Safety Evaluation Report

for

Certificate of Compliance No. 9979 Amendment for the Model 9979 Package

Docket No. 21-03-9979

Prepared by: James M. Shuler Digitally signed by James M. Shuler Date: 2023.10.02 09:54:19 -04'00'

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

Approved by: JULIA SHENK Digitally signed by JULIA SHENK Date: 2023.10.20 08:24:14 -04'00'

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

This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent review and confirmatory analysis of supplement to Safety Analysis Report for Packaging (SARP) Revision 7, prepared by the Savannah River National Laboratory (SRNL) on behalf of the DOE Savannah River Operations Office (SR) for amendment of DOE Certificate of Compliance (CoC) Number 9979, Revision 16, for the Model 9979 package design.

Summary

By email [1] dated August 2, 2022, the DOE CoC 9979 certificate holder, (Savannah River Operations Office (SR), requested an amendment of DOE CoC No 9979 Rev. 16, to authorize use of the package for shipment of up to 52 (quantity) Vogan or Plutonium Oxide Pod (POP) special form (SF) capsule assemblies, in any combination per package, in support of missions for Los Alamos National Laboratory (LANL). Table 5 of CoC Rev. 16 authorizes use of package for shipment of up to eight Vogan or POP Assemblies, or a mixture of eight per package, with other radioactive materials (RAM) in normal and special form (SF). This new content configuration limits the RAM to only Vogan and/or POP SF capsule assemblies.

The final application in support of this amendment request is SARP Revision 7 (Supplement for Docket 21-03-9979) [2] and its references. The references consist of updated and new thermal, shielding, and criticality analysis (i.e., engineering calculations) of this new package content configuration to demonstrate compliance with 10 CFR Part 71 or to demonstrate the new configuration is bounded by the current engineering calculations supporting SARP Revision 7.

There were no design changes required to the 9979 important-to-safety packaging components or Vogan or POP SF assemblies for this new package content configuration.

The proposed amendment would authorize:

- An increase of the total package RAM mass limits for
  - Pu metal from approximately 140 to 910 grams for a Vogan only configuration, or
  - Pu oxide from approximately 144 to 936 grams for a POP configuration only, or,
  - A combination of Vogan and POP assemblies from approximately 140 grams to 936 grams of total Pu.
- An increase of the maximum fissile mass of Pu from 135 to 880 grams per package, and
- A maximum decay heat of 2.2 watts for this content configuration.

Based on the statements and representations in the SARP, as supplemented, and the conditions listed in this SER, DOE PCP staff independently confirmed by review and analysis that the package design has been adequately described and evaluated for the new Vogan and POP content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71, have been met and recommends amendment of the CoC by the DOE

Headquarters Certifying Official (HCO).

Evaluation

The safety basis document for DOE CoC Rev 16 is SARP Revision 7.

The safety basis documents for the proposed CoC amendment are:

- SARP Revision 7 and
- SARP Revision 7 - Supplement for Docket 21-03-9979 (hereinafter referred to in this SER as the "Supplement")

The final application submittal included the following new or updated engineering calculations referenced in the Supplement:

- *Thermal Analyses of 9979 Type A(F) Shipping Package for the Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC)*, M-CLC-A-00354, Revision 3. This calc. was updated to incorporate errata page from SARP Rev 7)
- *NCT and HAC for a 9979 Shipping Package with Plutonium Special Form Capsules*, M-CLC-A-00664, Revision 2. This calc. was updated to account for saturated water vapor in the maximum normal operating pressure calculation – this updated calculation is a reference for M-CLC-A-00729 (below).
- *9979 Package NCT Thermal Analysis with 52 Special Form Capsules*, M-CLC-A-00729, Rev. 0. Initial issue (i.e., new).
- *Shielding Analysis for Pu Special Form Assemblies in the 9979 Shipping Package (U)*, N-CLC-G-00182, Revision 1. This calc. was updated to account for the mass increase of Pu per Vogan/POP assembly and to analyze the new content configuration.
- *Nuclear Criticality Safety Evaluation: Special Form Plutonium Content Analysis in 9979 Type AF Shipping Package*, N-NCS-A-00048, Revision 1. This calc. evaluates 52 special form assemblies per package each containing up to 18 grams of plutonium as metal or in an oxide form. Note - Revision 0, Initial issue, was not submitted to DOE PCP for review.

The applicant initially submitted SARP Revision 9a, dated July 2022 [3] for this docket, after a submittal of SARP Revision 8a, in April 2022 for Docket 21-52-9979 to amend the CoC to authorize use of the package for transport of high assay low enriched uranium. The applicant's intention was to first complete Docket 21-52-9979, based on a final SARP Rev. 8, then complete Docket 21-03-9979, based on a final SARP Rev. 9. DOE PCP staff's review alternated between these dockets. DOE PCP issued technical questions (Q1s) to the applicant in December 2022 [4] from staff's review of SARP Rev. 9a. The applicant addressed these questions and implemented their responses in SARP Rev. 9b page changes on February 8, 2023.[5] DOE PCP staff completed their independent technical review of SARP Revs. 9a and 9b on June 20, 2023 [6], pending implementation in a final consolidated SARP. However, due to significant applicant delays with Docket 21-52-9979, the applicant did not complete and submit a final SARP Rev. 8. Consequently, DOE PCP requested the applicant to submit a supplement to SARP Revision 7 in

lieu of a final SARP Rev. 9 for Docket 21-03-9979. The applicant submitted the final SARP Revision 7 – Supplement for Docket 21-03-9979 dated July 2023 and DOE PCP staff confirmed on August 7, 2023 [7] that all SARP Revs. 9a and 9b changes were correctly implemented in the Supplement.

The following sections in this SER document DOE PCP staff's chapter-by-chapter independent review and confirmatory analysis of the Supplement to confirm it contains a sufficient safety basis for HCO approval of the package design to the requirements of 10 CFR Part 71.

1.0 General Information

The Model 9979 is a Type A fissile package design composed of one 55-gallon drum overpack and one 30-gallon inner drum. The purpose of the Model 9979 package is to transport a Type A quantity of solid fissile radioactive material by public highway.

Except for CoC Table 5 contents (see CoC Condition 8), the applicant restricts the contents so that the package may offered for transport by non-exclusive use, in accordance with §§ 71.43(g) and 71.47(a).

The changes in the Supplement from SARP Revision 7 are indicated by "change bars" in the page margins. In addition to implementing changes for the content amendment, the applicant made many administrative improvements and clarifications, spelling corrections, and non-substantive changes to punctuation or editorial items, updates and additions to regulatory references and other references. In addition, the applicant converted many of the SARP Chapter Addendices to Chapter References in the Supplement to reduce the overall size and ease of maintenance of the document. DOE PCP staff reviewed and concurred with these changes.

1.1 Packaging

There were no important-to-safety changes to the packaging design currently authorized in CoC Revision 16. The 9979 packaging consists of a 30-gallon confinement drum nested inside an internally insulated 55-gallon protective (i.e., sacrificial) overpack drum. The safety function of the 30-gallon is to prevent loss or dispersal of its radioactive contents under Normal Conditions of Transport (NCT). There are no specific packaging design features for radiation safety (i.e., shielding) or nuclear criticality safety other than content mass limits.

The Supplement evaluates a new proposed configuration of up to 52 Vogan or POP SF Assemblies, in any combination per package. These SF Assemblies may be overpacked in two 5-quart NFT ™ SAVY 4000® containers (henceforth referred to in this SER as the "SAVY"), with up to 26 assemblies per SAVY, for convenience handling and loading into the 30-gallon confinement drum.

The SAVY and the internal packing items for this configuration are shown on Drawing Special Form Container Shielding – 5 Quart SAVY, 157Y701808-000: the SAVY and none of its internal packing items are important-to-safety items required to demonstrate compliance with 10 CFR Part 71. They are constructed of the same basic materials evaluated in SARP Rev. 7,

Section 2.2.2, Table 2.8, for compatibility in accordance with §71.43(d).

The SAVY is a commercially available item, filter vented, and the container is constructed of Type 316 stainless steel. The design is consistent with the CoC Section 5(b)(1) description for use with other authorized contents evaluated in the SARP, that is, "… convenience container such as steel cans (carbon or stainless)."

1.2 Contents

The authorized contents for the Vogan and POP SF capsule assemblies are Pu metal and oxide, respectively, as shown in CoC Rev. 16, Table 5 (SARP Rev. 7, Table 1.5).

There were no changes to the designs or radioactive content limits for each Vogan/POP SF capsule assembly, but the applicant is proposing to increase the maximum number of Vogan or POP assemblies per package from eight to 52, in any combination. Consequently, the applicant split SARP Rev 7., Table 1.5 into two sections in the Supplement: Table 1.5.A for the current configuration and Table 1.5.B for the proposed new configuration. This new configuration increases the package limit for total Pu metal from approximately 140 to 910 grams and fissile mass limit from approximately 132 to 855 grams for a Vogan only configuration, or total Pu oxide from approximately 144 to 936 grams and fissile mass limit from approximately 135 to 880 grams for a POP only configuration, as shown in Supplement Table 1.5.B.

The maximum radioactivity and decay heat calculations for the Supplement Table 1.5.B content configuration are shown in Supplement Appendix 4.1 and are based on a configuration of 52 POP SF assemblies per package, which is the bounding radioactivity for the Vogan/POP configuration. The sum of the radioisotope activity to A_1 fractions is 0.693, which confirms the requirements for transport in a Type A package are met (i.e., sum of the fractions ≤ 1). The calculated decay heat for this configuration is 2.11 watts.

The Criticality Safety Index (CSI) calculated for the Supplement Table 1.5.B content configuration is 0.1, as shown in Supplement Table 6.7. The applicant assumed the total Pu mass limit of 936 g per package is all Pu-239 in their criticality evaluation.

The calculated transport index (TI) for the Supplement Table 1.5.B content configuration is 0.6, based on a total Pu mass per SF capsule is rounded up to 18 grams of Pu metal or Pu oxide and with the Pu wt.% from Table 1.5.B [i.e., 0.935 (Pu-239), 0.06 (Pu-240), and 0.005 (Pu-241)]. The calculated TI for all contents is shown in Supplement Section 1.1.

The maximum mass of the Table 1.5.B contents offered for shipment, excluding dunnage and convenience handling containers, is approximately 4.1 kilograms for a Vogan only configuration and approximately 2.8 kilograms for a POP only configuration, based on the maximum gross weights of the Vogan SF capsule assembly (7.95E+01 grams) and POP SF capsule assembly (5.34E+01 grams).

1.3 Drawings

There were no changes to the CoC drawings for the SARP Supplement Table 1.5.B content configuration. Use of the SAVY container is for convenience handling only, so its drawing is not required in the CoC.

1.4 Conclusion

Based on a review of the statements and representations in the SARP, as supplemented, DOE PCP staff concludes that the content changes in support of the CoC amendment have been described in sufficient detail to provide an adequate basis for the package evaluation under 10 CFR Part 71.

2.0 Structural Evaluation

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

2.1 Structural Design

There were no changes to the structural design features of the packaging or Vogan and POP SF designs required for the Table 1.5.B content configuration. Use of SAVY containers for this configuration is for convenience handling only, so they are not credited in the Supplement as an important-to-safety feature for the structural performance of the package.

The total mass of 52 Vogan SF assemblies per package is approximately 4.13E+03 grams and 2.78E+03 grams for 52 POP SF assemblies, which is bounded by the CoC Rev. 16 Table 5 package payload limit of 9.0E+04 grams and allows a large margin for Table 1.5.B content configuration for the mass of handling and convenience containers, bags, and dunnage. Consequently, there are no changes or supplemental information required to the structural evaluation in the SARP for the Table 1.5.B content configuration.

2.2 Materials and Estimated Weight of the Table 1.5.B Content Configuration

The SAVY container and its internal packing items for this configuration are shown on Drawing *Special Form Container Shielding – 5 Quart SAVY*, 157Y701808-000. The internal packing items are nested and consist of the following removable items:

- Aluminum “chip holder assembly” used as carrier for loading and handling up to 26 special form assemblies,
- Tungsten tube with unsecured top and bottom caps (i.e., tungsten discs) that shield and envelope the chip holder assembly, and
- High-density polyethylene in the form of tubes and discs that shield and position the chip holder and tungsten within the SAVY 4000® container.

The SAVY is a commercially available filter-vented container constructed of Type 316 stainless steel. The design is consistent with the CoC Section 5(b)(1) description for use with other

authorized contents evaluated in the SARP, that is, "… convenience container such as steel cans (carbon or stainless)."

Each 5-quart SAVY container can hold up to 26 Vogan or POP SF assemblies. The estimated weight of a single fully loaded 5-quart SAVY 4000® container is 64 lb. (ref. 157Y701808-000); therefore, the maximum estimated content weight is 128 lb. per package, not including the weight of polyethylene foam disks as dunnage to surround the SAVY 4000® container in the 30-gallon drum. The estimated weight of a polyethylene foam structure, without custom cut-outs for two, 5-quart SAVY 4000® containers, is less than 8 lb. (e.g., polyethylene packing foam density is approximately 2 lb./ft^3 and the internal volume of the 30 gallon drum is approximately 4 ft^3 - ref. Supplement Table 3.6 & Section 3.6, Ref 19, Table 1).

The estimated maximum full content weight for the Table 1.5.B configuration of 136 lb., with dunnage, is less than the 200 lb. maximum allowable content weight for all items loaded in the 30-gallon drum. Therefore, the structural effects of the Table 1.5.B configuration on the packaging during NCT and HAC are bounded by the simulated payload weight and configuration used for regulatory testing.

DOE PCP staff verified the SAVY container and its internal packing items are constructed of materials evaluated in SARP Rev. 7, Section 2.2.2, Table 2.8, for compatibility in accordance with §71.43(d). There is no material incompatibility issue between the SF Vogan or POP assemblies, the SAVY containers, the polyethylene foam support structure, and the 30-gallon drum. In addition, a requirement in SARP Section 1.2.2 prohibits presence of free liquids including water in the package contents, which also prevents galvanic corrosion from occurring.

2.3 Conclusion

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

3.0 Thermal Evaluation

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

3.1 Thermal Design

There were no changes to the thermal design features of the packaging or Vogan and POP SF designs required for the SARP Supplement Table 1.5.B content configuration. Use of SAVY containers for this configuration is for convenience handling only, so they are not credited in the supplement as an important-to-safety feature for the thermal performance of the package.

The maximum decay heat of the Table 1.5.B content configuration is 2.11 watts (Supplement Appendix 4.1), which is higher than the decay heat for any content configuration authorized in CoC Rev 16 but is still bounded by the maximum decay heat for the package thermal design of

3.5 watts. Consequently, there are no changes or supplemental information required to the thermal evaluation in the SARP for the Table 1.5.B content configuration.

Nevertheless, the applicant performed a thermal calculation and analysis of the package with the Table 1.5.B content configuration, at 2.2 watts (rounded up from 2.11 watts), under NCT to demonstrate that the packaging component temperatures and pressures remains within their allowable thermal design limits, and that the package surface temperature meets § 71.43(g) for non-exclusive use transport of the package (Supplement, Ref. 3.6.19, *9979 Package NCT Thermal Analysis with 52 Special Form Capsules* M-CLC-G-00729).

DOE PCP staff confirmed the applicant's results by document review.

3.2 Thermal Model and Analysis of Table 1.5.B Content Configuration

The package was designed for transport of contents with maximum decay heat of 3.5 watts. The applicant modeled and evaluated the decay heat in two different loading configurations in the 30-gallon drum. The first configuration is a concentrated non-combustible heat source in a convenience container that is enveloped in low-density packing foam (i.e., dunnage). The second configuration is a combustible heat source uniformly distributed in a polyethylene plastic bag which fills the inner drum cavity.

The Table 1.5.B configuration is a non-combustible payload and was modeled and evaluated as concentrated 2.2 watts heat source in M-CLC-G-00729.

The applicant conducted a thermal analysis of the package with Table 1.5.B contents under NCT using the commercial software COMSOL Multiphysics®. Conduction, convection, and radiation are the heat transfer mechanisms considered in the thermal analysis. Twenty-six SF assemblies may be loaded in a single 5-quart SAVY container, with overall dimensions of 12 inches tall and 7.7 inches in diameter. The package limit is two SAVY containers with a maximum total of 52 SF Assemblies. These containers are placed in a polyethylene foam support structure inside the 30-gallon drum. Although the internal configuration of the SAVY container includes high density polyethylene (HDPE) for neutron shielding, tungsten for gamma shielding, and an aluminum chip holder assembly for handling up to 26 SF assemblies, the applicant modeled these materials as polyethylene foam, due to the fact that the foam is less thermally conductive than these materials and results in higher temperatures from the contents to the 30-gallon drum packaging components during NCT.

The applicant modeled the 52 SF assemblies as single, tightly packed, 2.2 watt heat source, and surrounded by polyethylene foam in the 30-gallon drum. The heat source was analyzed at the top, center, and bottom of the drum along its centerline as shown in Figure 4 of M-CLC-A-00729. DOE PCP staff concurs that this content configuration model is conservative and thermally bounding configuration for NCT thermal analysis.

3.3 Compliance with § 71.43(g)

The calculated results in M-CLC-A-00729 show that the maximum temperature at the accessible surface of the package (i.e., the 55-gallon drum surface) under NCT, in shade, is 101°F (38.3 C), which demonstrates compliance with § 71.43(g) for non-exclusive use transport of the package.

3.4 Packaging Component Temperatures and Pressure under NCT

The thermal design temperature and pressure limits of the packaging components under NCT and HAC from the SARP are included in Supplement Table 3.1.

The maximum packaging component temperatures under NCT for Table 1.5.B contents, with and without insolation are shown in M-CLC-A-00729, Tables 5 and 6 respectively and implemented in Supplement Table 3.2. These results in Supplement Table 3.2 demonstrate that the calculated peak component temperatures are within their allowable thermal service design limits under NCT as compared with Supplement Table 3.1.

SER Table 3.1 below summarizes the worst-case peak condition under NCT (i.e., heat with solar insolation) with the allowable limits for package. Note – The allowable limit for the contents (275 °F) is based on the melting temperature of the HPDE in the SAVY container. The actual SF assembly designs are qualified to the 49 CFR 173.469(b)(4) heat test at a temperature of 1475 °F, held at that temperature for a period of 10 minutes, and then allowed to cool.

Table 3.1 Comparison of peak temperatures with allowable limits under NCT

Condition	55-Gallon Overpack			30-Gallon Drum		
	Body	BETAFOAM@	Liner	Body	Gasket	Contents
NCT-solar (°F)	157	157	144	147	142	220
Allowable limit (°F)	650	200	650	650	500	275

The applicant did not calculate the maximum normal operating pressure for Table 1.5.B contents at 2.2 watts because it is bounded by the 3.5 watt configuration shown in M-CLC-A-00354 and included in Supplement Table 3.5. The Table 1.5.B do not have the potential of generating hydrogen gas from radiolysis of surface-absorbed moisture since all radioactive materials are sealed and there is no moisture inside the SF assemblies.

3.5 Packaging Component Temperatures and Pressure under HAC

The applicant did not perform a new thermal analysis of the package with the Table 1.5.B contents under HAC, since it is bounded by the analysis in SARP Revision 7, Section 3.1.4. The basis for the SARP HAC thermal evaluation results are calculations M-CLC-A-00354 and M-CLC-A-00664. The package component temperatures under HAC for the 3.5 watts configuration shown in Supplement Table 3.4 is bounding for the Table 1.5.B contents at 2.2 watts.

The applicant did not perform a new pressure calculation of the package with the Table 1.5.B contents under HAC, since it is bounded by the analysis is SARP Revision 7, Section 3.1.4. The

basis for the SARP HAC pressure results is calculation M-CLC-A-00664. The calculated maximum pressure under HAC is 68.1 psia, based on a maximum content temperature of 458 ºF, which bounds the maximum content temperature under HAC for Table 1.5.B configuration. The maximum pressure under HAC inside the 30-gallon drum is caused by increased internal temperature (25.5 psia), and evaporation of the moisture (42.6 psia). Under HAC, thermal decomposition of packing/dunnage foam inside the 30-gallon drum is not expected. The lid of the 30-gallon drum incorporates a pressure relieving plug rated between 12-15 psig to release internal pressure. In addition, the 55-gallon drum body incorporates ventilation holes specifically to prevent accumulation of pressure from heated air or thermal decomposition of packaging insulation under HAC.

3.6 Conclusion

Based on review of the statements and representations in the SARP, as supplemented, and DOE PCP staff's confirmatory evaluation, staff has reasonable assurance that the package thermal design has been adequately described and evaluated and that the package continues to meet the thermal requirements of 10 CFR Part 71.

4.0 Containment Evaluation

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

There were no changes to the containment design features of the packaging or the Vogan and POP SF assembly designs for the Supplement Table 1.5.B content configuration.

The package is limited to a Type A quantity of radioactive material. The applicant's activity calculation for the Table 1.5.B content configuration was added in Supplement Appendix 4.1.

DOE PCP staff confirmed by calculation that the A_1 mixture of the Table 1.5.B content configuration shown in Supplement Appendix 4.1 is 0.693, based on the POP SF assemblies which have slightly more Pu mass/radioactivity than the Vogan SF assemblies.

Based on review of the statements and representations in the SARP, as supplemented, and DOE PCP staff's confirmatory calculation, staff has reasonable assurance that the package containment design has been adequately described and evaluated and that the package continues to meet the containment requirements of 10 CFR Part 71.

5.0 Shielding Evaluation

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

For Type A packages, including Type A fissile, the compliance requirements are § 71.47(a) for non-exclusive use transport and § 71.47(b) for exclusive use transport.

There were no changes to the shielding safety design features of the packaging for the SARP

Supplement Table 1.5.B content configuration. The applicant intends to the limit the contents so that package meets § 71.47(a) for non-exclusive use transport.

The applicant updated shielding calculation N-CLC-G-00182 to evaluate the Table 1.5.B content configuration, of 52 SF assemblies, with each assembly loaded with 18 grams or Pu Metal or Oxide, and total of 936 grams per package, as shown in Supplement Table 5.9. The isotopic composition of the plutonium is 93.5% ^{239}Pu, 6.0% ^{240}Pu, and 0.5% ^{241}Pu by weigh.

The applicant calculated the maximum radiation level at the surface of the package and at 1-meter to determine the transport index (TI). The applicant's results are shown in Supplement Table 5.3 (summary): the maximum radiation level is at the side of the package and is approximately 150.2 mrem/hr., the radiation level at 1-meter from the package is 0.54 mrem/hr.; consequently, the calculated TI is 0.6. DOE PCP staff confirmed the applicant's results by analysis.

The applicant sufficiently demonstrated that the package with the Table 1.5.B content limits should meet the requirements of § 71.47(a), which is verified by measurement prior to offering the package for transport to ensure compliance.

Based on review of the statements and representations in the SARP, as supplemented, and DOE PCP staff's confirmatory analysis, staff has reasonable assurance that the package 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 purpose of the criticality review is to confirm that the package together with its contents meet the requirements in 10 CFR Part 71 for nuclear criticality safety (NCS).

There were no changes to the NCS safety design features of the packaging for the Supplement Table 1.5.B content configuration. The previous NCS evaluation (N-NCS-A-00047) for the Supplement Table 1.5 configuration authorized in CoC Rev.16 Table 5, requires supplementation for the new content configuration.

The applicant performed a new NCS evaluation of the Table 1.5.B content configuration in N-NCS-A-00048, of the package with 52 SF assemblies, with each assembly loaded with 18 grams or Pu Metal or Oxide, and total of 936 grams per package. Although the actual isotopic composition of the plutonium is 93.5% ^{239}Pu, 6.0% ^{240}Pu, and 0.5% ^{241}Pu by weigh, the applicant assumed all Pu was ^{239}Pu for maximum reactivity.

A summary of the nuclear criticality safety analysis of the Table1.5.B content configuration is listed in Supplement Table 6.3 for a single package evaluation, an NCT infinite-array, and an HAC 12x14x8 array of packages.

DOE PCP staff independently performed Monte Carlo analyses using the MCNP code (version

6.2) to confirm the criticality safety under the most reactive conditions of the proposed loading and compliance with §§ 71.55 and 59, for NCS under NCT and HAC.

6.1 Content Configuration for NCS Evaluation

The Table 1.5.B content configuration consists of plutonium metal and oxide in special form, with up to 52 SF assemblies packaged in two, 5-quart SAVY convenience containers. The actual maximum fissile mass (^{239}Pu and ^{241}Pu) per package is 880 grams, but for the NCS evaluation, the applicant assumed 936 grams of ^{239}Pu per package. The density of the Pu metal (in Vogan assemblies) is 19.84 g/cm^3 and the density of Pu oxide (in POP assemblies) is 11.46 g/cm^3. The NCS evaluation omitted the SAVY container from the model configuration and instead assumed the assemblies were arranged in 4 stacks of 13 each, in a triangular-pitched array.

The Vogan SF assembly is described and illustrated in Supplement Section 6.3.4.1. The overall dimensions of an assembly are 1.3 inches in diameter and 0.5 inch height. The total volume for a single Vogan assembly is less than 10.875 cm^3. The volume of the plutonium inside the assembly is close to 3.364 cm^3 based on the mass of the contents.

The POP SF assembly is described and illustrated in Supplement Section 6.3.4.2. The overall dimensions of an assembly are 1.3 inches in diameter and 0.460 inch in height (actual is 0.480). The total volume for a single POP assembly is about 10.440 cm^3. The plutonium oxide fills the innermost volume of about 5.99 cm^3.

6.2 Package Model Configuration for NCS Evaluation

The package model for applicant's NCS evaluation is described in Supplement Section 6.3.4, *Model Configurations for the Table 1.5 Content Envelope*.

The NCS model is based on a simplified geometrical representation of the package using right circular cylinders for the 30-gallon and 55-gallon drums, and nominal component dimensions using the SCALE 6.1/KENO-VI code with 238-group ENDF/B-VII cross sections (ORNL/TM-2005/39). The 52 Vogan or POP SF assemblies are modeled in four stacks with 13 SF assemblies in each stack, in a closely packed, triangular-pitched array. This model omits the spacing between stacks of SF assemblies that would occur if the assemblies were loaded in the chip carrier and overpacked in the SAVY containers. The array is vertically centered in the middle or side of the 30-gallon drum, with the remaining space inside the drum occupied by air, water, or polyethylene.

The packaging model dimensions are shown in Supplement Table 6-15 *Drum Dimensions for NCT and HAC Models (Content Table 1.5)* and are consistent with the applicable packaging drawings.

The 55-gallon drum and insulation between the drums are not included in the NCS model for HAC.

6.3 Summary of SARP NCS Evaluation and Staff's Confirmatory Analysis

Single Package Evaluation

The single package evaluation in Supplement, Section 6.4.4, considers an undamaged package surrounded by 30-cm of water on all sides (water reflected) and the 30-gallon drum is filled with air (dry), water (flooded), or polyethylene (dunnage). The applicant also included cases for each drum-fill configuration where the polyethylene foam between the 30-gallon and 55-gallon drum is also replaced with water. The 52 SF Vogan or POP SF assemblies are modeled in four stacks with 13 assemblies in each stack, in a closely packed, triangular-pitched array. The stacks were vertically centered on the center line or at the side of the 30-gallon drum. This four-stack arrangement is conservative since it provides more interaction between assemblies than modelling them as physically separated stacks. The applicant's results are shown in Supplement Table 6.31 – *Single Unit Results (Content Table 1.5)*.

SER Table 6.1 below shows a comparison of the applicant's NCS evaluation results of the most reactive single package configuration with DOE PCP staff's confirmatory analysis results. The applicant's $k_{eff} + 2\sigma$ results are consistent with staff's and well below the k_{safe} value of 0.892, per Supplement Table 6.48 – *Validation k_{safe} Values (Content Table 1.5)*. The results below demonstrate the most reactive configuration in accordance with § 71.55(b).

Table 6.1 Single Package Comparision

Single Package	$k_{eff} + 2\sigma$	
	SARP	**Staff**
Vogan SF Assemblies center-center of the 30-gal. drum filled with polyethylene dunnage, 30 cm of water reflection, and insulation between drums.	0.288	0.287
POP SF Assemblies center-center of the 30-gal drum filled with polyethylene dunnage, 30 cm of water reflection, and water between drums.	0.389	0.360

NCT Array

An NCT array of packages is evaluated in Supplement, Section 6.5.4. This configuration consists of an infinite, triangular pitched, array of undamaged drums. It is modeled infinite in both the vertical and horizontal directions meaning that neutron leakage does not occur. To make it an infinite array, a tightly fit hexagonal prism is modeled around the 55-gallon drum, with the six horizontal surfaces treated with a reflective boundary condition and the vertical surfaces treated with a periodic boundary condition. The 30-gallon drum is filled with air (dry), water (flooded), or polyethylene (dunnage). The 52 SF Vogan or POP SF assemblies are modeled in four stacks with 13 assemblies in each stack, in a closely packed, triangular-pitched array. The stacks were vertically centered or at the bottom at the center or at the side of the 30-gallon drum. The applicant's results are shown in Supplement Table 6.36 – *NCT Array Results (Content Table 1.5).*

SER Table 6.2 below shows a comparison of the applicant's NCS evaluation results of the most reactive configuration for an infinite array of packages under NCT with DOE PCP staff's confirmatory analysis results. The applicant's $k_{eff} + 2\sigma$ results are consistent with staff's and well below the k_{safe} value of 0.892, per Supplement Table 6.48 – *Validation k_{safe} Values (Content Table*

1.5). The results below demonstrate compliance with the §§ 71.55(b) and 71.59(a)(1).

Table 6.2 NCT Infinite Array Comparision

Infinite Number of Undamaged Packages	$k_{eff} + 2\sigma$	
	SARP	**Staff**
Vogan SF Assemblies at the side of the 30-gal. drum and drum filled with polyethylene dunnage.	0.290	0.284
POP SF Assemblies at the side of the 30-gal. drum and drum filled with polyethylene dunnage.	0.393	0.357

HAC Arrays

An HAC infinite and fixed array of packages are evaluated in Supplement, Section 6.6.4. Both arrays omit the 55-gallon drum and insulation between the drums, assuming they were damaged by the HAC tests.

To make it an infinite array, a tightly fit hexagonal prism is modeled around the 30-gallon drum, with the six horizontal surfaces treated with a reflective boundary condition and the vertical surfaces treated with a periodic boundary condition. The 30-gallon drum is filled with air (dry), water (flooded), or polyethylene (dunnage). The 52 SF Vogan or POP SF assemblies are modeled in four stacks with 13 assemblies in each stack, in a closely packed, triangular-pitched array. The stacks were vertically centered on the center line or at the side of the 30-gallon drum. The applicant's results for the HAC infinite array are shown in Supplement Table 6.43 – *Infinite HAC Array Results (Content Table 1.5).* For both Vogan and POP configurations, the $k_{eff} + 2\sigma$ results exceed the k_{safe} value of 0.892, per Supplement Table 6.48 – *Validation k_{safe} Values (Content Table 1.5)*. Two of the six Vogan configurations and six of six POP configurations exceed k_{safe}. In both Vogan cases the 30 gallons drums were filled with air (dry), and in one case the stacks of SF Assemblies were in the center of the drum and in the other case the stacks were at the side of the drum. Although all six POP cases exceed k_{safe}, the two most reactive cases were with the 30 gallons drums were filled with air (dry) and the stacks of SF Assemblies at the center or side of the drum.

Next, the applicant performed an evaluation of a 12x14x8 closely packed triangular array of packages, in the shape of a cube, and surrounded by 30 cm of water. The 30-gallon drum is filled with air (dry), water (flooded), or polyethylene (dunnage). The 52 SF Vogan or POP SF assemblies are modeled in four stacks with 13 assemblies in each stack, in a closely packed, triangular-pitched array. The stacks were vertically centered on the center line or at the side of the 30-gallon drum. The assemblies on adjacent packages were shifted on the right or left side of the drum to minimize the distance between them and to maximize their interaction. The applicant's results are shown in Supplement Table 6.44 – *Assemblies in HAC 9979 Packages in a Finite Array of 12x14x8 Drums (Content Table 1.5)*.

SER Table 6.3 below shows a comparison of the applicant's NCS evaluation results of the most reactive configuration for 12×14×8 array of packages under HAC with DOE PCP staff's confirmatory analysis results. The applicant's keff + 2σ results are consistent with staff's and

well below the k_{safe} value of 0.892, per Supplement Table 6.48 – *Validation k_{safe} Values (Content Table 1.5)*. The results below demonstrate compliance with the §§ 71.55(e) and 71.59(a)(2).

Table 6.3 HAC Finite Array Comparision

HAC 12×14×8 Array	$k_{eff} + 2\sigma$	
	SARP	Staff
Vogan SF Assemblies at the side of the 30-gal. drum and drum filled with polyethylene dunnage, array surrounded by 30-cm of water.	0.318	0.322
POP SF Assemblies at the side of the 30-gal. drum and drum filled with polyethylene dunnage, array surrounded by 30-cm of water.	0.460	0.438

The CSI calculation, of 0.1, in Supplement Section 6.1.3.4 and Table 6-7 is based on the 12×14×8 array for HAC for the Table 1.5.B contents.

6.5 Conclusion

Based on review of the statements and representations in the SARP, as supplemented, and DOE PCP staff's confirmatory analysis, staff has reasonable assurance that the package nuclear criticality safety design has been adequately described and evaluated and that the package meets the sub-criticality requirements of 10 CFR Part 71.

7.0 Operating Procedures

The SARP provides a description of package operations, including package loading and unloading operations, and the preparation of an empty package for shipment. Loading and unloading procedures show a general approach to perform operational activities because site-specific conditions may require the use of different equipment and loading or unloading steps.

The new content configuration for Supplement Table 1.5.B does not affect the existing Operating Procedures for the packaging. The applicant made one technical change in the Supplement to correct an error in SARP Section 7.4.4 *Hydrogen Gas Measurement and Sampling*, Step 4(a)(ii) to change the shipping extension for CoC Table 1.4 materials from 360 days to 180 days. This correction in the Supplement is consistent with Condition 6 of the CoC.

For the Table 1.5.B content configuration, up to 52 Vogan or POP SF assemblies, or any combination of the two may be offered for transport in the package. These contents may be loaded directly in the 30-gallon drum in accordance with the *General Payload Configuration* requirements in Supplement Section 1.2.2.3, or loaded in two, 5-quart SAVY containers, up to 26 assemblies per container, in accordance with *Packing Configuration* in Supplement Section 1.2.2.7.

DOE PCP staff reviewed the operating procedures in Supplement Chapter7 and concluded that the procedures are adequate for use of the package for shipping the Table 1.5.B contents.

Based on review of the statements and representations in the SARP, as supplemented, DOE PCP

staff has reasonable assurance that the package operating procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will continue to 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.

The new content configuration in Supplement Table 1.5.B does not affect the existing Acceptance Tests and Maintenance Program for the packaging. The packaging components internal to the 30-gallon drum for the Table 1.5.B configuration are not important-to-safety items (i.e., are non-safety items), and require no acceptance testing or maintenance program for use in the package.

Based on review of the statements and representations in the SARP, as supplemented, DOE PCP staff has reasonable assurance that the packaging acceptance tests and maintenance program meet the requirements of 10 CFR Part 71 and are adequate to assure packaging performance during its service life.

9.0 QUALITY ASSURANCE

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

The new content configuration for SARP Supplement Table 1.5.B does not affect the existing QA requirements for the 9979 packaging regarding packaging design, purchasing, fabrication, handling, shipping, storage, cleaning, assembly, inspection, testing, operation, maintenance, repair, and component modification, etc.

The applicant made many changes in the Supplement Chapter 9 for administrative improvements and clarifications, organization name-change due to the contract spin-off of SRNL to Battelle Savannah River Alliance (BSRA) from SRNS, spelling corrections, and non-substantive changes to punctuation or editorial items, including updates to the DOT and NRC regulatory references and other references in Supplement Section 9.20. SRNL/BSRA is working under the same Subpart H QAP approved by the DOE HCO (https://rampac.energy.gov/docs/default-source/qa/approval_0035_r0.pdf) for SRNS. DOE PCP staff confirmed by document review that these changes in the Supplement do not reduce the commitments in the QAP approved by the DOE HCO.

Based on review of the statements and representations in the SARP, as supplemented, DOE PCP staff has reasonable assurance that the package-specific requirements are consistent with their DOE approved Quality Assurance Program Document (QAPD), meet the requirements of 10 CFR 71 Subpart H, and are therefore adequate to assure the package will be operated in a

manner consistent with its evaluation for approval.

Conditions of Approval

The following changes to CoC Revision 16 are required to implement the amendment evaluated in this SER.

- Section 5(a)(3) Drawings – add missing "U" to drawing title for R-R4-G-00064.
- Section 5(b)(2) Maximum quantity of material per package:
  - Revise 5th paragraph to "Table 5a defines the limits for Pu and Am-241 in Special Form and Cesium-137 & Thorium-232 samples in Normal Form. One package may be used to ship eight Vogan or POP Assemblies, or combination of eight thereof, with ten Am1.N02 Assemblies, and Cs-137 and Th-232 samples in accordance with Table 5a." (split CoC Table 5 into Tables 5a and 5b).
  - Add new 6th (last) paragraph "Table 5b defines the limits for Pu in Special Form. One package may be used to ship a maximum of 52 Vogan or POP Assemblies, or combination thereof in accordance with Table 5b." (added reference to Table 5b).
  - Revise Table 5:
    - Revise table caption to "Table 5a – Content Envelope Limits for Vogan/POP, Am1.N02, Cs-137, & Th-232"
    - Revise Table 5 row header to "Total Mass per Special Form Assembly (For Tables 5a and 5b)" (added Tables 5a and 5b)
  - Add new table "Table 5b. – Content Envelope Limits for Vogan/POP" based on the mass/isotope values from SARP Rev 7 supplement Table 5b.
  - Add Table 5b notes as follows:
    - "a. Up to 52 Vogan or POP Assemblies, or a mixture of 52 per package. Pu may include up to 4.5% gallium as an alloying metal."
    - "b. Total radioactive material per package is based on 52 POP Assemblies."
- Section 5(b)(3) Maximum Decay Heat:
  - Revise to "Tables 5a is 3.42E-01 watts and 5b is 2.11 watts." (changed Table 5 to 5a and added Table 5b)
- Section 5(c) Criticality Safety Index:
  - Revise to "CSI = 0.1 for Table 3 and Tables 5a and 5b contents." (changed Table 5 to 5a and added Table 5b))
- Section 5(d) Conditions:
  - Revise (3)(b) and (c) to add "…, as supplemented by 5.(e) of this certificate …"
  - Revise (6), 2nd bullet to "Tables 3, 5a, and 5b - shipping period is unlimited and with no minimum void volume." (changed Table 5 to 5a and added Table 5b))
  - Revise (8) to "The calculated external radiation for the package with Table 5a contents exceeds the limits in §71.47(a), so the package with Table 5a contents must be transported by exclusive use shipment only, in accordance with §71.47(b)." (changed Table 5 to Table 5a)
  - Revise (10) to "Revision 16 of this CoC may be used until October 31, 2024."
  - Revise (12) and (13) to "… package for domestic transport …" (clarification for foreign use of the package under a DOT certificate for import/export)

- Section 5(e) Supplements"
  - Add (1), "Safety Analysis Report for Packaging Model 9979 Type AF Shipping Package, S-SARP-G-00006, Revision 7 (Supplement for Docket 21-03-9979), July 2023."

Conclusion

Based on the statements and representations contained in the SARP, as supplemented, and the conditions listed above, DOE PCP staff concludes that the package design has been adequately described and evaluated and the Model 9979 continues to meet the requirements of 10 CFR Part 71.

References

[1] *Submittal of S-SARP-G-00006 Rev. 9a for Docket 21-03-9979*, Email Sobus to Shuler, August 2, 2022.
[2] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package*, S-SARP-G-00006, Revision 7 (Supplement for Docket 21-03-9979), July 2023.
[3] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package,* S-SARP-G-00006, Revision 9a, July 2022.
[4] *Q1 Comments from Review of Document Submittals for Docket 21-03-9979*, Memorandum Shuler to Sobus, December 22, 2022.
[5] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package,* S-SARP-G-00006, Revision 9b, page changes, February 8, 2023.
[6] *Docket 21-03-9979 Independent Technical Complete*, Memorandum Shuler to Sobus, June 20, 2023.
[7] *RE: Docket 21-03-9979, Submittal of 9979 Rev 9a/9b*, Email Han to Gelder, August 7, 2023.