MEMORANDUM FOR WILLIAM E. KILMARTIN  
DIRECTOR, MATERIAL DISPOSITION PROGRAM  
OFFICE OF MATERIALS MANAGEMENT AND  
MINIMIZATION  
NATIONAL NUCLEAR SECURITY ADMINISTRATION  

FROM: JULIA C. SHENK  
HEADQUARTERS CERTIFYING OFFICIAL  
DIRECTOR  
OFFICE OF PACKAGING AND TRANSPORTATION  

SUBJECT: Amendment to DOE Certificate of Compliance 9315 to Authorize Use of the Model ES-3100 Packaging for Shipment of Highly Enriched Uranium/Molybdenum Alloy Right Annular Cylinder  

In response to your request dated September 11, 2019, Department of Energy Certificate of the Compliance (CoC) Number 9315, Revision 16, is amended to authorize use of the Model ES-3100 packaging for shipment of a Highly Enriched Uranium/Molybdenum Alloy Right Annular Cylinder (annulus), based on this memorandum and its attached Safety Evaluation Report, with the following conditions:

1. The annulus, prior to aluminum plating, is limited to the following dimensions: 5.80 inches in length (max), outer diameter of 3.86 inches (max), and an inner diameter of 1.35 inches (min),

2. The annulus may be plated with aluminum to a thickness of approximately 0.01 inch (the plating thickness is not included in the dimensional limits given above; however, the criticality evaluation included the annulus with zero aluminum plating, up to a plating thickness of 0.25 inch),

3. The maximum radioactive mass for the annulus is 16.79 kg,

4. The maximum fissile mass and enrichment for the annulus is 14.91 kg of U-235 and 93.5% respectively,

5. The total mass of the annulus loading configuration and all packing materials loaded in the Containment Vessel (CV) shall not exceed the CoC limit of 40.82 kg,

6. Prior to loading in the CV, the annulus may be placed in polyethylene bagging and then metal steel caps placed over each end of the annulus which may then be secured to the bagging with metal tape, as necessary; the metal steel caps are optional,

7. Only one annulus per CV per package is authorized,
8. Only ground transport is authorized; all other modes of transportation are prohibited.

9. This authorization may be used only with DOE CoC 9315 Revision 15 or Revision 16: conditions in the CoC applicable to uranium metal and alloy in the form of solid geometric shapes, Cylinder A, for ground transport, apply to the annulus content configuration, except Condition 5.(d)(3), as neutron absorber spacers are not required, and

10. This authorization shall expire on September 30, 2020.

If you have any questions, please contact me or Dr. James Shuler of my office at (301) 903-5513.

Attachment

cc: Virginia Kay, NA-233
    Stan Thomas, Y-12
    Yung Liu, ANL
    James M. Shuler, EM-4.24
Safety Evaluation Report
for
Model No. ES-3100
Certificate of Compliance No. 9315, Revision 16
Letter of Authorization to use the Model ES-3100 for
Shipment of Highly Enriched Uranium/Molybdenum Alloy
Right Annular Cylinder
Docket No. 19-35-9315

Prepared by: James M. Shuler
Manager, Packaging Certification Program
Office of Packaging and Transportation

Date: 1/21/20

Approved by: Julia C. Shenk
Headquarters Certifying Official
Director, Office of Packaging and Transportation

Digitally signed by Julia C. Shenk
Date: 2020.03.31 18:14:05
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Summary
By letter [1] dated September 11, 2019, the National Nuclear Security Administration (NNSA) Office of Material Management and Minimization (NA-23) requested that the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) amend DOE Certificate of Compliance (CoC) No. 9315 to authorize use of the Model ES-3100 for shipment of highly enriched uranium/molybdenum (HEU/Mo) alloy in annular form for an upcoming shipment. In response, the DOE Headquarters Certifying Official (HCO) will issue a Letter of Authorization (a.k.a., Letter Amendment) to amend Revision 16 of the CoC based on this Safety Evaluation Report (SER), in lieu of a permanent revision to the CoC.

An amendment to DOE CoC No. 9315 is required because the geometric shape of the proposed content is not authorized in the CoC, Section 5(b) and Table 1.3, or evaluated in the ES-3100 Safety Analysis Report for Packaging (SARP) [2] for nuclear criticality safety. The CoC authorizes bulk HEU in the form of uranium metal and alloy in the form of solid geometric shapes, such as cylinders, but not annular shapes.

The application [3] for package approval was prepared for NA-23 by Consolidated Nuclear Security, LLC, the current management and operating contractor of the Y-12 National Security Complex. The application is a nuclear criticality safety evaluation (NCSE) of the HEU/Mo alloy annulus design to supplement Chapter 6 of the SARP.

The HEU/Mo alloy annulus design, hereinafter referred to as “annulus,” is based on the Fast Burst Reactor Safety Block (FBRSB) design that was authorized by the HCO, by a letter amendment [4] issued March 12, 2018 (Docket No. 18-20-9315), for shipment in the ES-3100. The annulus has slightly greater dimensions than the FBRSB design and is intended to provide a bounding generic content definition for similar shapes and designs.

The overall dimensions; concentration, enrichment, and mass of U-235; and total radioactive material mass of the annulus are bounded by the limits in CoC Table 1.3 content description for Solid HEU metal, Cylinder A.

The annulus content loading configuration in the packaging containment vessel (CV) consists of a single annulus wrapped in a maximum of 500 grams of polyethylene, with metal end caps (optional), and approved can spacer materials and stainless steel scrubbers (sponges) for dunnage to fill the CV void space. This configuration complies with the Cylinder A content loading configuration authorized in Section 5(b) and Conditions 5(d)(7) and 5(d)(9) of the CoC.

There are no changes to the packaging design or operations for the annulus content configuration, but to demonstrate compliance with the requirements of §§71.55 and 71.59 of 10 CFR Part 71, Packaging and Transportation of Radioactive Material, for ground transport, the applicant performed an NCSE of the package with the annulus content configuration. PCP staff performed an independent technical review and confirmatory analysis of application to verify that the applicant’s maximum $k_{eff} \pm 2\sigma$ of 0.855 is adequately below the upper subcritical
limit (USL) of 0.9352 calculated in the NCSE and USL of 0.925 in SARP Section 6.8.3, and to verify the applicant’s CSI of 0.0 for the proposed content configuration.

Based on the statements and representations in the application, the SARP, PCP staff’s confirmatory evaluation, and the conditions listed in this SER, staff finds that the NA-23 request to authorize use of the packaging acceptable for shipment of the HEU/Mo alloy annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

**Evaluation**

**1.0 General Information**

The application submitted by NA-23 to DOE PCP in support of this request consists of the letter dated September 11, 2019 and supplemental NCSE to the ES-3100 SARP.

The annulus design is based on the FBR design that was authorized by the HCO for shipment in the ES-3100 by a letter amendment issued March 12, 2018 (Docket No. 18-20-9315). The annulus has slightly greater dimensions than the FBRSE design and is intended to provide a bounding generic content definition for similar shapes and designs.

There are no changes required to the packaging design or operations for the annulus content configuration.

**1.1 Packaging Description**

Detailed packaging descriptions, drawings, and content packing materials can be found in the SARP. The components of the packaging include a drum enhanced by impact-limiting and thermal-insulating materials, neutron-absorbing materials, and a containment vessel (CV) inside the drum.

A single annulus is prepared for loading in the CV with the same packing materials evaluated in the SARP for loading Solid HEU metal or alloy (specified geometric shapes), Cylinder A, for ground transport. Prior to loading in the CV, the annulus will be placed in a polyethylene bag, then carbon steel caps may be placed over each end of the annulus which may then be secured to the bag with metal tape, as necessary. The caps are optional. This configuration is limited to a maximum of 500 grams of polyethylene to comply with Conditions 5(d)(7) and 5(d)(9) of the CoC.

The annulus and packing materials will be loaded in the CV in the following order and is defined in this SER as the annulus content configuration:

1. Annulus in the bottom of the CV,
2. The remaining CV void space is filled with empty convenience can(s), with minimum vent hole size of 0.125-inch diameter hole through each can lid per CoC Condition 5(d)(8), and stainless steel scrubbers per CoC Condition 5(d)(8).

1.2 Contents
The annulus is a single piece of HEU in the form of uranium/molybdenum alloy with a maximum uranium weight of 95% and maximum U-235 enrichment of 93.5%. The calculated mass of the annulus is 16.79 kg. The maximum fissile mass of the annulus is 14.91 kg of U-235.

The annulus design is bounded by CoC limits for uranium enrichment (93.5% < 100 %), U-235 mass (14.91 kg < 15.000 kg) and total radioactive material mass (16.79 kg < 35.2 kg) for the package with Cylinder A, and must not exceed the concentrations of uranium isotopes and transuranic isotopes listed in CoC Tables 1.1 and 1.2b, respectively, or maximum content decay heat load of 5.0 watts for the package.

The annulus design dimensions used for the criticality model are 5.80 inches in length (max), outer diameter of 3.86 inches (max), and an inner diameter of 1.35 inches (min). The annulus may be plated with aluminum to a thickness of approximately 0.01 inch (the plating thickness is not included in the dimensional limits given above; however, the criticality evaluation included the annulus with zero aluminum plating, up to a plating thickness of 0.25 inch). The overall diameter of the annulus, 3.86 inches, is bounded by the CoC Table 1.3 limits for Cylinder A: 3.24 inches (min) and 4.25 inches (max).

The annulus content configuration is limited to 500 grams of polyethylene per package and must comply with CoC Conditions 5(d)(7) and 5(d)(9).

The maximum mass of the annulus content configuration, including all packing materials must not exceed the CoC limit of 40.82 kg.

1.3 Criticality Safety Index
The CSI of the package for annulus content configuration is 0.0. PCP staff confirmed the applicant’s results, using the procedure in 10 CFR 71.59(b).

1.4 Radiation Level and Transport Index
PCP staff confirmed that the radiation transport indices (TIs) are less than 10, which is the TI limit in 10 CFR 71.47(a) for non-exclusive use shipment. The actual TI of the package will be determined by measurement prior to shipment.

1.5 Conclusion
Based on a review of the statements and representations in the application, SARP, and PCP staff’s confirmatory evaluation, staff concludes that the information provided by the applicant is
adequate to evaluate the package for the annulus content configuration to the requirements of 10 CFR Part 71 for each technical discipline addressed in the subsequent sections of this SER.

2.0 Structural Evaluation
Based on the review of the statements and representations in the application, the SARP, and PCP staff’s confirmatory evaluation, staff finds that there are no structural issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

3.0 Thermal Evaluation
Based on the review of the statements and representations in the application, the SARP, and PCP staff’s confirmatory evaluation, staff finds that there are no thermal issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

4.0 Containment
Based on the review of the statements and representations in the application, the SARP, and PCP staff’s confirmatory evaluation, staff finds that there are no containment issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

5.0 Shielding Evaluation
Based on the review of the statements and representations in the application, the SARP, and PCP staff’s confirmatory evaluation, staff finds that there are no shielding issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

6.0 Criticality Evaluation
PCP staff reviewed the SARP and the applicant’s supplemental NCSE of the package for the proposed annulus content configuration and performed a confirmatory nuclear criticality safety analysis using the Monte Carlo N-Particle Transport Code (MCNP6) to independently evaluate the nuclear criticality safety of the package under the most reactive conditions.

6.1 Criticality Safety Design
The criticality safety design features of the packaging are addressed in Section 6.1.1 of the SARP and have not changed for annulus content configuration. The applicant used the same package performance assumptions in the supplemental NCSE as SARP Section 6.1.2, for consistency in the methodology for demonstrating maximum reactivity.

The annulus content configuration does not require the use of 277-4 Heavy Can Spacer Assemblies (CoC Drawing M2E801580A043) in the CV for nuclear criticality safety.
Empty convenience can(s), with a minimum vent hole size of 0.125 inch in diameter in the can lid, and stainless steel scrubbers are used for spacing and dunnage in the CV. SARP Table 2-7 lists the material specifications for the packaging components.

The package content loading restrictions stated in SARP Sect. 6.2.4 are modified below in this SER for applicability to the annulus content configuration, based on the supplemental NCSE:

1. The annulus to be shipped in the packaging may be placed in polyethylene bagging, and then metal caps placed over each end of the annulus which may then be secured to the bag with metal tape, as necessary. The end caps are optional.
2. Each annulus shall not exceed 14.92 kg of U-235 and only one annulus per package.
3. Not applicable for this content based on the supplemental NCSE: 277-4 canned spacers are not required.
4. Only one annulus per package. The void space in the CV may be filled with empty convenience cans and stainless steel scrubbers. The empty cans must have a vent hole in the lid, 0.32 cm (0.125 in.) minimum diameter, to prevent over-pressurization of the can in the event of a thermal accident.
5. The maximum uranium content of the annulus is 95 weight % and maximum U-235 enrichment is 93.5%.
6. The annulus dimensions are 5.80 inches in length (max), outer diameter of 3.86 inches (max), and an inner diameter of 1.35 inches (min).
7. The content loaded in the CV is defined as: one annulus (HEU fissile material) prepared in accordance with Step 1 (above); one empty vented convenience can(s); and stainless steel scrubbers. The maximum amount of hydrogenous packing material inside the CV shall not exceed an equivalent mass of 500 grams of polyethylene.
8. Not applicable for this content. The content configuration is specific to the annulus and unidentified HEU constituents are prohibited.
9. Not applicable for this content. HEU oxide and air transport prohibited.
10. Not applicable for this content. Only ground transport is authorized for use of the package to ship the annulus content configuration.

6.2 Contents
The annulus is a single piece of HEU in the form of uranium/molybdenum alloy with a maximum uranium weight of 95% and maximum U-235 enrichment of 93.5%. The calculated mass of the annulus is 16.79 kg. Any impurities in the uranium is bounded by the U-235. The maximum fissile mass of the annulus is 14.91 kg of U-235.

The applicant’s supplemental NCSE modeled the annulus with a length of 5.80 inches, outer diameter of 3.86 inches, and an inner diameter of 1.35 in inches, and wrapped in 500 grams of polyethylene with a uniform thickness of 0.78401 cm under normal conditions (poly thickness is slightly different for the varying of the aluminum plating cases). The annulus is plated with aluminum so the model evaluated cases with zero aluminum plating up to a plating thickness of 0.25 inch.
6.3 Model Configuration and Material Properties
The applicant evaluated the annulus model configuration described in Section 4.1 of the NSCE.

The material properties for the annulus (U-Mo, Aluminum, and polyethylene) are listed in NCSE Table 3. The material properties used in the NCSE for all other packaging components are from SARP Table 6.4.

6.4 Summary of NCSE Results and PCP Staff’s Criticality Safety Analyses
Table 6-1 of this SER summarizes and compares the applicant’s NCSE results and PCP staff’s nuclear criticality safety analyses results for the annulus content configuration for a single package and an infinite array of packages under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) in accordance with §§71.55 and 71.59.

The USL for the calculations performed in the NCSE (which are intermediate energy HEU systems per the results from KENO V.a outputs) would be 0.9352.

Based on the NCSE calculation results, $k_{\text{eff}} \pm 2\sigma$ values for the annulus content configuration are well below the NCSE USL of 0.9352 and SARP USL of 0.925, for a single package under the conditions of 71.55(b), (d), and (e), an array of undamaged packages under the conditions of 71.59(a)(1), and an array of damaged packages under the conditions of 71.59(a)(2).

The NCSE single package calculations were performed with the CV flooded with water and the annulus wrapped with 500 grams of polyethylene. Cases were run with annulus in bottom and center of the CV. Centering the annulus vertically in the CV is slightly more reactive. Additional cases were run by varying the aluminum plating thickness on the annulus from 0 to 0.25 inch, which displaces water in the CV: reactivity decreases as the aluminum thickness is increased. PCP staff performed independent confirmatory calculations and confirmed the system was more reactive with 500 grams of polyethylene.

NCSE array calculations were performed with the CV flooded with water and the annulus wrapped with 500 grams of polyethylene. Cases were run with annulus in bottom and center of the CV. Centering the annulus vertically in the CV is slightly more reactive. Additional cases were run by varying the aluminum plating thickness on the annulus from 0 to 0.25 inch, which displaces water in the CV: reactivity decreases as the aluminum thickness is increased. PCP staff confirmed the NCSE array calculation results for normal and accident conditions by independent confirmatory calculations.
6.5 **Single Package Evaluation (NCT and HAC)**

The applicant’s analyses in SARP Sect. 6.4 demonstrates that the calculated $k_{\text{eff}} \pm 2\sigma$ values increase as a function of increasing moisture fraction of the package external to the containment vessel (MOIFR). The applicant used a fully flooded, reflected package to calculate the neutron multiplication factors for the single package evaluation. For the annulus loading configuration in the NCSE Section 4.1 and SARP Section 6.3.1.1, the applicant modeled the annulus with 500 grams (max) of polyethylene wrapping, inside a flooded CV that is reflected on all sides by 30.48 cm of water. The applicant displaced water in the CV with various thicknesses of aluminum plating on the annulus. Full water reflection around the flooded CV was a more effective moderator and reflector than the flooded CV and the system was less reactive with aluminum in place of water (i.e., water is more reactive than aluminum.)

6.6 **Package Array Evaluation (NCT and HAC)**

The applicant’s analyses in SARP Sections 6.5 through 6.6 demonstrates that maximum reactivity occurs in an array of packages when the moisture fraction inside the containment vessel (MOIFR) equals 1.0 (i.e., CV is flooded) and the MOIFR in 1E-04 (i.e., package is dry). A MOIFR of 1E-04 pertains specifically to NCT or HAC, where the neutron poison of the body weldment liner inner cavity and the Kaolite are dry and where the recesses of the packaging outside of the CV and the interstitial space between packages in the array do not contain any residual moisture. There is an insignificant difference between the applicant’s calculated $k_{\text{eff}} \pm 2\sigma$ values for undamaged packages under NCT and for damaged packages under HAC. The applicant’s infinite package array calculation models for the annulus loading configuration
in the NCSE, Section 4.1, were based on the infinite package array model described in SARP Section 6.3.1.2.

6.7 Evaluation Findings

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no nuclear criticality safety issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

7.0 Package Operations

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no package operations issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

8.0 Acceptance Tests and Maintenance Program

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no acceptance tests and maintenance issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

9.0 Quality Assurance

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no quality assurance issues related to the request to authorize use of the packaging to ship the annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

Conditions of Approval

PCP staff finds the requested change to authorize use of the Model ES-3100 to ship HEU/Mo annulus configuration is acceptable and does not affect the ability of the package to meet 10 CFR Part 71 subject to the following conditions to amend the CoC:

1. The annulus, prior to aluminum plating, is limited to the following dimensions: 5.80 inches in length (max), outer diameter of 3.86 inches (max), and an inner diameter of 1.35 inches (min).
2. The annulus may be plated with aluminum to a thickness of approximately 0.01 inch (the plating thickness is not included in the dimensional limits given above; however, the
Criticality evaluation included the annulus with zero aluminum plating, up to a plating thickness of 0.25 inch,
3. The maximum radioactive mass for the annulus is 16.79 kg,
4. The maximum fissile mass and enrichment for the annulus are 14.91 kg of U-235 and 93.5% respectively,
5. The total mass of the annulus loading configuration and all packing materials loaded in the Containment Vessel (CV) shall not exceed the CoC limit of 40.82 kg,
6. Prior to loading in the CV, the annulus may be placed in polyethylene bagging and then metal steel caps placed over each end of the annulus which may then be secured to the bagging with metal tape, as necessary; the metal steel caps are optional,
7. Only one annulus per CV per package,
8. Only ground transport is authorized; all other modes of transportation are prohibited,
9. This authorization may be used only with DOE CoC 9315 Revision 15 or Revision 16: all conditions in the CoC applicable to uranium metal and alloy in the form of solid geometric shapes, Cylinder A, for ground transport, apply to the annulus content configuration, except Condition 5.(d)(3), as neutron absorber spacers are not required, and
10. This authorization shall expire on September 30, 2020.

Conclusion
Based on the review of the statements and representations in the application and the SARP, and PCP staff’s confirmatory evaluation as summarized in this SER and the conditions listed above, staff finds the use of the Model ES-3100 packaging acceptable for shipment of the HEU/Mo annulus content configuration. Therefore, staff has reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

References

