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DOE Packaging Certification Program

Safety Evaluation Report for Addition of Low Enriched Uranium Cube or Plates as Authorized Contents in the 9979 Package & Renewal of the Certificate of Compliance

Dockets No. 13-33-9979 and 15-13-9979

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) staff's technical review of the application submitted by the Savannah River Operations Office (SROO) for the Los Alamos National Laboratory (LANL) in support of LANL missions and renewal of the DOE Certificate of Compliance.

SUMMARY

By application [1, 2] dated July 22, 2013, as supplemented May 14, 2015, [3] SROO (the Applicant) requested an amendment to DOE Certificate of Compliance (CoC) Number 9979, Revision 4 [4], to add low enriched uranium (LEU) cube or plates as authorized contents in the package and renewal of the CoC. The Applicant revised the 9979 Safety Analysis Report for Packaging (SARP) to add the new LEU contents, update drawings to match the current drawing revisions of the "licensed" in the CoC, clarify the definition of the package containment boundary, make corrections and minor updates (administrative changes), and incorporate previously approved SARP supplements (i.e., all items approved in CoC Rev 4).

PCP staff reviewed the application using the guidance in the DOE *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*.[5] Based on staff's confirmatory analyses and review of the statements and representation in the application, staff concludes that the package continues to meet the requirements of 10 CFR Part 71 [6], subject to the conditions in this Safety Evaluation Report (SER).

EVALUATION

1. GENERAL INFORMATION AND DRAWINGS

PCP staff performed a review of the general information and drawings provided in the application.

There are no changes to the packaging design for LEU contents (hereinafter referred to as "contents".) The Applicant assigned these contents to the Non-Combustible category and the "Standard and Sources" material form and added them to SARP Table 1-1. PCP staff concurs with this assignment.

The contents are uranium metal plates of less than or equal to 19.8 weight percent uranium-235 (U-235) and 80.2 weight percent uranium-238 (U-238). The radioactive material mass limits for these contents per package are 3.796 kg of U-235 and 15.396 kg of uranium-238 (U-238). LEU content limits are listed in SARP Table 1.3. Each plate is approximately 10 by 10 by 2 cm and weighs approximately 8.5 lbs. Contents may be offered for shipment as 4 individual plates or a 5 plate encapsulated assembly (i.e., cube). The cube assembly's encapsulant is a 30-mil thick stainless steel welded shell. Contents may be loaded directly into the 30-gallon Drum Assembly or may be first loaded in a convenience can and then loaded into the drum. The convenience can is stainless steel and approximately 15.9 cm diameter by 18.5 cm tall. Figure 1.5 in the SARP illustrates the LEU content configuration in the 9979 packaging. Dunnage is allowed to secure contents in the package; however, if combustible material is used for dunnage, then the contents

and dunnage must be loaded in the Thermal Insulation Bag (i.e., the Thermal Insulation Bag must be installed in the 30-gallon Drum Assembly, prior to content loading).

SARP Table 1.2 was revised to correct the content envelope limits for Tc-99, U-233, and Pu-238 to ensure these radioisotopes do not exceed one A_2.

CoC Revision 3 authorized packaging design changes to the "license" drawings to address commercial grade dedication, without a concurrent revision to the SARP. PCP staff verified the SARP drawings are now consistent with the CoC license drawings.

PCP staff concludes the information presented in the application provides an adequate basis for the evaluation of the package against the 10 CFR Part 71 requirements.

2. STRUCTURAL

There were no significant changes to the structural design of the packaging. PCP staff evaluated the new LEU contents for material compatibility between the plates and the stainless convenience cans, and between the stainless convenience cans and other packaging components, and concluded there will be no significant chemical, galvanic, or other reaction among them.

Based on the PCP staff's review of the statements and representations in the application, staff concludes the structural performance of the package is not affected by the new contents and the package continues to meet the requirements of 10 CFR Part 71.

3. THERMAL

There were no significant changes to the thermal design of the packaging. PCP staff confirmed, by document review, that the decay heat of the new LEU contents (3.6×10^{-4} watts) is significantly less than the maximum decay heat of the package (i.e., 3.5 watts). Therefore, the Applicant's previous thermal analyses are bounding for the LEU contents.

Based on the PCP staff's review of the statements and representations in the application, staff concludes the thermal performance of the package is not affected by the new contents and the package continues to meet the requirements of 10 CFR Part 71.

4. CONTAINMENT

There were no changes to the containment system design of the packaging; however, for consistency with §71.43(c) and (d), the Applicant revised the SARP to clarify the description of the containment system as "containment" verses "confinement" of the radioactive material and provided an illustration of the containment system in SARP Figure 4-1. PCP staff concurs with the SARP changes to clarify containment system description.

Based on the PCP staff's review of the statements and representations in the application, staff concludes the containment performance of the package is not affected by the new contents and the package continues to meet the requirements of 10 CFR Part 71.

5. SHIELDING

There were no changes to the shielding design of the packaging. PCP staff confirmed, by document review, the dose rate of the new LEU contents is bounded by the previous shielding evaluation for the sources used to calculate package dose rates. The Applicant noted the LEU content mass limit for U-235 (3,796 grams) exceeds the value (3,500 grams) used to calculate package dose rates, but justified the higher limit by reasoning that U-235 emits low energy photons so the photon dose rate from the additional U-235 will be minimal. PCP staff concurs with the Applicant's reasoning and agrees the existing shield evaluation is bounding for the new contents.

Based on the PCP staff's review of the statements and representations in the application, staff concludes the shielding performance of the package is not affected by the new contents and the package continues to meet the requirements of 10 CFR Part 71.

6. CRITICALITY

There were no changes to the criticality safety design of the packaging. The Applicant performed a criticality safety evaluation of the new LEU contents and documented the results in SARP Appendix 6.2. PCP staff confirmed, by document review and independent confirmatory analyses (Monte Carlo), that the package complies with §71.55 and §71.59 for criticality safety.

Packaging Description

There were no changes to the packaging description. PCP staff confirmed that the materials and models used in the Applicant's criticality calculations are consistent with the SARP drawings and the detailed package description.

Contents

LEU plates in cube and individual-plate form are as described in SARP Section 1.2.2.5 and Table 1-3.

Criticality Models

The Applicant used KENO-VI code for criticality analyses of the LEU contents. The contents and neutronically significant components of the packaging were included in the KENO-VI models. Separate models were developed to analyze a single package and arrays of the various sizes under normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

The Standard Composition Library and the 238GROUPNDF5 nuclear data library in the SCALE code package were used for all KENO-VI calculations in the SARP and in the PCP staff's confirmatory analyses. The benchmark evaluations for the new LEU contents are documented in SARP Section 6.8.2. The minimum k_{safe} value for LEU contents is 0.916; however, the Applicant chose to use minimum k_{safe} value 0.912 (highly enriched uranium) for the criticality evaluation for simplicity. Therefore, any configurations of 9979 packages containing LEU cubes

or plates where $k_{eff} + 2\sigma$ is less than k_{safe} are deemed subcritical. All SARP criticality calculations incorporated sufficient neutron histories to ensure statistical uncertainty (σ) less than 0.002 and adequate convergence. PCP staff concurs that the benchmark experiments and corresponding bias value are applicable and conservative as applied to the 9979 package with the LEU contents described in the SARP.

Summary of SARP Criticality Evaluation and PCP Staff's Confirmatory Analyses

The results of the criticality safety evaluation are summarized in SARP Table 6-1, for single package, NCT arrays, and HAC arrays. PCP staff confirmed the results by analyses.

Single Package Evaluation

SARP Section 6.4.2 considers two single package LEU content configurations with the package surrounded by water. The first content configuration is one LEU cube positioned in various locations in the inner drum and evaluated for conditions when the drums are dry or flooded with water and/or the inner drum is filled with polyethylene. The most reactive case for this configuration is $k_{eff} + 2\sigma = 0.593$, when the cube is centered in the inner drum and drum is filled with polyethylene. The most reactive water moderated case is $k_{eff} + 2\sigma = 0.568$, when water density equals one. The second package content configuration is four individual LEU plates positioned in the inner drum in horizontal and vertical orientations and the distance between plates varied, and evaluated for conditions when the drums are flooded with water and/or the inner drum filled with polyethylene. The most reactive case for this configuration is $k_{eff} + 2\sigma = 0.683$, when the plates are horizontally or vertically oriented in the center of the inner drum, each separated by 3.11 inches, and the inner drum and drum is filled with polyethylene. The Applicant demonstrated a single package with LEU contents is subcritical under the most reactive credible conditions and meets the requirements of §71.55(b).

NCT Array Evaluation

The NCT models for LEU cubes in triangular pitched arrays varied from 3 x 3 x 3 units up to 15 x 15 x 15 units to determine the array size for which k_{eff} is less than k_{safe}. The Applicant modeled flooded conditions for the NCT with water or polyethylene filling the inner drum and water filling the outer drum. An infinite NCT array model resulted in a critical configuration ($k_{eff} + 2\sigma = 1.322$). The maximum $k_{eff} + 2\sigma$ for finite arrays is 0.591, for inner drums filled with polyethylene. This result is significantly below k_{safe} (0.912) and demonstrates that a finite array of LEU cubes will remain subcritical under conditions of optimal moderation.

The NCT models for LEU plates considered only 15 x 15 x 15 units since the analysis for LEU cubes determined that this size was less than k_{safe}. Arrays with LEU Plates parallel to any of the axes used the optimally moderated spacing determined during Single Package evaluation. The Applicant modeled flooded conditions for the NCT analysis with water or polyethylene filling the inner drum and water filling the outer drum. The plates were modeled as perpendicular to the z-axis or the x-axis with water or polyethylene between them. The maximum $k_{eff} + 2\sigma$ for finite arrays is 0.675 for inner drums filled with polyethylene. This result is significantly below

k_{safe} (0.912) and demonstrates that a finite array of LEU plates will remain subcritical under conditions of optimal moderation.

PCP staff confirms that the package with LEU contents meets the requirements of §71.55(d) and §71.59((a)(1).

HAC Array Evaluation

The HAC array models assumed the outer drum was completely removed and the inner drum dry or flooded. The fissile material was modeled as shifted to the right or left side of the drum so that each set of two drums has material as close together as possible.

The HAC array models for LEU cubes in triangular pitched arrays varied from 3 x 3 x 3 units up to 15 x 15 x 15 units to determine the array size for which k_{eff} is less than k_{safe}. The infinite HAC array model resulted in a critical configuration ($k_{eff} + 2\sigma = 1.486$). The maximum $k_{eff} + 2\sigma$ for finite arrays is 0.768, for drums filled with polyethylene. This result is significantly below k_{safe} (0.912) and demonstrates that a finite array of LEU cubes will remain subcritical under conditions of optimal moderation.

The HAC array models for LEU plates considered only 15 x 15 x 15 units since the analysis for LEU cubes determined that this size was less than k_{safe}. The array models evaluated cases with the plates at the center of the inner drum for all rows and with the plates alternating between the top and bottom of the inner drums. The Applicant modeled plates with 3.11 cm spacing (i.e., optimal spacing from single package cases) perpendicular to either the z-axis or the x-axis and the inner drum filled with either water or polyethylene. The maximum $k_{eff} + 2\sigma$ for finite arrays is 0.859, for drums filled with polyethylene. This result is significantly below k_{safe} (0.912) and demonstrates that a finite array of LEU plates will remain subcritical under conditions of optimal moderation.

PCP staff confirms that the package with LEU contents meets the requirements of §71.55(e) and §71.59(a)(2).

Criticality Safety Index

The Applicant calculated the criticality safety index (CSI) for 15 x 15 x 15 NCT and HAC arrays in accordance with §71.59(b). The CSI is 0.1 (rounded up to one decimal place). PCP staff confirmed that the CSI calculation is correct.

Based on the PCP staff's confirmatory analyses and review of the statements and representations in the application, staff concludes the nuclear criticality safety performance of the package is not affected by the new contents and the package continues to meet the requirements of 10 CFR Part 71.

7. PACKAGE OPERATIONS

There were no changes to the package operations. Based on the PCP staff's review of the statements and representations in the application, 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. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

There were no changes to the acceptance and maintenance for the packaging. Based on the PCP staff's review of the statements and representations in the application, staff concludes the acceptance tests and maintenance program for the packaging meet the requirements of 10 CFR Part 71 to assure packaging performance during its service life. The procedure for repair of Serial Numbers 11-100 thru 11-599 was added as Appendix 8.2 and removed from the CoC.

9. QUALITY ASSURANCE

There were no changes to the quality assurance requirements for the packaging. Based on the PCP staff's review of the statements and representations in the application, staff concludes the quality assurance program requirements for the packaging meet the requirements of 10 CFR Part 71, Subpart H.

CONDITIONS

1. Drawings (updated from CoC Rev 4)

    - R-R5-G-00006, Revision 4, 9979 Type AF Package Tree (U)
    - R-R2-G-00057, Rev 7, 9979 Type AF 55 Gallon Drum Sub-Assembly and Weldment (U)
    - R-R2-G-00059, Revision 5, 9979 Type AF 55 Gallon Drum Lid Sub-Assembly and Weldment (U)

2. Packaging serial numbers 11-100 through 11-599 must be modified in accordance with Appendix 8.2 of the SARP, prior to authorized use under this certificate.

CONCLUSION

Based on the PCP staff's confirmatory analyses and review of the statements and representations in the application, staff concludes that the Model No. 9979 package design has been adequately described and evaluated and that new LEU contents do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

REFERENCES

[1] *Submittal of the Safety Analysis Report for Packaging (SARP) Model 9979 (S-SARP-G-00006, Revision 3)*, Memorandum from Patrick McGuire to James M. Shuler, July 22, 2013.

[2] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package*, S-SARP-G-00006, Revision 3, July 2013, Savannah River National Laboratory, Aiken, South Carolina.

[3] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package*, S-SARP-G-00006, Revision 4, March 2015, Savannah River National Laboratory, Aiken, South Carolina.

[4] DOE Certificate of Compliance, Certificate Number 9979, Revision 4, November 24, 2014.

[5] Lawrence Livermore National Laboratory, *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings,* UCID-21218, Revision 3, February 2008, Livermore, California.

[6] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), Packaging and Transportation of Radioactive Materials.