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DOE Packaging Certification Program

Safety Evaluation Report for Content Amendment to Department of Energy Certificate of Compliance 9315 for the Model ES-3100 Package Design for Low Density Bulk Uranium Oxide

Docket No. 18-43-9315

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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 by the National Nuclear Security Administration (NNSA) Office of Material Management and Minimization (NA-23) to amend DOE Certificate of Compliance (CoC) Number 9315, to lower the bulk density limit for Highly Enriched Uranium (HEU) oxide for air transport.

Evaluation

By letter [1] dated June 28, 2018, NNSA NA-23 requested DOE PCP to authorize lowering the bulk density limit of HEU oxide for air transport in the packaging, from 2.0 grams/cm^3 to 1.0 grams/cm^3.

The applicant (NA-23) submitted a supplemental nuclear criticality safety evaluation [2] to the ES-3100 Safety Analysis Report for Packaging (SARP) [3] in support of this request, and provided, as an attachment [4] to the request letter, a chapter-by-chapter evaluation of the impact of the bulk density change with respect to the SARP.

PCP staff reviewed the SARP and the applicant's chapter-by-chapter evaluation (Ref. 4) to confirm that lowering the bulk density limit of HEU oxide for air transport does not affect the safety features of the packaging design, operational features, or quality assurance requirements.

The scope of this SER is staff's review and confirmatory analysis of the applicant's supplemental nuclear criticality safety evaluation (Ref. 2).

1.0 Criticality Evaluation

PCP staff reviewed the SARP and supplemental nuclear criticality safety evaluation for the change requested by the applicant and performed a confirmatory criticality safety analysis, as described in the following sections.

1.1 Package Description

The Model ES-3100 package design includes a stainless steel containment vessel (CV) inside a 30 gallon outer drum (See Figures 1.1 and 1.2 of the SARP). The contents are placed in convenience cans or bottles or otherwise protected to prevent contamination of the interior surface of the CV. The package includes two features intended for criticality control: a neutron absorber that surrounds the CV and can spacers placed between convenience cans; both the neutron absorber and the can spacers are filled with alumina borated cement. The SARP drawings provide the dimensions of the relevant packaging components. Chapter 2 of the SARP provides material specifications for the packaging components.

Descriptions of the package design features include identification of packaging materials, densities and compositions of packaging materials, and the fissile/fissionable material forms, masses, and isotopic compositions of the payloads. PCP staff confirmed that criticality-related

information in the SARP is complete and representative of the actual materials specified for the package.

1.2 Contents

The authorized contents of the ES-3100 package are bulk HEU in the form of oxide (UO_2, UO_3, $U3O_8$, U_3O_8-Al, UO_2-Mg and UO_2-ZrO_2), uranium metal and alloy in the form of solid geometric shapes or broken pieces, uranium compounds, uranyl nitrate crystals (UNX), fuel elements from TRIGA reactors, and research reactor fuel elements or fuel components (See Tables 1.3, 1.3a, and 1.3b of the CoC for loading limits).

The applicant proposed to amend the lower density limit for bulk HEU in the form of oxide from 2.0 to 1.0 g/cm^3, for air transport.

1.3 Criticality Models

The design features of the ES-3100 package addressed in Section 6.1.1 of the SARP have not changed, and the same codes and standards addressed in Section 6.1.2 still apply. No change is employed in the methodology for demonstrating maximum reactivity. The criticality safety evaluation of the air transport limits for the ES-3100 package with HEU product oxide as low as 1.0 g/cm^3 is derived based on using explicit models of the HEU product oxides and materials of construction of the ES-3100 package.

The calculation models for air transport of HEU product oxide at densities down to 1.0 g/cm^3 are the same as found in the SARP, Section 6.9.10. These models evaluated HEU product oxides for densities from 6.54 to 2.0 g/cm^3. Model 5, as described in Section 6.3.1.4 of the SARP (with the excess water from wet Kaolite® homogenized with the HEU product oxide in the core, along with the water of saturation) is the configuration producing the highest k_{eff}. Therefore, it is the bounding model for air transport. The $k_{eff} + 2\sigma$ values are below the upper subcritical limit (USL) of 0.9368 for thermal energy HEU systems and 0.9352 for intermediate energy HEU systems; therefore, any configurations of ES-3100 packages with $k_{eff} + 2\sigma < k_{safe}$ are deemed subcritical.

1.4 Summary of Criticality Analysis and PCP Staff's Confirmatory Evaluation

Table 1 below compares the maximum $k_{eff} + 2\sigma$ results from the applicant's SCALE 6.0 calculations from the supplemental nuclear criticality evaluation (Ref. 2) and PCP staff's MCNP6 confirmatory analysis, for HEU oxide densities ranging from 1.0 to 5.0 g/cm^3, to the applicant's USL.

Staff's calculated maximum $k_{eff} + 2\sigma$ is 0.93694 for the case with U-235 mass of 4,753 grams and oxide density of 3.0 g/cm^3, and exceed the USL of 0.9368. However, the applicant's U-235 mass limit for HEU oxide in the density range of 3.0 g/cm^3 to 4.0 g/cm^3 is 4,750 grams (Ref 2,

Table 1). Staff's calculated maximum $k_{eff} + 2\sigma$ is 0.93619 for this case with U-235 mass of 4,750 grams and oxide density of 3.0 g/cm^3, and is less than the USL.

Table 1 - Criticality Analysis Results for HEU Oxide Densities Ranging from 1.0 to 5.0 g/cm^3

U-235 mass (g)	Oxide density (g/cm^3)	Maximum keff + 2σ		
		Applicant (SCALE 6.0)	Staff (MCNP6)	USL
7570	5.0	0.93440	0.93514	0.9352
6030	4.0	0.93362	0.93343	0.9352
4753	3.0	0.93643	0.93694	0.9368
3389	2.0	0.93570	0.93629	0.9368
2773	1.5	0.93643	0.93589	0.9368
2157	1.0	0.93546	0.93615	0.9368

Table 2 below shows the applicant's and PCP staff's calculated U-235 mass limits for HEU oxide loading at densities ranging from 1.0 to 6.54 g/cm^3. Staff's results are slightly higher than the applicant's results.

Table 2 - Calculated U-235 Mass Limits for HEU oxide loading at densities ranging from 1.0 to 6.54 g/cm^3

Density Range (g/cm^3)	U-235 mass limit (g)	
	Applicant	Staff
≥ 5.0 and ≤ 6.54	7570	7570
≥ 4.0 and < 5.0	6020	6030
≥ 3.0 and < 4.0	4750	4753
≥ 2.0 and <3.0	3380	3389
≥ 1.5 and < 2.0	2770	2773
≥ 1.0 and < 1.5	2150	2157

1.6 Evaluation Findings

Based on the statements and representations in the SARP, as supplemented by RP 801940-0020 000 00, and PCP staff's confirmatory evaluation, staff finds that the criticality safety design and performance presented in Chapter 6, as supplemented, is acceptable and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

Conditions of Approval

The following changes to the CoC are required to implement the conditions in this SER.

- Table 1.3b for HEU Oxide – add CSI and loading limits for HEU oxide bulk densities from 1.0 to 6.54 g/cm^3.
- Table 1.3b Notes – revise as follows:
  - i – Allowable uranium oxide bulk densities are 1.0–6.54 g/cm^3. Moisture content in oxide is limited to 3 wt.% water.

- Condition 5.(d)(13) revise 1st sentence to " Revisions 12, 13, or 14 of the certificate may be used until December 31, 2018."
- Supplement 5.(e)(5) add for this application, "Request for Certificate Revision or Letter Amendment to Ship Low Density Oxide by Air Transport in the ES-3100 Package, CoC USA/9315/B(U)F-96 (DOE), Letter Kilmartin to Shuler, June 28, 2018."
- Supplement 5.(e)(5) add for this application, "Criticality Evaluation of Low Density Product Oxides for Air Transport for the ES-3100 Package, RP 801940-0020 000 00, June 2018."

Conclusion

On the basis of the statements and representations in the SARP, as supplemented by RP 801940-0020 000 00, and PCP staff's confirmatory evaluation, staff finds that the changes do not affect the performance of the package and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met, subject to the conditions above.

References

[1] Request for Certificate Revision or Letter Amendment to Ship Low Density Oxide by Air Transport in the ES-3100 Package, CoC USA/9315/B(U)F-96 (DOE), Letter Kilmartin to Shuler, June 28, 2018.

[2] Criticality Evaluation of Low Density Product Oxides for Air Transport for the ES-3100 Package, RP 801940-0020 000 00, Consolidated Nuclear Security, LLC, June 2018

[3] Safety Analysis Report for Packaging, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents, SP-PKG-801940-A001 Revision 2 with Page Change 1, Consolidated Nuclear Security, LLC, June 26, 2017.

[4] Evaluation of ES-3100 SARP Chapters for Impacts of Increasing the Range of Bulk Oxide Densities by Air Transport, attachment to Reference [1].