Part 71.

### 1.2 Package Description

The package is shown on Figure 1-1. *9516 Package*, in the SARP and Figure 1 in the CoC. The packaging components and components inside the containment vessel (CV) for each shipping configuration are listed in SARP Table 1-4, *9516 Package Content Shipping Configurations*, with their respective drawings.

#### 1.2.1 Packaging

There were no design changes to the primary packaging components, which consist of a personnel shield (cask frame), cask (body and lid), and containment vessel (CV). The CV is a one-time use welded vessel. The packaging is sufficiently and thoroughly described in SARP Section 1.2.1, *Packaging*. The internal dimensions of the CV are approximately 6.14 in. diameter and 15.18 in. height (SARP Figure 1-4. *Containment Vessel Dimensions*).

### 1.2.2 Contents

The plutonium dioxide ($PuO_2$) contents of the package are shipped in fourteen discrete shipping configurations – twelve of the fourteen configurations are currently authorized in the CoC. Two new configurations were added to the SARP and described in Section 1.2.2.4 of this SER. The principal isotope for each configuration is $^{238}$Pu in solid form (for example, powder, pellets, granules, etc.).

The initial radioisotopic composition and limits for each shipping configuration, including two new configurations, are listed in SARP Table 1-1, *Plutonium Initial Isotopic Limits.* The maximum activity for the package is 15,930 Ci. The specific neutron emission rate, decay heat limit, and fuel density for each configuration are listed in SARP Table 1.2 *Maximum Specific Neutron Emission Rate and Wattage, and Approximate Fuel Density for Plutonium Dioxide in the 9516 Package*. The maximum decay-heat limit for the package is 500 watts.

The SARP and this SER uses the term “payload” to refer to the radioactive contents loaded in one or more specialized containers or devices for end use or handling. The shipping configuration refers to the arrangement of the payload and dunnage in the CV. Dunnage is required to prevent movement of the payload in CV. Payload containers and devices may also include internal dunnage to prevent movement of the payload.

All shipping configurations are described in detail in SARP Sections 1.2.2.1.1 through 1.2.2.1.14 and listed in Table 1-3 *Internal Components for Positioning the Contents inside the CV*.

Because of helium generation from alpha-decay of $^{238}$Pu, the applicant’s internal pressure calculations of the CV considers the cumulated helium in product cans and powder cans that may be sealed (welded) and stored prior to being loaded into the CV, in addition to the helium gas that could be generated during a one-year period after the CV is sealed (welded), or in the case of Shipping Configurations 9-11, up to a three-year period. The package shipment must be completed within a specified period after the $PuO_2$ is processed to ensure the CV pressure limit under NCT is not exceeded. The conditions and age limits for each shipping configuration are listed in SARP Table 3-12 *Maximum Allowable Age of Fuel*.

#### 1.2.2.1 Changes to Authorized Shipping Configuration Description or Arrangement

The applicant revised the names of three shipping configurations for consistency with the SARP Addendums and accuracy of the material descriptions, and made this name change throughout the SARP to distinguish fueled clads (FC) from fueled capsule assembly (FCA).

- Shipping Configuration 1 “GPHS FCA” revised to “GPHS FC”,
- Shipping Configuration 8 “GPHS FCA with ORNL Plutonium Dioxide ($PuO_2$)” revised to “GPHS FC with ORNL Plutonium Dioxide ($PuO_2$)”, and
- Shipping Configuration 12 “ALTB fueled capsule assembly” revised to “ALTB FCA.”

The applicant revised the following shipping configurations to provide additional loading arrangement options for reduced payloads:

- *Shipping Configuration 2 - GPHS Graphite Impact Shell (GIS)* – The CoC authorizes a max. payload of four GPHS GISs. Each GPHS GIS is packaged in a product can, with dunnage. A max. of two product cans then overpacked in a 5.75-in.-tall, vented liner (Drawing 756182). A max. of two liners may be loaded in the CV, with dunnage. For a reduced payload of two GPHS GISs, additional dunnage may be used in the form of a 5.63 in.-tall graphite filler block (Drawing 756183, Item 3) in the space normally occupied by the second liner.

  The applicant revised SARP Section 1.2.2.1.2., to add the option of using an empty 5.75-in.-tall, vented liner as additional dunnage instead of the graphite filler block for a reduced payload arrangement of two GPHS GISs. This option increases the void volume inside the CV, and, since the liner is vented, improves the margin of safety with respect to internal CV pressure and gas generation.

- *Shipping Configuration 3 - GPHS Module* – The CoC authorizes a max. payload of two GPHS Modules. Each GPHS Module is packaged in 5.00 in.-tall, vented liner (Drawing 756181) with dunnage. A max. of two liners may be loaded in CV, with dunnage. The liners are separated in the CV by a 4.88 in.-tall graphite filler block (Drawing 756183, Item 2).

  SARP Section 1.2.2.1.3., was revised to add three options for shipping a reduced payload of a single GPHS Module. The first option is to use another 4.88 in.-tall graphite filler block for dunnage in the space normally occupied by the second liner. The second option is to use an empty 5.00-in.-tall, vented liner as dunnage. The third option is to package the GPHS Module in a 5.75-in.-tall, vented liner, with dunnage, and load the CV with the taller liner, use an empty 5.75-in.-tall, vented liner as dunnage, and separate these liners with a 3.38-in.-tall graphite filler block (Drawing 756183, Item 1). The first option marginally decreases the void volume in the CV, the second option increases it, and the third option increases it even more. Since the liners are vented, the second and third options improve the safety margin with respect to internal CV pressure and gas generation. The weight of these optional shipping configurations for shipment of a single GPHS Module payload is bounded by the weight of the currently authorized payload.

- *Shipping Configuration 9 — Large Containers with Plutonium Dioxide Powder* - The CoC authorizes a max. payload of two large containers with a max. of 453 grams/each of $PuO_2$ powder. Each large container is overpacked in large radiography can. Each can, with dunnage, is loaded in the CV.

  SARP Section 1.2.2.1.9., was revised to add an option for shipping a reduced payload of a single large container payload in a large radiography can, with no additional dunnage required. This option increased CV void volume by the volume of the large radiography can.

- *Shipping Configuration 10 — Medium Overpack Containers and Small Containers with Plutonium Dioxide Powder* - The CoC authorizes a max. payload of four small containers with a max. of 194 gram/each of $PuO_2$ powder. Each small container may be overpacked in either a small radiography can or overpacked in a nested arrangement of a medium overpack container and medium radiography can. The radiography cans are loaded in the CV, with dunnage. The radiography cans are arranged with dunnage in three spaces within the CV (top, middle, bottom), with the two small cans in the top space, with one medium can in the middle space, and another in the bottom space of the CV. For reduced payloads, two small cans remain in the top space, only dunnage in the middle space, and a medium can in the bottom space.

  SARP Section 1.2.2.1.10., was revised to add second and third reduced payload options. The second option has two small cans positioned in the top space, a medium can in the middle space, and only dunnage in the bottom space of the CV. The third option has two small cans positioned in the top, and only dunnage in the middle and spaces of the CV, that is, no medium cans in the CV. Only the third option changes the CV void volume – it increased it by the by the volume of the medium radiography can.

- *Shipping Configuration 11 – Medium Overpack Containers with Plutonium Dioxide Powder* - The CoC authorizes a max. payload of three small containers with a max. of 194 gram/each of $PuO_2$ powder. Each small container is overpacked in a nested arrangement of a medium overpack container and medium radiography can. Three radiography cans are loaded in the CV, with dunnage. The radiography cans are arranged with dunnage in three spaces within the CV (top, middle, bottom).

  SARP Section 1.2.2.1.11., was revised to add two reduced payload options – a single small container or two small containers, with each small container overpacked in a nested arrangement of a medium overpack container and medium radiography can. For the single small container payload option, the medium radiography can is positioned in any of three spaces in the CV, with dunnage. For the two small container payload option, each medium radiography can is positioned in any two of three spaces in the CV, with dunnage. Both options increase the void volume in the CV by one or two by the volume of the medium radiography can.

### 1.2.2.3 Changes to Authorized Contents

The applicant increased the max. $^{238}Pu$ limit for Shipping Configuration 7 payload and to authorize shipment of $PuO_2$ powder from other sources than ORNL for Shipping Configuration 8.

- *Shipping Configuration 7 - FSO Container* - The CoC authorizes a max. payload of

175 grams of ORNL $PuO_2$ powder in a capsule or powder can. Each capsule or powder can is packaged in an FSO Container. A max. of two FSO Containers are loaded in the CV, with dunnage.

SARP Section 1.2.2.1.7., was revised to allow $PuO_2$ powder from other sources than ORNL if the powder meets SARP Table 1-1 *Plutonium Initial Isotopic Limits*. Table 1-1 was also revised for this payload to increase the max. $^{238}$Pu percentage from 92% to 94%, because of the potential for higher $^{238}$Pu yields based on available reactor positions. In addition, SARP Table 1-2 *Maximum Specific Neutron Emission Rate and Wattage, and Approximate Fuel Density for Plutonium Dioxide in the 9516 Packag*e for the payload was increased ease the max., specific neutron emission rate (NER) for this payload is increasing from 24,000 n/s/g-$^{238}$Pu to 30,000 n/s/g-$^{238}$Pu due to the higher percentage of $^{238}$Pu. The change does not affect the decay heat rate limit and the payload weight limit but does require an evaluation of the effect on radiation shielding and nuclear criticality safety.

- *Shipping Configuration 8 — GPHS FC with ORNL Plutonium Dioxide* - The CoC authorizes a max. payload of 1,000 grams of ORNL $PuO_2$ powder in a max. of five GPHS FCs, packaged in product can assemblies. A max. of two product can assemblies are loaded in a 5.75-in.-tall, vented liner, with dunnage.

  SARP Section 1.2.2.1.8., was revised to allow $PuO_2$ powder from sources other than ORNL if the powder meets SARP Table 1-1 *Plutonium Initial Isotopic Limits*.

#### 1.2.2.4 New Shipping Configurations

The applicant added two new shipping configurations to authorize use of the package for shipment of $PuO_2$ Lightweight Radioisotope Heater Unit (LWRHU) Fuel Pellets and Assemblies, as described in SARP Sections 1.2.2.1.13, *Shipping Configuration 13 — LWRHU Clad Pellets*, and 1.2.2.1.14, *Shipping Configuration 14 — LWRHU Assemblies*.

- *Shipping Configuration 13 — LWRHU Clad Pellets* - The CoC would authorize a max. payload of 144 LWRHU Clad Pellets. Each pellet contains 2.670 ± 0.01 g of $PuO_2$, with the plutonium being $\geq 79\%$ $^{238}$Pu (SARP Table 1-1), with a density of 9.614 g/cm$^3$ (SARP Table 1-2), a nominal wattage of 1.1 W and a maximum wattage of 1.2 W per pellet. Each LWHRU fuel pellet is defined by SARP Ref. 1.31, Drawing 26Y-318192, and has a maximum diameter of 6.35 mm (0.25 in.) and maximum length of 9.80 mm (0.39 in.).

  Each LWRHU fuel pellet is encapsulated in a Clad Body Assembly (CBA), which consists of a Clad Body Subassembly (SARP Ref. 1.32, Drawing ORC13003) and Closure Cap (SARP Ref. 1.34, Drawing ORC13009), all constructed from platinum-30 rhodium (Pt-30 Rh) alloy. The Clad Body Subassembly consists of a Clad Body and Vent Cap Assembly. The CBA max. length is 12.85 mm (0.51 in.) and a max. outer diameter of 8.65 mm (0.34 in.). To protect the CBA, the Vent Cap Assembly includes a blind hole and recess for Frit made of a pressed and sintered disk of platinum powder (SARP Ref 1.36, Drawing ORC13005). After the CBA is loaded, welded closed, decontaminated, and leakage tested, the vent is activated by drilling a small hole (nominally 0.635 mm dia.) through the Vent Cap Assembly to the blind hole (Ref. *LWRHU Fueled Capsule*, Drawing 26Y-318191, Rev. C). These features prevent over pressurization and a controlled release of helium gas generated from the decay of $PuO_2$ in the CBA.

A max. of eighteen CBA are installed in a single Clad Dunnage Assembly (SARP Appendix 1.3.2, Drawing 1027426) or single Welded Can Clad Dunnage Assembly (SARP Appendix 1.3.2, Drawing 1042469), depending on the end use of the CBA and subsequent operation. Both clad dunnage assemblies are constructed of stainless steel, with minor dimensional differences in design. Each dunnage assembly consists of two threaded carriers ("Dunnage Threaded"), each holding nine CBAs, that are joined by a spacer ("Dunnage Joint") to form a stack of eighteen CBA in the respective dunnage assembly. The Welded Can Clad Dunnage Assembly also includes end caps on the assembly.

Next, each clad dunnage assembly, with its eighteen CBAs, is packaged in either a threaded or welded stainless steel (SS) Product Can. The Clad Dunnage Assembly (Type 304 SS) is packaged in a 304 stainless steel threaded (closure) Product Can per SARP Appendix 1.3.2, *$PuO_2$ Powder Can Set*, Drawing 756186, which is the same 2-in dia. by 4.25-in. tall can design authorized for use with Shipping Configurations 1, 2, 4, and 8. The Welded Can Clad Dunnage Assembly (316L SS), with its eighteen CBAs, are packaged in a 304 or 304L SS welded Product Can per SARP Appendix 1.3.2, *Cylinder Product Can*, Drawing 756180, which is the same 2-in dia. by 4.31-in. tall can design authorized for use with Shipping Configurations 1, 2, 4, and 8.

At this point the subsequent packaging and loading steps, secondary containers, and dunnage are the same as Shipping Configurations 1, 2, 4, and 8, that is, up to four product cans are installed in the recesses of a graphite support block (Drawing 756186), then overpacked in into a 5.75-in.-tall, vented liner (Drawing 756182).

For loading in the CV, two 5.75-in.-tall, vented liners are placed into the CV with a 3.38-in.-tall graphite filler block (Drawing 756183, Item 1) between the liners as dunnage, as shown in SARP Figure 1-34. *Typical Loading Arrangement with Eight Product Cans in a CV*.

The max. payload therefore consists of 144 LWRHU Clad Pellets, including their CBAs – based on eighteen CBAs per Product Can, eight Product Cans per liner, and two liners per CV. The max. payload weight including dunnage and CV is 71.3 lb., which is bounded by the max. weight of 72.2 lb. for Shipping Configuration 3. The max. heat load is 172.8 W.

For a reduced payload configuration of only one liner per CV, that is, 72 LWRHU

Clad Pellets, a 5.63 in. tall graphite filler block (Drawing 756183, Item 3) is used in place of the second liner.

- *Shipping Configuration 14 —LWRHU Assemblies* - The CoC would authorize a max. payload of 40 LWRHU Clad Pellets. Each LWRHU Fuel Pellet is encapsulated in a Clad Body Assembly (CBA), per SARP Ref. 1.32, Drawing ORC13003.

  Each CBA is then packaged in an Aeroshell Assembly as defined in SARP Ref. 1.38, Drawing 818506. The CBA is nested within three pyrolytic graphite insulator bodies (concentric cylinders) that are capped at both ends, then overpacked in the Aeroshell Body. To close the assembly, the Aeroshell End Cap is secured (bonded) to the Aeroshell Body with adhesive. The Aeroshell Body and End Cap are fabricated from fine-weave pierced fabric (FWPF), which is the same material used for a similar application in Shipping Configurations 2 and 3. The Aeroshell Assembly is approximately 31.95 mm (1.26 in.) high with an outside diameter of 25.95 mm (1.02 in.), and has a maximum weight of 42.0 g.

  Next, Aeroshell Assemblies are loaded in the Packaging Organizer Assembly (POA) (SARP Appendix 1.3.2, Drawing 1027425), which consists of a Base, nine stackable Trays, a Top Spacer, and a Thumb Screw Weldment. The Base and Top Spacer are dunnage for the POA and installed with the POA in the CV. Each Tray has the capacity to hold ten Aeroshell Assemblies, which are loaded in the top side of the Tray, and a thru-hole in the center of each tray for the Thumb Screw Weldment. The bottom side of the Tray includes recesses that fit over Aeroshell Assemblies in the next Tray down and a slot for housing a hex nut, which is used in the bottom tray to receive the threaded end of the Thumb Screw Weldment and fasten the POA together. For populating the POA, the bottom four Trays are loaded with Aeroshell Assemblies (40 total Aeroshell Assemblies) and the top five remaining "empty" Trays are for dunnage. Even though the POA capacity is 80 Aeroshell Assemblies (top Tray is always empty), the max. number evaluated in the SARP is 40 Aeroshell Assemblies. The Trays are fabricated from 6061-T6 aluminum, the Base and Thumb Screw Weldment are 304L SS, and the Top Spacer is graphite.

  For loading the payload in the CV, the Base (SARP Appendix 1.3.2, Drawing 1040139) is installed first, then the POA, and last the graphite Top Spacer (SARP Appendix 1.3.2, Drawing 1040136), as shown in SARP Figure 1-35, *Packaging Organizer Assembly*.

  The max. payload therefore consists of 40 LWRHU Clad Pellets, including their CBAs and Aeroshell Assemblies – based on 40 Aeroshell Assemblies in a single POA loaded in the CV. The max. payload weight, including dunnage and CV, is 70.8 lb., which is bounded by the max. weight of 72.2 lb. for Shipping Configuration 3. The max. heat load is 48 W.

#### 1.2.3 Special Requirements for Plutonium

Each package contains plutonium in excess of 0.74 TBq (20 Ci); therefore, the applicant restricts the payload to plutonium dioxide in any solid form, per § 71.63.

#### 1.2.4 Operational Features

The applicant revised SARP Section 1.2.4, *Operational Features*, to add additional detail for loading and unloading the CV from the cask and liners from the CV using the threaded holes in the top of the items.

### 1.3 Drawings

The list of packaging components, secondary containers, and dunnage are listed in SARP Section 1.3.2, *Drawings of the 9516 Package*. This list was revised and expanded to incorporate drawings and drawing revisions authorized in DOE CoC Rev 13 based on the approved SARP supplements, and to add seven new drawings for Shipping Configurations 13 and 14. In addition, SARP Table 1-4, *9516 Package Content Shipping Configurations* identifies each drawing and item number/part required for each shipping configuration.

### 1.4 Conclusion

Based on review of the statements and representations in the consolidated SARP, DOE PCP staff concludes that the package design has been described in sufficient detail to provide an adequate basis for its evaluation relative to the regulatory requirements in 10 CFR 71.

### 2.0 Structural Evaluation

The objective of this review is to verify that the structural performance of the package design has been adequately evaluated for the tests specified under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

DOE PCP staff reviewed the changes in Chapter 2 of the SARP to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- review the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11,
- review the structural performance of the package for the two new Shipping Configurations 13 and 14,
- Review the effect of increasing to the maximum normal operating pressure (MNOP), and
- Review the new tie-down analysis in SARP Appendix 2.12.3, for the option transport of the package via a commercial trailer.

### 2.1 Description of Structural Design

The applicant did not request any changes to the primary packaging components for the package structural design as described in SARP Section 2.1, *Description of Structural Design*, which consists of a personnel shield (cask frame), cask (body), and containment vessel (CV).

The content loading configuration descriptions in SARP Section 2.1 were updated to incorporate previously approved SARP Addenda 1, 2 and 3, revised options for reduced payloads, and updated to add the loading configurations for Shipping Configurations 13 and 14.

The reduced payload options for Shipping Configurations 2, 3, and 9 through 11 results in less payload mass and increases the free volume in the CV for most configurations; therefore, these changes do not affect the structural evaluation of the package.

Incorporation of SARP Addenda 1, 2 and 3, for Shipping Confirmations 7 through 12, does not affect the structural evaluation of the package.

The use of $PuO_2$ powder from sources other than ORNL for Shipping Configurations 7 and 8 are still bounded by the same radioisotopic and payload mass limits as the ORNL material; therefore, these changes do not affect the structural evaluation of the package.

The max. payload weight, which includes the dunnage and CV weight, for Shipping Configurations 13 or 14 is bounded by the max. payload weight of 72.2 lb. for Shipping Configuration 3 (Ref SARP Table 2-3, *CV Assembly Weights*). The max. payload weight for Shipping Configuration 13, *LWRHU Clad Pellets,* and Shipping Configuration 14, *LWRHU Assemblies*, are of 71.3 lb. and 70.8 lb., respectively. The design and configuration for these new shipping configurations are sufficiently like the previously approved Shipping Configurations 1 through 12 to conclude that Shipping Configurations 13 and 14 are bounded by the existing structural analysis of the package.

### 2.1.1 Design Criteria

The Model 9516 package is a Type B(U)F package design; therefore, the maximum normal operating pressure (MNOP) may not exceed 100 psig per the "*Package*" definition in § 71.4.(3). The design pressure of the CV is 200 psig at a design temperature of 600 ºF, per SARP Section 2.3.1, *Fabrication*.

The applicant revised the structural analysis in SARP Section 2 to increase the bounding MNOP from 50.3 psig (65.0 psia) to 98.3 psig (113.0 psia) and demonstrate that the CV has sufficient structural integrity to satisfy the design loading stress intensity limits of the ASME Boiler and Pressure Vessel Code (BPVC), Section III, Division 1, Subsection NB. The increased MNOP was reviewed and approved in SARP Supplement 3 (CoC 9516 Rev. 11).

SARP Section 2.1.2, *Design Criteria* was revised to increase the MNOP of the CV from 50.3 psig (65.0 psia) to 98.3 psig (113.0 psia), except for Shipping Configurations 7 and 14 which have an MNOP of 35.3 psig (50.0 psia). This change was made to account for helium gas that may accumulate in a secondary container or CV from the time the payload was first sealed in it, in addition to accumulation in the CV under the § 71.71(c)(1) heat condition for one year. This change to the MNOP calculation accounts for gases (argon and helium) initially present prior to loading in the package for shipment.

For Shipping Configurations 7 (FSO Container) and 14 (LWRHU Assemblies), the lower MNOP, 35.3 psig (50.0 psia), accounts for potential off-gassing of organic components, such as, the O-rings in the FSO Containers for Shipping Configuration 7, and adhesive used on the Aeroshell Assemblies in Shipping Configuration 14, that could occur under HAC thermal condition, as discussed in Chapter 3 of the SARP. The structural evaluation performed in Chapter 2 of the SARP was therefore updated using the bounding MNOP of 98.3 psig (113.0 psia), and demonstrated that the CV has sufficient structural integrity to satisfy the design loading stress intensity limits in ASME Boiler and Pressure Vessel Code (BPVC), Section III, Division 1, Subsection NB. The evaluation and the results are documented in SARP Appendix 2.12.10. As shown in Appendix 2.12.10 and its Attachment 2 for CV NCT load combinations, Attachment 3 for CV HAC load combinations, and Attachment 4 for HAC thermal condition, the stresses on the CV from the combined loadings of NCT or HAC conditions with the bounding MNOP are less than the corresponding service limits as specified in the ASME BPVC, Section III, Division 1, Subsection NB, with positive margin of safety (MOS). Although the lowest calculated MOS is only 1.52E-03, which occur under NCT conditions at the junction between the CV shell and the end closure plates, the calculations in Appendix 2.12.10 conservatively use the bounding MNOP that is much larger than the pressure for each individual content and conservatively combine the maximum stress intensity from the free drop with the maximum stress intensity due to pressure. Therefore, the CV has sufficient structural integrity to sustain the loadings from the bounding MNOP, in combination with reduced external pressure, the NCT drops, the HAC impacts, or the HAC fire.

The applicant added SARP Appendix 2.12.13, *Shipping Configuration 9 Spacer Weldment NCT and HAC Buckling Assessment* from SARP Addendum No. 2, Appendix 2.12.2, without changes.

## 2.2 Materials

The applicant did not request any changes to the materials authorized for use in Shipping Configurations 1 through 12, except for Shipping Configuration 3, *GPHS Module*, for an optional single payload configuration. For Shipping Configuration 3, each GPHS module is typically packaged in a 5.00-in.-tall liner; however, the applicant requested the option to the module in a 5.75-in.-tall liner, with Grade WDF Felt Cushion (Drawing 756187) placed in the top and bottom of the taller liner for dunnage. This optional configuration is authorized for use with Shipping Configuration 5. The Grade WDF Felt Cushion is graphite felt has no material compatibility issue with the other materials or payload.

The dunnage materials used for Shipping Configurations 13 and 14 consist of graphite, stainless steel, and aluminum 6061-T6 (see SARP Table 1-4). The graphite materials (for example, Graphite Support Block, Graphite Filler Block) and the stainless-steel materials (for example, Stainless Filler Block Spacer, Stainless Steel Spacer Weldment, liners) are authorized for use in the package since their compatibility has been previously evaluated for other shipping configurations. The CV and payload liners are also stainless steel. In general, stainless steel and aluminum material have the potential for galvanic corrosion when in close contact and in presence of moisture. During loading operations, the stainless-steel liner(s) and CV are inspected and protected from moisture. The liners and CV are seal welded to prevent the moisture ingress. Given these controls, use of aluminum 6061-T6 for dunnage in Shipping Configuration 14, *Packaging Organization Assembly,* is not expected to result in significant galvanic corrosion with the one-time-use CV or other dunnage material in this configuration.

### 2.3 Fabrication and Examination

The applicant updated SARP Appendix 2.12.12, *Comparison of CV Construction to ASME BPVC, Section III, Division 1, Subsection NB, Requirements*, to note that the MNOP for Shipping Configurations 9, 10, and 11 have been evaluated for a shipment period of three years, instead of one year per § 71.4, as described in SARP Sections 2.1.2 and 3.3.2.2 *CV MNOP*, that is, the three years period is from the time of welding the CV closed to opening it. A clarification is also added in this appendix to note that the hydrostatic test pressure of the CV at 1.25 times the design pressure [1.25 × 200 psig = 250 psig, according to ASME BPVC, Section III, Division 1, Subsection NB, NB-6221(a)] is still bounding for the hydrostatic pressure test required in § 71.85(b) with the increased bounding MNOP of 98.3 psig (113.0 psia) (that is, 1.5 × MNOP = 169.5 psia).

The applicant added SARP Appendix 2.12.13, *Shipping Configuration 9 Spacer Weldment NCT and HAC Buckling Assessment*, to implement Appendix 2.12.2, from SARP Addendum 2, without any changes.

### 2.4 Lifting and Tie-Down Standards for All Packages

The applicant updated SARP Appendix 2.12.3, *Tiedown Analysis for the 9516 Package*, to include a tie-down analysis for shipment by commercial trailer as an option to shipment by the Office of Secure Transportation (OST) Safeguards Transporter (SGT). The analysis in SARP Appendix 2.12.3 was originally completed for shipment by the Safe Secure Transport (SST) (SST), which was retired in the 1990s and replaced by the SGT. The tiedown loading and associated requirements for the SGT are bounded by the SST tiedown analysis. The maximum load on the Personnel Shield tiedown bracket is calculated on SARP Appendix 2.12.3, page 2.12.3-11, which the staff reviewed and verified the calculations were correct. SARP Appendix 2.12.3, Figure 2.12.3-8, *Tiedown for Shipment via Commercial Vehicle*, shows the package will be blocked to prevent longitudinal and lateral sliding, and shoring bars are used to prevent longitudinal tipping in both the forward and reverse direction. This configuration results in fewer straps than the number of chains required for the SST configuration. The load is applied to the tiedown bracket at strap angle α (45 degrees), resulting in X and Z force components of 2,666 lb. each, which is sufficient for 2G vertical (2 times 900 lb.) per § 71.45(b). The 3,770 lb. load on the tiedown bracket is significantly lower than the 14,900 lb. load calculated in the SST analysis. The SST tiedown analysis of the tiedown brackets therefore bounds the commercial trailer tiedown configuration of the package. The staff confirmed the applicant met the § 71.45 requirements by document review and calculation.

## 2.5 Conclusion

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

## 3.0 Thermal Evaluation

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

DOE PCP staff reviewed the changes in SARP Chapter 3 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- review the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11,
- review the thermal performance of the package for the two new Shipping Configurations 13 and 14, and
- Review the effect of increasing MNOP.

DOE PCP staff confirmed by document review that SARP Addenda 1, 2 and 3 for Shipping Configurations 7 through 12 were correctly incorporated in the SARP Chapter 3. In addition, the staff confirmed by document review that changes made to Shipping Configurations 2, 3, 7, and 9 through 11 do not increase the total decay heat loads, or decrease the Cask or the CV void volumes of these shipping configurations; therefore, these changes would not affect the existing thermal evaluation regarding the maximum temperatures and the maximum pressures under NCT and HAC, as well as the calculated limits for fuel age.

The new content configurations, Shipping Configurations 13 and 14, are bounded by the thermal evaluations for Shipping Configurations 4 and 9, respectively, which are similar to the new configurations.

The increased MNOP was previously reviewed and approved in SARP Addendum No. 3 (CoC Rev 11).

## 3.1 Description of Thermal Design

The applicant did not request any changes to the primary packaging components for the package thermal design as described in SARP Section 3.1, *Description of Thermal Design*, which consists of a personnel shield (cask frame), cask (body), and containment vessel (CV).

The calculated maximum temperatures of the packaging components and the gases in the Cask and the CV are based on decay heat loads of 500 W for Shipping Configurations 1 through 5 and 12, and 420 W for Shipping Configuration 9, which are considered as the bounding thermal cases based on the thermal modeling and analysis documented in SARP Appendices 3.5.2 and 3.5.3. The results are summarized in SARP Tables 3.1, *Summary of NCT and HAC Maximum*

*Temperatures*, 3.9, *NCT Hot Temperatures for Payload Shipping Configurations*, and 3.14, *Maximum HAC Temperatures*.

### 3.2 Decay Heat, Component and Gas Temperatures for New Shipping Configurations

Shipping Configuration 13 has a maximum decay heat of 172.8 W per package from a maximum loading of 144 LWRHU Clad Pellets. The clad pellets are contained in eight product cans in two 5.75-in.-tall liners with a 3.38-in.-tall graphite filler block in-between in the CV, which is similar to Shipping Configuration 4. The maximum packaging component and gas temperatures for Shipping Configuration 13 are bounded by Shipping Configuration 4 which has a maximum authorized decay heat of 500 W per package.

Shipping Configuration 14 for LWRHU Assemblies has a maximum decay heat of 48 W per package from a maximum loading of 40 assemblies. Shipping Configuration 14 does not use liners in the CV, which is similar to Shipping Configuration 9. The maximum packaging component and gas temperatures for Shipping Configuration 14 are bounded by Shipping Configuration 9 which has a maximum authorized decay heat of 420 W per package.

The staff concurs with the applicant's analysis by comparison, that the maximum packaging component temperatures and gas temperatures in the Cask and the CV for Shipping Configurations 13 and 14 are bounded by Shipping Configurations 4 and 9, respectively, and the maximum temperatures of the packaging components are all below their allowable limits.

Shipping Configuration 14 utilizes 6061-T6 aluminum alloy trays in the Packaging Organizer Assembly as dunnage within the CV, which is a new material used in the CV. This aluminum alloy has a relatively low melting temperature of 1100 °F, but due to the low wattage of the contents for this shipping configuration (48 W/package), the internal CV temperature is not likely to approach 1100 °F under HAC thermal. For comparison, the maximum internal CV temperature for Shipping Configuration 9 (420 W/package) under HAC thermal is 1166 °F per SARP Table 3.14. The staff concurs that it is highly unlikely for the internal CV temperature under HAC thermal to approach 1100 °F for Shipping Configuration 14 due to its much lower wattage than Shipping Configuration 9.

### 3.3 MNOP and Maximum Pressure under HAC

The design pressure limits for the Cask and CV are 300 psig and 200 psig, respectively, per SARP Section 3.1.4 *Summary Tables of Maximum Pressures*. The pressurization in the Cask and CV are caused by expansion of the air or gas mixtures and are calculated using ideal gas law and assuming the initial cavity gas temperature is 70 °F at the time of closure.

The applicant limits void CV void volume, fuel age, and the wattage of the shipping configuration to ensure the MNOP is not exceeded. The updated calculations are shown in SARP Appendices 3.5.6, *Determination of Void Volume within the CV* and 3.5.7, *Fuel Age Calculations for All Shipping Configurations*, and summarized in SARP Table 3-12, *Maximum Allowable Age of Fuel*. The staff confirmed the applicant's results by document review and calculation.

The applicant updated SARP Table 3-11, *Maximum Normal Operating Package NCT Pressures*, to show the gas temperatures and pressures for calculating the MNOP for the Cask and all shipping configurations. The applicant also updated SARP Tables 3-14, *Maximum HAC Temperatures,* for the seven bounding shipping configurations and 3-15, *Maximum Package HAC Pressures*, for all shipping configurations to show the maximum gas temperatures and pressures under HAC thermal.

For the Cask, the limiting pressure component is a one-time use metallic Cask Seal, which is designed to relieve internal pressures greater than 300 psig and prevent water in leakage into the Cask. The applicant estimates in SARP Section 3.3.2.1 *Cask MNOP*, the Cask MNOP is 8.9 psig (23.6 psia) for all shipping configurations. The maximum Cask pressure under HAC thermal is 33.7 psig (48.4 psia). The MNOP and maximum pressure under HAC thermal remain well below the 300-psig design pressure limit for the Cask.

For the CV, the design pressure limit of 200 psig at 600 °F is based on the ASME BPV Code. The CV MNOP of 98.3 psig (113.0 psia) was first established in SARP Supplement No. 3 (approved in CoC 9516 Rev. 11). The applicant estimates in SARP Section 3.3.2.2 *CV MNOP*, two different MNOP based on whether the payload excludes or includes "offgassing" components. All shipping configurations exclude offgassing components, except for Shipping Configurations 7 and 14, and for these configurations the MNOP is 98.3 psig (113.0 psia). For Shipping Configurations 7 and 14, their MNOP is estimated to be 35.3 psig (50.0 psia), due to possible offgassing of organic components under HAC thermal. The maximum CV pressure under HAC is 171.0 psig (185.7 psia). The MNOPs and maximum pressure under HAC thermal remain below the 200-psig design pressure limit for the CV.

### 3.4 Conclusion

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

## 4.0 Containment Evaluation

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

DOE PCP staff reviewed the changes in Chapter 4 of the SARP to confirm the previously approved SARP Addenda 1, 2 and 3, and new MNOP and maximum pressure under HAC thermal were incorporated.

The applicant did not request any changes to the containment design of the package for Shipping Configurations 13 and 14. The applicant did update the reference to ANSI N14.5, *American National Standard for Radioactive Materials — Leakage Tests on Packages for Shipment*, from the 1997 to the 2014 edition.

The applicant did not increase the maximum $A_2$ of the package as reported in SARP Table 4-1, *Determination of $A_2$ in Payload.*

### 4.1 Description of the Containment System

The package containment system is fully described in SARP Section 4.1. In summary, the package containment system (boundary) 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).

The additional packaging components required for these new shipping configurations are internal to the CV and therefore are not important-to-safety items for package containment. Their uses are dunnage, handling convenience, or end use. The staff confirmed in Chapter 2 and 3 of this SER that the CV MNOP and maximum pressure under HAC are below the design pressure limits of the CV; therefore, the existing containment evaluation in Chapter 4 of the SARP remains bounding under NCT and HAC for Shipping Configurations 13 and 14.

### 4.3 Conclusion

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

## 5.0 Shielding Evaluation

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

DOE PCP staff reviewed the changes in SARP Chapter 5 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- evaluate the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11,
- evaluate the shielding performance of the package for the two new Shipping Configurations 13 and 14,
- evaluate the new HAC model developed that bounds all fourteen shipping configurations, and
- evaluate the effect of increasing $^{238}$Pu in Shipping Configuration 7 (FSO Container) from 92 to 94 % and maximum neutron emission rate from 24,000 n/s/g-$^{238}$Pu to 30,000 n/s/g-$^{238}$Pu, due to potential higher $^{238}$Pu yields based on available reactor positions,

DOE PCP staff confirmed by document review that SARP Addenda 1, 2 and 3 for Shipping Configurations 7 through 12 were correctly incorporated in SARP Chapter 5, including the increased specific neutron emission rate for Shipping Configuration 7. In addition, the staff confirmed by document review that changes made to Shipping Configurations 2, 3, 7, and 9 through 11, and the new Shipping Configurations 13 and 14 do not increase radiation levels of the package; therefore, these changes would not affect the existing shielding evaluation regarding package radiation levels under NCT and HAC for Shipping Configurations 1 through

12. The staff performed a confirmatory analysis of Shipping Configuration 13 as a bounding case for Shipping Configuration 14, since it ships 144 clad pellets vs. 40 clad pellets for Shipping Configuration 14.

External radiation levels under NCT are referenced from the surface of the Personnel Shield, since it is essentially undamaged under NCT and is the only accessible surface of the package under NCT. It is also unlikely that external radiation levels under NCT would meet § 71.47(a), so the applicant's shielding evaluation demonstrates compliance with § 71.47(b) for transport of the package by exclusive use only.

External radiation levels under HAC are referenced from the surface of the Cask, since the structural analysis assumes the Personnel Shield is damaged from HAC free drop and the Cask accessible after the drop.

## 5.1 Description of Shielding Design

### 5.1.1 Design Features

The applicant did not request any changes to the shielding design of the package. The package shielding design is fully described in SARP Section 5.1. In summary, the package design has a maximum gross weight of 900 lb. and consists of a 9.5-in. outside diameter cylindrical Cask housed in a 30.75-in. square by 35.25-in. high mesh Personnel Shield. The package is designed to ship plutonium dioxide heat source material. The package does not contain materials specifically intended for radiation shielding; however, the stainless-steel Cask and CV, secondary containers, and graphite or other dunnage material do provide some radiation attenuation, but these materials are not credited features in the shielding model to reduce external package radiation.

The dunnage and secondary containers in the CV for each shipping configuration and the Cask fastened to the Personnel Shield skid ensures there is no significant increase in external surface radiation levels under NCT per §71.51(a).

### 5.1.2 Summary Table of Maximum Radiation Levels

Maximum package and vehicle radiation levels are described in SARP Section 5.1.2, *Summary Table of Maximum Radiation Levels* and Table 5-1, *Calculated Maximum Dose Rates for Exclusive Use Shipment of a Single 9516 Package*, and show the package and consignment meets external radiation requirements of § 71.47(b) and the package meets § 71.51(a)(2) under HAC. For multiple packages on a consignment, the vehicle radiation levels are shown in SARP Table 5-2, *Calculated Maximum Dose Rates for Exclusive Use Shipment of Six 9516 Packages*, and show that the consignment meets external radiation requirements of § 71.47(b).

## 5.2 Source Specification

The applicant's shielding evaluation was completed with individual actinide impurities ($^{241}$Am, Np, U, and Th) at their average concentrations based on historic assay data. None of these impurities are major contributors to the neutron or photon source terms. Sensitivity cases with all the individual actinide impurities set to 1 wt.% resulted in very small (<1%) increases in the overall dose rates outside the package; therefore, from a practical shielding standpoint, the individual actinide impurities could be as high as 1 wt.% of the total plutonium content with a negligible impact on the overall dose rates.

The applicant's source specifications for each shipping configuration are described in SARP Sections 5.2.1, *Gamma Source* and 5.2.2, *Neutron Source.*

### 5.3 Shielding Model

The applicant's NCT shielding model assumes an undamaged package configuration, whereas the HAC shielding model assumes a damaged package configuration, which is loss of the Personnel Shield. Dose-point locations as shown in SARP Figure 5-1, *Dose Points*.

The applicant modeled 7 of 14 shipping configurations to bound all 14 shipping configurations for the shielding analysis under NCT. All configurations are described in SARP Sections 5.3.1.1 through 5.3.1.14.

For new Shipping Configurations 13 and 14, the shielding evaluation for the package uses the Shipping Configuration 13 as the bounding case, since it represents the higher plutonium dioxide ($PuO_2$) mass loading of these two new shipping configurations. For both configurations, the radioactive payload consists of LWRHU fuel pellets in Clad Body Assemblies (CBAs) - one fuel pellet per CBA. Shipping Configuration 13 is limited to 144 CBA/package whereas Shipping Configuration 14 is limited to 40 CBA/package, although its dunnage is designed to hold 80 CBA/package.

The NCT shielding model for Shipping Configuration 13 is used to analyze 144 CBA packaged in product cans and liners, surrounded by graphite support and filler blocks (dunnage). The entire payload and dunnage are loaded in the CV, which is in turn loaded in the Cask. A detailed description of applicant's model and assumptions are in SARP Section 5.3.1.13, *Description of Shipping Configuration 13 — LWRHU Clad Pellets* and Figures 5-17, *Cross-Section of the Shipping Cask Containing Hypothetical Shipping Configuration 13 (LWRHU Clad Pellet) in the X-Y Plane* and 5-18, *Cut-Away of the Shipping Cask with Hypothetical Shipping Configuration 13 (LWRHU Clad Pellets)*.

The applicant notes in SARP Section 5.3.1.14, *Description of Shipping Configuration 14 — LWRHU Assemblies*, although Configuration 14 uses an aluminum Packaging Organizer Assembly for dunnage in the CV, the potential for alpha-neutron interactions between $PuO_2$ and aluminum is not credible due to isolation of the plutonium from the aluminum and the absence of sufficient thermal conditions to breach material isolation. The fuel pellets are first encapsulated in the CBA, then nested within three pyrolytic graphite insulator bodies (concentric cylinders) that are capped at both ends, then overpacked in the Aeroshell Body.

DOE PCP staff concurs that the applicant's NCT shielding model for Shipping Configuration 13, and bounding HAC model from Shipping Configuration 6, assume a conservative geometry, where:

- For NCT and HAC - No material resides inside the CV except for the plutonium dioxide. No credit is taken for internal components inside the CV that could attenuate radiation (e.g., support structures, cladding)
- For NCT – the Personnel Shield dimensions are used for calculating dose points, but the materials provide no radiation attenuation (shielding).
- For HAC – the Personnel Shield omitted
- For NCT, Shipping Configuration 13, the source is modeled as a single $PuO_2$ sphere with a mass equal to the configuration's maximum mass —387.36 g of $PuO_2$.
- For the HAC bounding configuration, the source is modeled as a single $PuO_2$ sphere with a mass equal to the largest mass of 1360.88 g of $PuO_2$ from Configuration 6,
- The bounding sphere radius is 3.84 cm and is derived using the maximum $PuO_2$ density of 11.46 g/cm³,

### 5.4 Shielding Evaluation

For Shipping Configuration 7, the applicant increased the $^{238}$Pu wt. % limit from 92 to 94% and the maximum specific neutron emission rate from 24,000 n/s/g-$^{238}$Pu to 30,000 n/s/g-$^{238}$Pu because of the potential for higher $^{238}$Pu yields based on available reactor positions. The applicant addressed this change and its impact on dose rate in SARP Sections 5.2.1.7, *Gamma Source for Shipping Configuration 7 — FSO Container*, and 5.2.2.7 *Neutron Source for Shipping Configuration 7 — FSO Container*, and concluded this increase in $^{238}$Pu wt.% does not affect the bounding external dose rate reported for this configuration, which is based on 80 wt.% $^{238}$Pu. SARP Tables 5-15 and Table 5-16 demonstrate that an enrichment of 80 wt.% $^{238}$Pu yields the largest photon source, especially in the energy intervals of 0.25 – 2.75 MeV that contribute more heavily to personnel dose. The neutron dose rate is bounded by 80 wt.% $^{238}$Pu 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 80 wt.% $^{238}$Pu mixture yields the largest dose rate for this shipping configuration. Consequently, the photon and neutron dose rates at 94 wt.% $^{238}$Pu is bounded by the existing evaluation at 80 or 92 wt.% $^{238}$Pu.

The applicant addressed the increased maximum specific neutron emission rate to 30,000 n/s/g-$^{238}$Pu in SARP Section 5.2.2.7 by comparing the neutron source term calculated using the ORIGEN-S code for both a 10-day and 17.5-year decay with the results of a simple calculation using the revised neutron emission rate. The 10-day and 17.5-year decay results are 4.1E+06 and 3.5E+06 neutrons/s, respectively (ref. SARP Tables 5-37 and 5-38). For comparison, the applicant's simple calculation used 246.4 grams of $^{238}$Pu (ref. SARP Table 5-14) at 30,000 n/s/g-$^{238}$Pu to determine an emission rate of 7.39E+06 neutrons/s. Therefore, the applicant uses the higher emission rate in their Monte Carlo N-Particle Transport Code (MCNP) code.

DOE PCP staff confirmed that ORIGEN-based calculations are consistent with expected emissions for aged $^{238}$Pu oxide and concurs that use of the increased maximum specific neutron emission rate is conservative.

Both the applicant and the staff used MCNP for their shielding analyses: the applicant used Version 6.1, and the staff used Version 6.2, to confirm the applicant's results. Both used the ENDF/B-VII.1 cross sections and ANSI/ANS-6.1.1-1977 recommended neutron and gamma flux-to-dose-rate conversion factors.

The staff performed a shielding analysis to confirm the consistency of the applicant's results for Shipping Configuration 13 LWRHU Clad Pellets single package analysis under NCT to § 71.47(b), the bounding HAC analysis for all shipping configurations to § 71.5(a)(2), and a six-package analysis of Shipping Configuration 13 LWRHU under NCT to § 71.47(b). The results are shown for comparison Tables 5-1 through 5-3 below.

Table 5-1 below compares SARP Table 5-63, Calculated Maximum NCT Dose Rates for Shipping Configuration 13 (LWRHU Clad Pellets) for Exclusive Use Shipments, with the staff's results.

**Table 5-1 Shipping Configuration 13 (LWRHU Clad Pellets) Single Package Dose-Rates under NCT**

| | **Package surface (mrem/h)** | | | | | | **Outer surface of vehicle (mrem/h)** | | **2 m from vehicle external surface (mrem/h)** | | **Normally occupied position in vehicle (mrem/h)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Side** | | **Top** | | **Bottom** | | | | | | | |
| | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** |
| **Photon** | 19.0 | 20.1 | 3.03 | 3.00 | 58.7 | 59.7 | 39.9 | 40.5 | 0.19 | 0.18 | 0.27 | 0.26 |
| **Neutron** | 58.9 | 58.5 | 10.1 | 9.6 | 167.6 | 169.3 | 115.9 | 113.6 | 0.66 | 0.65 | 0.93 | 0.93 |
| **Total** | 78.0 | 78.6 | 13.1 | 12.6 | 226.3 | 229.1 | 155.8 | 154.1 | 0.85 | 0.83 | 1.20 | 1.19 |
| **71.47(b) limits** | 1000 | | | | | | 200 | | 10 | | 2 | |

Table 5-2 below compares SARP Table 5-64, *Calculated Maximum HAC Dose Rate for Bounding Configuration*, with the staff's results.

**Table 5-2 Bounding Dose Rates for all Shipping Configurations under HAC**

| | **Side (mrem/h)** | | **Top (mrem/h)** | | **Bottom (mrem/h)** | |
|---|---|---|---|---|---|---|
| | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** |
| **Photon** | 16.4 | 13.3 | 4.95 | 5.01 | 19.0 | 20.4 |
| **Neutron** | 23.1 | 18.9 | 5.93 | 5.11 | 27.6 | 22.8 |
| **Total** | 39.5 | 32.2 | 10.9 | 10.1 | 46.6 | 43.2 |
| **71.51 (a)(2) limit** | 1000 | | | | | |

Table 5-3 below compares SARP Table 5-72, Calculated Maximum Dose Rates for Transporting Six Packages for Shipping Configuration 13 (LWRHU Clad Pellets) for Exclusive Use Shipments, with the staff's results.

**Table 5-3 Shipping Configuration 13 (LWRHU Clad Pellets) Six-Package Dose-Rates under NCT.**

| | Outer surface of vehicle (mrem/h) | | 2 m from external surface (mrem/h) | | Normally occupied position in vehicle (mrem/h) | |
|---|---|---|---|---|---|---|
| | **SARP** | **Staff** | **SARP** | **Staff** | **SARP** | **Staff** |
| **Photon** | 41.15 | 39.37 | 0.66 | 0.66 | 0.30 | 0.27 |
| **Neutron** | 112.7 | 114.0 | 2.05 | 2.06 | 1.05 | 0.88 |
| **Total** | 153.8 | 153.4 | 2.71 | 2.73 | 1.35 | 1.15 |
| **71.47(b) limits** | 200 | | 10 | | 2.0 | |

The staff concluded that the applicant's bounding shielding evaluations, supported by conservative modeling assumptions and validated by the staff's confirmatory analysis using MCNP, demonstrate compliance with the dose rate limits prescribed in 10 CFR 71.47(b) under both NCT and HAC.

## 5.5 Conclusion

Based on review of the statements and representations in the SARP and DOE PCP staff's confirmatory analysis, the staff concludes that the shielding design has been adequately described and evaluated and that the package meets the external radiation requirements of 10 CFR Part 71.

## 6.0 Criticality Evaluation

The objective of this review is to verify that the package design meets the nuclear criticality safety (NCS) requirements of 10 CFR Part 71 under NCT and HAC.

DOE PCP staff reviewed the changes in SARP Chapter 6 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- evaluate the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11,
- evaluate the two new Shipping Configurations 13 and 14 for NCS, and
- confirm the new NCS analysis using a bounding analysis approach that assumed a maximum wattage of 1,000 W per package and approximately 2,698 g of dioxide fuel per shipment meets §§ 71.55 and 71.59.

DOE PCP staff confirmed by document review that SARP Addenda 1, 2 and 3 for Shipping Configurations 7 through 12 were correctly incorporated in SARP Chapter 6.

The changes made to Shipping Configurations 2, 3, 7, 9, 10, and 11 do not increase the maximum $PuO_2$ mass and therefore have no impact on the NCS. These configurations are still bounded by the limiting configuration for the NCS evaluation in SARP Chapter 6.

The staff also concurs that new Shipping Configurations 13 and 14 added to SARP Chapter 6 do not affect NCS since each clad fuel pellet for these configurations contain a maximum of 2.671 g of $PuO_2$, at 1.2 watts, with a maximum of 23.9 wt.% $^{239}Pu + ^{241}Pu$ (0.6384 g fissile mass/pellet). Shipping Configuration 13 is limited to 144 Clad Pellets/package (approximately 91.9 g fissile mass/package) and Shipping Configuration 14 is limited to 40 Clad Pellets/package (approximately 25.5 g fissile mass/package). These configurations are bounded by the previous

NCS evaluation of 1,350 g of $PuO_2$/package (approximately 322.7 g of fissile mass/package) for Shipping Configuration 12 in SARP Addendum 3, and the new bounding configuration of 2,698 g of $PuO_2$/package (approximately 701.5 g of fissile mass/package) in SARP Revision 6.

The previous bounding case for the NCS evaluation is Shipping Configuration 3: a single package of three GPHS Modules consisting of 2,215 g of $PuO_2$. Based on SARP Revision 5, for a single package under NCT, the maximum $k_{eff}$ value of 0.30312 occurs for 74 wt.% $^{238}$Pu with fully flooded package conditions, and for an infinite array of packages under HAC, the maximum $k_{eff}$ value of 0.53250 occurs for 74 wt.% $^{238}$Pu with dry package conditions, which maximizes the neutron communication between adjacent packages. These $k_{eff}$ values are below the Upper Subcritical Limit (USL) of 0.7000 after allowing for bias and uncertainties. The applicant simplified the NCS evaluation in SARP Revision 6, Chapter 6, by creating a new bounding analysis case, which evaluates a single package and an infinite array of packages with 2,698 g of $PuO_2$ that generates 1,000 W of decay heat. The staff reviewed the new bounding NCS analysis case and concluded it meets §§ 71.55 and 71.59.

## 6.1 Description of Criticality Design

### 6.1.1 Design Features

The applicant did not request any changes to the NCS design of the package. The package NCS design is fully described in SARP Section 6.1. In summary, the packaging features important for NCS are the stainless-steel Cask and the stainless-steel CV. Based on the analyses and test results described in SARP Chapters 2 and 3, the CV remains leaktight under NCT and HAC; consequently, water leakage into the CV is not a credible event, nevertheless, the applicant does evaluate the CV flooded in the NCS evaluation. The Personnel Shield is not credited for NCS in the analysis. The Cask is designed to provide confinement of the CV and contents during NCT and HAC.

### 6.1.2 Summary Table of Criticality Evaluation

SARP Table 6-1 summarizes the results of the criticality evaluation for a single package and an infinite array of packages per §§ 71.55 and 71.59 to show they remain subcritical under NCT and HAC.

For a single package under NCT, the maximum $k_{eff}$ value of 0.63467 occurs for 74 wt.% $^{238}$Pu, 25 wt.% $^{239}$Pu, and 1 wt.% $^{241}$Pu with fully flooded package conditions, and for an infinite array of packages under HAC, the maximum $k_{eff}$ value of 0.85773 occurs for the same wt.% of plutonium with dry package conditions, which maximizes the neutron communication between adjacent packages. These $k_{eff}$ values are below the Upper Subcritical Limit (USL) of 0.9000 after allowing for bias and uncertainties.

### 6.1.3 Criticality Safety Index

Because an infinite array of packages is safely subcritical, N=infinity, and the criticality safety index (CSI) remains 0.0.

## 6.2 Fissile Material Contents

The maximum bounding fissile mass is based on a mixture of 74 wt.% $^{238}$Pu, 25 wt.% $^{239}$Pu, and 1 wt.% $^{241}$Pu that would generate 1,000 Watts of decay heat/package. This content mixture provides an upper limit on the effective multiplication factor (i.e., $k_{eff}$) and results in 2,698 g of $PuO_2$, of which, approximately 701.5 g are fissile ($^{239}$Pu + $^{241}$Pu).

The fissile material contents for all shipping configurations are described in SARP Sections 6.2.1 through 6.2.14 and are bounded by the 2,698 g $PuO_2$ case.

## 6.3 General Considerations

The packaging geometry is essentially unchanged in SARP Chapter 6. The dunnage and secondary containers in the CV are not physically modeled. The CV contents for the new NCS evaluation are now represented as a single $PuO_2$ sphere until the sphere radius contacts the walls of CV, then it is represented as a single cylinder until the cylinder length fills the CV. The sphere and cylinder increases are from varying the moderating materials (for example, water, graphite, stainless steel, etc.) mixed homogeneously in the sphere or cylinder with the $PuO_2$. In addition, the applicant represents the same mixtures of $PuO_2$, and moderating materials divided into a hexagonal pattern of 14, 37, 61, 91, and 547 rods, and refers to this model as the heterogeneous rodded configuration. The staff concurs that the package is sufficiently described in SARP Section 6.3.1 *Model Configuration*.

The materials for all shipping configurations are described in SARP Sections 6.3.1.1 through 6.3.1.14 and are bounded by the moderators in the 2,698 g $PuO_2$ case.

Aluminum was added to SARP Table 6-2. *Material Compositions for All Materials*, to account for the Packaging Organizer Assembly that is required for Shipping Configuration 14. The aluminum is evaluated as a moderating material in the NCS evaluation.

The applicant used the MCNP 6.1 computer code with continuous energy cross sections for all isotopes taken from Evaluated Nuclear Data Files (ENDF/B-VII.1) (LA-UR-17-20709), as described in SARP Section *6.3.3 Computer Codes and Cross-Section Libraries.*

## 6.4 Single Package Evaluation

The single package model is described in SARP Section *6.4.1 Configuration* to evaluate the $PuO_2$ sphere, cylinder and rod models described in SARP Section 6.4.1.1 *Plutonium Dioxide Sphere*) and mixtures described in SARP Sections 6.4.1.2 *Homogeneous Mixture Calculation* and 6.4.1.3 *Heterogeneous Rodded Calculation*. These single package model configurations are shown in SARP Figures 6-1 through 6-8.

The results are reported in SARP Section 6.4.2 and demonstrate compliance with the requirements of §§ 71.55(b) and 71.55(d)(1). Since the package is undamaged under NCT based on SARP Chapter 2, the requirements of §§ 71.55(d)(2) through (d)(4) are met. And since the single package configuration omits the Personnel Shield (and skid), it is the same configuration to evaluate a damaged package under HAC per § 71.55(e) and an array of packages per § 71.59.

For the homogeneous mixture in the sphere, the most reactive single package configuration results in a maximum $k_{eff}$ of 0.63465 and occurs with 5,487 $cm^3$ of water mixed with $PuO_2$, the Cask and CV cavities flooded, and the Cask reflected by 30 cm of water. The results are fully described in the text and tables in SARP Section 6.4.2.1 *Homogeneous Configurations*.

For the heterogeneous rodded configuration, the most reactive single package configuration results in a maximum $k_{eff}$ of 0.56862 and occurs with 547 full CV length rods, normally spaced, and the Cask and CV cavities flooded, and the Cask reflected by 30 cm of water. The results are fully described in the text and table in SARP Section 6.4.2.2 *Heterogeneous Configurations*.

The staff confirmed by document review that a single package remains subcritical under NCT and HAC.

### 6.5 Evaluation of Package Arrays under Normal Conditions of Transport

The applicant did not perform an evaluation of an undamaged package array under NCT but demonstrates compliance with § 71.59(a)(1) by demonstrating an infinite array of damaged packages is subcritical per § 71.59(a)(2).

### 6.6 Package Arrays under Hypothetical Accident Conditions

The applicant performed an evaluation of an infinite array of damaged packages, that is, packages without the Personnel Shield (and skid), to minimize the distance between packages in an array. Since the CV is leaktight under NCT and HAC, the CV is dry, and the void space is air or filled with moderating material such as stainless steel, aluminum, or graphite. The applicant evaluated $PuO_2$ as a homogenous sphere or heterogeneous rods. The Cask is evaluated with and without flooding between the Cask Body and CV and interstitial water in the array, at ten different water densities. These models are described in SARP Section 6.6.1 *Configuration* and SARP Figures 6-9 and 6-10.

The results are reported in SARP Section 6.6.2 and demonstrate compliance with the requirements of §§ 71.59(a)(1) and 71.59(a)(2).

For the homogeneous sphere, the most reactive array configuration case results in a maximum $k_{eff} = 0.85773$ and occurs with only the $PuO_2$ sphere in the CV and no other material, with low-density water, 1.0E-20 $g/cm^3$, flooded in the Cask and in between packages in the array. The maximum reactivity for the same CV configuration, but with no water flooding the Cask or between packages in the array is $k_{eff} = 0.85772$. When the water density in and around the Cask is 1.0E+00 $g/cm^3$, the most reactive case, $k_{eff} = 0.65107$, occurs when the CV void space is filled with aluminum. The applicant shows that as the interstitial water density increases, $k_{eff}$ drops significantly for all cases. Reactivity is greater with no material in the CV (void) as compared with aluminum, graphite, and 304-grade stainless steel. The results are fully described in the text in SARP Section 6.6.2.1 *Homogeneous Results* and Table 6-8, *HAC Infinite Array Results for the Homogeneous Configuration*.

For the heterogeneous rodded configuration, the most reactive array configuration case results in a maximum $k_{eff}$ of 0.78488 and occurs with 37 $PuO_2$ rods in the CV and no other material. The rods are 1/3-length of the CV in close pitch, and the Cask cavity is dry (void) and with no water between the packages in the array. By comparison, the rodded model reactivities of the CV void and graphite filled configurations are significantly lower than the "dry" homogeneous sphere models; consequently, the applicant surmises that no other materials in the CV, such as aluminum or stainless steel would be more reactive than the spherical configuration and thus did not evaluate these other materials in the heterogenous rodded configuration. The results are fully described in the text in SARP Section 6.6.2.1 *Homogeneous Results* and Table 6-9, *HAC Infinite Array Results for the Heterogeneous Configurations*.

The staff confirmed by document review that an infinite array of damaged or undamaged packages remains subcritical under NCT and HAC.

### 6.7 Fissile Material Packages for Air Transport

The package is not authorized for air transport.

### 6.8 Benchmark Evaluations

The applicant describes and summarizes in SARP Section 6.8, the calculations for experimental criticality benchmarks used to validate the MCNP 6.1 computer code with continuous energy ENDF/B-VII.1 cross sections.

The staff reviewed the applicant's benchmark experiments in SARP Section 6.8.1 *Applicability of Benchmark Experiments* and confirmed that they are appropriately referenced and applicable to the packaging design and contents. Due to the lack of benchmark experiments for $^{238}$Pu, the applicant used plutonium experiments that address a broad range of neutron energies and numerous moderator and reflector materials. The validation of ENDF/B-VII.1 continuous energy cross sections in the MCNP data library was made using benchmarks involving plutonium in fast, intermediate, and thermal systems. All of the experiments reported with estimated reactivity near $k_{eff}$=1 for the dimensions and materials modeled include an uncertainty of the actual $k_{eff}$ for the reported model. ENDF/B-VII.1 cross sections were used for all isotopes, and all thermal scattering cross-sections were from ENDF/B-VII.0. All MCNP file names are listed in SARP Appendix 6.9.2, *MCNP 6.1 Input and Output Listings*.

The staff reviewed the applicant's method for determining bias and uncertainty in SARP Section 6.8.2 *Bias Determination*. The applicant summarized 163 MCNP plutonium benchmark calculations in SARP Table 6-11, *Results of MCNP Calculations for Plutonium Benchmark Experiments*, which show there is good agreement between these experiments and the MCNP calculations with the average $k_{eff}$ over all of the experiments being 0.99952 and the average of the MCNP calculations being 1.00819. The average neutron lethargy causing fission (AEF) values for the 361 package criticality cases for the Pu content are in the 1.85E+04 to 1.98E+06 eV range. SARP Table 6-11 shows that the range of AEF values for the benchmark experiments adequately covers this range, giving confidence that the $k_{eff}$ values for the package evaluation are valid and that the effective USL determined by the applicant is appropriate. The applicant followed the recommendations in NUREG/CR-5661, *Recommendations for Preparing the*

*Criticality Safety Evaluation of Transportation Packaging for Radioactive Material* to calculate the USL using the upper limit of $k_{eff}$ is 0.95, based on a minimum required margin of subcriticality of 0.05 for packaging applications, then reducing it by the difference in benchmark calculation bias and uncertainties at the 95-percent confidence level (ref. SARP page 6-31 equation for USL). The results for the package cases include the $k_{eff}$ value along with the standard deviation ($\sigma_m$) for each case. For simplicity, the applicant's $k_{eff}$ from the package case is directly compared to the USL calculated on SARP page 6-31 based on an assumed $\sigma_m$ of 0.0001 instead of using the actual standard deviation for each case, because all package results in SARP Chapter 6 are run long enough that the reported uncertainty ($\sigma_m$) is less than or equal to 0.0001. The applicant then calculated the USL for the plutonium benchmark experiments, using an average $k_{eff}$ of 0.99805 of the MCNP calculations with a $k_{eff}$ of less than 1 to determine the bias (-0.00195), then using the USL equation on SARP page 6-31, with the uncertainties shown and described, resulted in a USL 0.94137, rounded to 0.9400. The staff concludes that comparing the case results to a USL limit of 0.9400 sufficiently accounts for the MCNP bias and uncertainties.

The staff reviewed the applicant's Area of Applicability (AOA) discussion for the benchmark experiments along with a comparison to the modeled system as shown SARP Table 6-10, MCNP 6.1 *Area of Applicability*. All modeled parameters are within the AOA except for the plutonium isotopic concentrations and the use of aluminum or stainless steel as a moderator. The applicant argues that the benchmark experiments adequately exercise the cross sections for the plutonium isotopes of interest in the package content cases across a broad range of neutron energies, providing confidence that the results from the criticality evaluation accurately reflect the reactivity of the system. To account for the plutonium isotopic concentrations outside the AOA and for the use of aluminum or stainless steel as a moderator, the applicant applies an AOA reduction of 0.04 to the USL, which reduces it to 0.9000 for the criticality evaluation of the package. The staff concurs with the applicant's evaluation of the AOA and judgement to reduce the USL for AOA parameters out of range.

## 6.9 Conclusion

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the nuclear criticality safety design has been adequately described and evaluated and that the package meets the subcriticality requirements of 10 CFR Part 71.

## 7.0 Operating Procedures

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

DOE PCP staff reviewed the changes in SARP Chapter 7 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- evaluate the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11,
- evaluate the operating procedures for the two new Shipping Configurations 13 and 14,

and
- evaluate procedure improvements and clarifications.

DOE PCP staff confirmed by document review the previously approved SARP Addenda 1, 2 and 3, package operations procedures were consolidated and incorporated in the SARP. Since each payload will be in a liner, such as Shipping Configurations 1 through 6, 8, 12, and 13, or directly loaded in the CV, such as Shipping Configurations 7, 9 through 11, and 14, the applicant made clarifications and improvements in this section of the SARP to address loading/unloading procedures for all shipping configurations and their optional configurations.

In SARP Section 7.1, the applicant added clarification for determining the weighted average age of fuel of a shipping configuration, moved the decay heat wattage verification and the content shipping configuration requirements per SARP Chapter 1 to SARP Section 7.1.1, and added clarification for using additional site-specific tooling for handling other thermally hot and radioactive components to be loaded into the CV.

The staff confirmed that operating procedures 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.

### 7.1 Package Loading

The applicant revised SARP Section 7.1.1, *Preparation of Loading*, Step 8 was revised to include other CV internal components used in Shipping Configurations 7 to 14. The step for determining the decay heat wattage was deleted in this section and included in SARP Section 7.1, 2nd paragraph, last sentence, that is, "A calorimetric assay measurement or equivalent means is taken to verify that the decay heat wattage of all radioactive materials does not exceed the heat generation limits specified in Chapter 1."

The applicant clarified SARP Section 7.1.2, *Loading of Contents*, by adding a new Step 2 that the loading and closure welding of the CV is to be performed in an inert atmosphere containing at least 10% helium, to meet the requirements of ANSI N14.5-2014, paragraph A.3.6 (see SARP Section 4.1.3), and added a new Step 4 to address shipping configurations without using a Liner. The existing loading requirement specifically for shipping configurations with Liners were consolidated in Step 5.

The applicant combined SARP Revision 5, Section 7.1.3, *Preparation for Transport*, Steps 9 and 10 in SARP Revision 6, Section 7.1.3, Step 8, with clarifications that ensure the package is to be shipped by exclusive use, and in an enclosed uninsulated trailer with no material impeding natural convection. Section 7.1.3, Step 9, was added to address SGT tiedown requirements, and tiedown requirements for shipment by commercial trailer, based on the commercial trailer tiedown analysis in SARP Appendix 2.12.3.

### 7.2 Package Unloading

The applicant revised SARP Section 7.2.1, *Receipt of Package from Carrier*, to split steps (Steps 8 through 15) into a new section. The applicant added SARP Section 7.2.2 *Removal of CV from*

*Package*, Steps 1 through 7 to provide simple concise steps for opening the Personnel Shield to access the Cask, remove the Cask Lid, and access and remove the CV.

### 7.3 Preparation of Empty Package for Transport

The applicant combined SARP Revision 5, Section 7.3, *Preparation of Empty Package for Transport*, Steps 1 and 2 in SARP Revision 6, Section 7.3, Step 1 and provided additional information to include "reusable" internal CV components to be returned with empty packaging per 49 CFR173.728 (d). The applicant also added clarification to SARP Section 7.3, Step 5 for removal and radiological survey of the "reusable" internal components prior to inspection for reuse.

### 7.4 Conclusion

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

## 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.

DOE PCP staff reviewed the changes in SARP Chapter 8 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- evaluate the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11, and
- evaluate the acceptance tests and maintenance for the components used in the two new Shipping Configurations 13 and 14.

DOE PCP staff confirmed by document review the previously approved SARP Addenda 1, 2 and 3, packaging acceptance tests and maintenance requirements were incorporated in SARP Chapter 8.

The changes to the loading options for Shipping Configurations 2, 3, and 7 through 8, and the new Shipping Configurations 13 and 14, did not require any changes in SARP Chapter 8, since acceptance of internal components is addressed in SARP Section 8.1.1.3, *Internal Components*, per the design drawings in SARP Appendix 1.3.2. The applicant added "stainless steel components" to the SARP Section 8.1 *ACCEPTANCE TESTS*, and SARP Section 8.1.1.3, to the list of examples of internal components, in addition to the liner and graphite components, since stainless-steel components are used in the CV for Shipping Configurations 9 through 11 and 14.

The applicant updated the reference to ANSI N14.5 to the 2014 edition, as a best practice improvement and recommended by NRC. This change has no effect on the safety basis for package approval. The staff notes that ANSI N14.5-1987 remains as reference 4.4 in SARP

Chapter 4, as it was the standard of record for the original testing and evaluation of the package. The staff reviewed the changes associated with this update and found them acceptable.

### 8.1 Acceptance Tests

The applicant added "stainless steel components" to the SARP Sections 8.1 and 8.1.1.3, to the list of examples of internal components, in addition to the liner and graphite components, since stainless-steel components are used in the CV for Shipping Configurations 9 through 11 and 14.

### 8.2 Maintenance Program

The applicant clarified in SARP Section 8.2.3 *Component and Material Tests*, the maintenance requirement of the Cask bolts and seal and that maintenance of the one-time-use CV is not required.

The safety function (Q-Cat C minor to safety) of the reusable internal components in the CV is dunnage. These components have no containment or confinement safety function and require no maintenance prior to initial use. They may be reused for subsequent shipments if incidental damage, if any, is acceptable per the inspection criteria in SARP Section 8.2.3.1, *Internal Components* and Table 8-1, *Maintenance Reuse Inspection Criteria*. The applicant updated Table 8-1 to include reusable internal components from Shipping Configuration 12 through 14 and added the requirement that "Reused components must be free from radiological contamination.", presumably to the 49 CFR 173.428(d), empty package limit for internal contamination. The staff reviewed the maintenance reuse inspection criteria and found them appropriate and acceptable per § 71.87(b).

### 8.3 Conclusion

Based on review of the statements and representations in the SARP, 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 applicant's Quality Assurance (QA) program description is approved by the DOE Certifying Official and the application demonstrates that the package-specific QA requirements comply with the requirements of 10 CFR Part 71.

The applicant's 10 CFR 71 Subpart H Quality Assurance Program (QAP), *Quality Assurance Program Description for Type B and Fissile Material Packaging, Program Description Document*, PDD-199, Revision 3, is approved by DOE (https://rampac.energy.gov/docs/default-source/qa/approval_0010_r2.pdf).

DOE PCP staff reviewed the changes in SARP Chapter 9 to:

- confirm the previously approved SARP Addenda 1, 2 and 3, were incorporated,
- evaluate the changes to the loading options for Shipping Configurations 2, 3, and 7 through 11, and

- evaluate the quality level for the components used in the two new Shipping Configurations 13 and 14.

The staff confirmed by document review the previously approved SARP Addenda 1, 2 and 3, packaging quality assurance requirements were incorporated in SARP Chapter 9, Table 9-1, *Q-List for the 9516 Packaging Design, Procurement, and Fabrication*. The changes to the loading options for Shipping Configurations 2, 3, and 7 through 11 do not impact quality assurance requirements, since there was no change to the Q-Cat C safety function of these internal components. The quality levels for Shipping Configurations 13 and 14 were added to SARP Table 9-1.

### 9.1 Package-Specific QAP Requirements

The quality levels for Shipping Configurations 13 and 14 were added to SARP Table 9-1. The primary safety function of the internal components for Shipping Configurations 13 and 14 is dunnage, that is, “restrict movement” payload in the of payload 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 and nuclear criticality models under NCT and HAC. The staff finds the shielding and criticality model assumptions consistent with the applicant’s Q-Cat-C classification of these components.

### 9.2 Quality Assurance Program

The applicant updated SARP Chapter 9 for consistency with PDD-199, Rev. 2, and updated references in SARP Chapter 9 to the INL Radioisotope Power Systems (RPS) Program Quality Assurance Program Plan (QAPP), R1037-0008-QP, Rev. 7, which implements PDD-199 for the INL Space Nuclear Power and Isotope Technologies directorate responsible for the 9516 package. The applicant updated SARP Table 9-3, *Comparison of the 9516 SARP, RPS QAPP and PDD-199 with 10 CFR 71, Subpart H* to provide a side-by-side comparison matrix of the relationship of these documents to Subpart H. The staff reviewed the changes in SARP Chapter 9 and concluded that they would not reduce the commitments in the QA program description.

### 9.3 Conclusion

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the applicant’s QA program has been adequately described and meets the QA requirements of 10 CFR 71.

## CONDITIONS OF APPROVAL

The following changes to CoC Rev 13 are required to implement changes evaluated in this SER and simplify the CoC by removing excessive detail.

- Note – style changes throughout (“in.”, “stainless-steel”, etc.)
- 3(2) *Title and Identification of report or application*: Revise to “… R1033-0062-ES, Rev. 6, June 2025.
- 3(3) *Date*: Revise to “June 2025”
- 5(a)(2) *Description*:
    - Revise this section to simplify the description the packaging.

  - Add a table of the dimensions or weight of the package features.
- 5(a)(3) *Drawings*:
  - Revise Drawing No. 756189, *Containment Vessel, 16.25 High*, from Rev. 2 to Rev. 3. (update)
  - Revise drawing titles (for consistency with drawings)
  - Add drawings 1027426, 1042469, and 1027425 from SARP Table 1-4 for Shipping Configurations 13 and 14.
- 5(b)(1) *Type and Form of Material*:
  - Revise this section to simplify the type and form of material description.
  - Remove the text describing the shipping configurations and replace it with a reference to SARP Section 1.2.2.1.
  - Replace Table 1 with updated Table 1-1 from the SARP, which adds Shipping Configurations 13 and 14 as authorized contents.
- 5(b)(2) *Maximum Quantity of Material per Package*
  - Revise this section of the CoC to address the following subsections:
    - A. Maximum package decay heat – 500 W.
    - B. Maximum package activity – 15,930 Ci.
    - C. Maximum quantity of PuO2 items or mass per package and decay heat per item for each shipping configuration.
      - Created new table, *Table 2 Package Limits per Content Items*, from SARP Sections 1.2.2.1.1 through 1.2.2.1.14.
    - D. Maximum specific neutron emission rate, maximum package wattage, and estimated fuel density for each shipping configuration.
      - Added new table, , from SARP Table 1-2.
    - E. Maximum fuel age – added this section to reference to SARP Table 3-12 and SARP Section 3.3.2.2.

5(d) Conditions:

(2) Revise to "…the plutonium dioxide contents shall be shipped within a specified time after the …" (removed "period") …"Depending on the content for Shipping Configurations 1 through 14, the maximum age the processed plutonium dioxide can be at the end of a shipment ranges from 4.77 to 86.23 years as shown in SARP Table 3-12, which shows the maximum age for the most common authorized shipping configurations. For authorized configurations not shown in SARP Table 3-12, the maximum allowable fuel age shall be determined following the methodology in SARP Chapter 3, Section 3.3.2.2." (update fuel age condition for all configs due to revised MNOP calculation.).

(3) Revise to "… under the conditions provided in SARP Chapter 7 or except as provided in Condition 5.(d)(5), the 9516 Package shall be shipped exclusive use in an enclosed uninsulated trailer with no material impeding natural convection heat transfer within the trailer." (remove ref to addendums and clarify condition).

(5) Revise to "… Each package shall be positioned on the centerline of the cargo container floor as shown in SARP Figure 5-22… on-deck stacks with at least 2-feet of clearance." (update Figure no and clearance unit)

(8) Remove "… as supplemented by SARP Addendums 1, 2, and 3." (addendums incorporated in SARP).

(10) Revise to "Revision 13 of this certificate may be used until October 31, 2026." (grace period).

5(e) Supplements:

- Revise to "none"

## CONCLUSION

Based on the statements and representations contained in the SARP, 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] *FW: CCN 256944 Request for 9516 Certificate Renewal*, Email, N. McBride to J. Shenk, October 17, 2024.
[2] *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 6a, October 2024.
[3] *Q1s for Docket 25-05-9516*, Memorandum, C. Cable to N. McBride, April 29, 2025.
[4] *RE: Q1s for Docket 25-05-9516*, Email, N. McBride to L. Gelder, May 29, 2025.
[5] *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 6b page changes, May 29, 2025 (email attachment)
[6] *Safety Analysis Report for Packaging (SARP) for the 9516 Package*, R1033-0062-ES, Rev. 6, June 2025.