UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT

Docket No. 71-9342
Model No. Versa-Pac
Certificate of Compliance No. 71-9342
Revision 17

Summary

By application dated December 22, 2021 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21356B708), as supplemented on June 30, 2022, and July 28, 2022 (ADAMS Accession No. ML22180A114 and ML22209A190, respectively), Orano-Transport Logistics International, Inc. (Orano-TLI, TLI, or the applicant) requested that the U.S. Nuclear Regulatory Commission (NRC) revise Certificate of Compliance (CoC) No. 9342 for the Model No. Versa-Pac package per the details of the submitted revision of the safety analysis report (SAR or the application), Revision 13. TLI also requested renewal of the CoC for a five-year term. As requested, enclosed is CoC No. 9342, Revision No. 17, amended and renewed for a new five-year term.

The NRC staff (the staff) reviewed the application, as supplemented, including relevant information in the attachment to the application, using the guidance in NUREG-2216, “Standard Review Plan for Transportation Packages for Spend Fuel and Radioactive Material,” August 2020 (ADAMS Accession No. ML20234A651). Based on the statements and representations in the application, as supplemented, and the “conditions” section of this safety evaluation report (SER), the staff concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71, “Packaging and Transportation of Radioactive Material.”

The staff reviewed the performance of the package under normal conditions of transport (NCT) as required by 10 CFR 71.71 and the performance of the package under hypothetical accident conditions (HAC) as required by 10 CFR 71.73. Their analyses are included in the sections below.

1.0 GENERAL INFORMATION

1.1 Packaging Description

The Versa-Pac packaging consists of two designs, i.e., the VP-55, a 55-gallon drum, and the VP-110, a 110-gallon version. The Versa-Pac standard configuration shipping packages have been designed to transport Type A fissile materials limited to U-235 masses based on the loading limits in SAR Table 1-1.

Among the changes in this application, is an addition to the packaging to allow for the use of a “high-capacity basket” (HCB). The HCB consists of an aluminum frame that holds two of the licensed 5-inch pipe components. The basket also includes insulation and neutron moderating materials used to isolate the 5-inch pipes from each other.

1.2 High-Capacity Basket

When utilizing the 5-inch steel pipe inner container in the Model No. VP-55, (5-inch pipe with the threaded cap), the containment boundary is defined as the payload cavity with its associated welds, the containment end plate, the inner flange ring, the silicone-coated fiberglass gasket, the payload vessel blind flange, and the bolts. The HCB is constructed of an aluminum frame, insulation, and neutron moderating material and may be utilized in conjunction with the 5-inch pipe container for increased content limits.

1.3 Contents

In addition to the packaging changes, the applicant proposes some changes to the contents for the 5-inch pipes. The proposed contents for the 5-inch pipes loaded into the HCB are uranium compounds enriched to up to 20 wt% U-235 with a limit on hydrogenous materials, similar to the hydrogen limited contents already in the Versa-Pac certificate. All uranium compounds permissible in the package are included as contents for the HCB, with the exceptions of uranium metal, uranium hexafluoride, and uranium compounds containing hydrogen. To supplement this content addition, a new licensing drawing is included for the HCB and revisions have been made to the VP-55 and 5-inch pipe licensing drawings.

1.4 Drawings

The applicant revised two drawings and added a new drawing:

- VP-55-LD was updated to Revision 6
- VP-55-2R, updated to Revision 1, and
- VP-55-HCB was added to reflect the HCB, Revision 1.

The changes in the application have been reviewed and do not affect the package’s ability to meet the requirements of 10 CFR Part 71.

1.5 Evaluation Findings

The staff has reviewed the revised description of the contents and associated changes to the drawing and concludes that the requested changes continue to meet the requirements of 10 CFR Part 71.

F1-1 The application describes the package in sufficient detail to provide an adequate basis for its evaluation.

F1-2 Drawings contain information that provides an adequate basis for evaluation against 10 CFR Part 71 requirements. Each drawing is identified, consistent with the text of the application, and contains keys or annotations to explain and clarify information on the drawing.

F1-3 The application for package approval includes a reference to the applicant’s approved quality assurance program.

F1-4 The application for package approval identifies applicable codes and standards for the package design, fabrication, assembly, testing, maintenance, and use.

F1-5 Drawings submitted with the application provide a detailed packaging description that can be evaluated for compliance with 10 CFR Part 71 for each of the technical disciplines.

F1-6 The application specifies any restrictions on the use of the package.

2.0 STRUCTURAL EVALUATION

The applicant, Orano-TLI, submitted the application for amendment of license USA/9342/AF-96 for Model No. Versa-Pac transportation package. In the application, the applicant proposed to add an HCB in the VP-55 shipping container and provided two structural analyses of the HCB to Revision 13 of the SAR: (1) SAR Section 2.12.2, “VP-55 LS-DYNA Analysis,” and (2) SAR Section 2.12.3, “High-Capacity Basket Stress Analysis.”

The objective of the structural evaluation is to verify that the structural performance of the package is adequately demonstrated to meet the requirements of 10 CFR Part 71.71, “Normal conditions of transport,” and 10 CFR Part 71.73, “Hypothetical Accident Conditions.”

2.1 Structural Analyses for VP-55 Shipping Container under NCT and HAC

The applicant performed structural analyses for the VP-55 shipping container under NCT and HAC in SAR Appendix 2.12.2, “VP-55 LS-DYNA Analysis”. The VP-55 container, with a total weight of 750 lbs. including contents, was analyzed under NCT and HAC as shown in SAR Table 2-7. The calculated acceleration values from these analyses were used as inputs to evaluate the HCB in Appendix 2.12.3, “High-Capacity Basket Stress Analysis.”

2.1.1 Method of Analysis

The applicant used the LS-DYNA explicit nonlinear dynamic finite element (FE) program to determine the dynamic responses of the VP-55 shipping container to the NCT and HAC free drops. A three-dimensional (3-D), full-symmetry model of the VP-55 loaded with mock contents that represent the weight of the actual contents was developed. The model was used to evaluate the structural performance of the VP-55 under the NCT and HAC free drops using the LS-DYNA 3-D FE program. Four package drop orientations (bottom-end, top-end, side, and center-of-gravity over top-corner) were considered as shown in SAR Figure 2-1 to find the most critical dynamic responses of the package under the NCT and HAC free drops.

2.1.2 Drop Analyses under NCT

The applicant analyzed the VP-55 shipping container under the NCT 4-ft free drop using the FE model as described in SAR Section 2.12.2.3. The NCT 4-ft free drop was simulated with the LS-DYNA program by positioning the VP-55 model in the desired orientation onto a flat, horizontal, unyielding surface. The gravitational constant of 386.04 in/s^2 was applied to the model as a body force in the vertical z-direction. Both hot/soft and cold/hard material properties of the polyurethane foam for insulation were used in the model analyses.

The results of the NCT 4-ft free drops were presented in SAR Section 2.12.2.6.1 through SAR Section 2.12.2.6.4 and they were summarized in SAR Table 2-18. The calculated maximum peak acceleration was 133 g at the impact location during the center-of-gravity over top-corner drop.

2.1.3 Drop Analyses under HAC

The applicant analyzed the VP-55 shipping container under the HAC 30-ft free drop using the FE model as described in SAR Section 2.12.2.3. The HAC 30-ft free drop was simulated with the LS-DYNA FE program by positioning the VP-55 model in the desired orientation onto a flat, horizontal, unyielding surface. The gravitational constant of 386.04 in/s^2 was applied to the model as a body force in the vertical z-direction. Both hot/soft and cold/hard material properties of the polyurethane foam for insulation were used in the model analyses.

The results of the HAC 30-ft free drop were presented in SAR Section 2.12.2.7.1 through SAR Section 2.12.2.7.4 and were summarized in SAR Table 2-19. The calculated maximum peak acceleration was 515 g at the impact location during the side drop.

2.2 Stress Analyses for the HCB

The applicant calculated stresses in the HCB under the NCT and HAC using the ANSYS FE computer program with the calculated bounding g-loads as provided in SAR Appendix 2.12.2. A 3-D ANSYS model of the HCB was developed, and appropriate loads and boundary conditions were applied to the model. The calculated stresses were compared with the allowable stresses provided in American Society of Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, Subsection NF. A margin of safety (MS) was calculated, where MS was defined as MS = [(allowable stress/calculated stress) - 1.0]. Therefore, a structural component of the HCB that has an MS larger than zero (0) indicates that the structural component meets requirements of the ASME Code.

The applicant provided the stress results of the structural analyses in SAR Table 2-20 through SAR Table 2-23, where the stress results were compared with the allowable stresses specified in ASME B&PV Code Section III, Division 1, Subsection NF. Additionally, the MS were also calculated and provided in the tables. The lowest MS for the NCT free drop was +0.85 for bearing stress in the top disk due to the NCT side drop 90-degree orientation. The lowest MS for the HAC free drops was +0.23 for primary membrane stress intensity in the middle support disk due to the HAC side drop 90-degree orientation.

The bolting evaluation was also documented for the threaded connections in SAR Section 2.12.3.8. The lowest MS for the socket head cap screw connection was +10.7 and +3.17 for NCT and HAC, respectively. The lowest MS for the threaded rod connection was +11.9 and +3.85 for NCT and HAC, respectively.

The staff reviewed the ANSYS FE model and stress analyses of the HCB and concludes that the stress analyses of the HCB are acceptable because: (1) the use of the solid and contact elements to represent the body of the components of the HCB in the ANSYS FE model was adequate, (2) the ANSYS FE mesh was sufficient to capture the detailed behavior of the components of the HCB, (3) proper material properties of the components were used in the analyses, (4) the ANSYS stress analyses were conservative by applying the bounding g-loads from the results of the VP-55 LS-DYNA analysis in SAR Appendix 2.12.2, (5) the calculated stresses of the HCB were compared with the ASME allowable stresses, and (6) all calculated MS were larger than zero (0) indicating that the structural components of the HCB met the requirements of the ASME Code.

The staff determined that the structural performance of the HCB under NCT and HAC satisfies the requirements of 10 CFR 71.71 and 71.73.

2.3 Materials Evaluation

The staff's materials review focused on materials issues relevant to the addition of the HCB. In addition to the HCB changes, the applicant requested the referenced version of American National Standards Institute (ANSI) N14.1, "Nuclear Materials - Uranium Hexafluoride - Packagings for Transport," be revised to "version effective at time of fabrication," which will also be addressed in this evaluation. The aspects of other packaging components, unless specifically named in this evaluation, are considered bounded by the conditions previously evaluated by the staff in prior reviews of the Versa-Pac package and are thus not evaluated further in this review.

2.3.1 Drawings

The staff reviewed the drawing changes associated with Revision 13 of the SAR. Of note, Drawing VP-55-HCB was added to the SAR to provide information on the HCB. The staff verified that the drawing provided material specifications for the components in the parts list, including the material grades (and temper), applicable standards, and component dimensions. The staff concluded that the information provided in the new drawing was sufficient as it adequately described the attributes of the HCB.

2.3.2 Codes and Standards

The applicant requested that the referenced ANSI N14.1 version be revised to the version effective at time of fabrication. The staff finds this change acceptable, as it is in accordance with 49 CFR 173.420(a)(2)(i), in which the U.S. Department of Transportation requires that the packagings must be designed, fabricated, inspected, tested, and marked in accordance with ANSI N14.1 in effect at the time the packaging was manufactured.

2.3.3 Mechanical Properties

The applicant provided tables of material properties in SAR Section 2.12.3.4. The staff verified that the properties for stainless steel and aluminum materials are consistent with Section II-D of the ASME B&PV Code. The staff also verified that the structural properties provided for the chlorinated polyvinyl chloride (CPVC) are consistent with those provided by the manufacturer. The staff verified that the material properties provided for other materials were consistent with the references cited by the applicant and are generally reasonable for the materials in question.

Based on the evaluations above, the staff concluded that the applicant provided sufficient information to adequately describe the mechanical properties of the materials used in the package.

2.3.4 Thermal Properties of Materials

The applicant provided tables of thermal properties for the HCB. The staff verified that the properties for Aluminum 6061 and Stainless Steel 304 are consistent with Section II-D of the ASME B&PV Code. SAR Tables 3-23 and 3-24 for the thermal properties of Rockwool Rockboard 60 and CPVC, respectively, were based on vendor information, and the staff confirmed the accuracy of these tables compared to the referenced vendor information.

Further discussion of the thermal analysis is provided in Section 3.0 of this SER. The staff concludes that the applicant provided sufficient information regarding the thermal properties of the materials used in the HCB.

2.3.5 Neutron-shielding materials

The applicant incorporates silos and isolating plates made of CPVC to reduce neutron communication between the two adjacent pipe containers in the HCB. The critical characteristics of the CPVC material are provided in SAR Table 1-9. The characteristics are established using the optimally moderated case in their criticality analysis to establish bounding values. The staff's review of the adequacy of the CPVC is documented in SER Chapter 6.

2.3.6 Content Reactions

The addition of the HCB introduces several new materials to the internal environment of the transportation package, such as 6061 aluminum, Rockwool Rockboard insulation, and CPVC. The applicant directly addressed compatibility of these materials as part of their application and emphasized that no chemical or galvanic reaction is expected with other components of the HCB. The staff reviewed the information provided and observes that Rockwool Rockboard insulation is inorganic, non-combustible, and will not rot, corrode, or promote the growth of fungi or bacteria. The staff also observes that CPVC is stable and not subject to the leaching of chlorides. Both materials are used in industrial applications which are subject to environmental conditions. Given these factors, as well as the limited timeframe of transportation, the staff concludes that the applicant provided sufficient information regarding the potential for significant chemical, galvanic, or other reactions.

2.4 Evaluation Findings

Based on review of the statements and presentations in the application, the staff concludes that the structural design of the HCB has been adequately evaluated, and that the VP-55 shipping container package with the proposed HCB has adequate structural integrity to meet the requirements of 10 CFR Parts 71.71 and 71.73.

In addition, the NRC staff concludes that the materials used in the transportation package design have been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71. The applicant described the materials in sufficient detail, identified appliable codes and standards, demonstrated effective materials performance of packaging components under normal conditions of transport and hypothetical accident conditions, determined that there are no defects that could significantly reduce the effectiveness of the packaging, and demonstrated that the analyzed geometric form of its contents will not be substantially altered and no loss or dispersal of the contents will occur under the tests for NCT.

F2-1 The staff has reviewed the package structural design description and concludes that the contents of the application satisfy the requirements of 10 CFR 71.31(a)(1) and (a)(2) as well as 10 CFR 71.33(a) and (b).

F2-2 The staff has reviewed the structural codes and standards used in package design and finds that they are acceptable and therefore satisfy the requirements of 10 CFR 71.31(c).

F2-3 The staff reviewed the structural performance of the packaging under NCT required by 10 CFR 71.71 and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.55(d)(2) as a fissile material package.

F2-4 The staff reviewed the structural performance of the packaging under the HAC required by 10 CFR 71.73 and concludes that the packaging has adequate structural integrity to satisfy the subcriticality, containment, and shielding requirements of 10 CFR 71.55(e) as a fissile material package.

F2-5 The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f). The applicant demonstrated effective materials performance of packaging components under NCT and HAC.

F2-6 The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(d), 10 CFR 71.85(a), and 10 CFR 71.87(b) and (g). The applicant has demonstrated that there will be no significant corrosion, chemical reactions, or radiation effects that could impair the effectiveness of the packaging. In addition, the package will be inspected before each shipment to verify its condition.

F2-7 The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.55(d)(2). The applicant has demonstrated that the package will be designed and constructed such that the analyzed geometric form of its contents will not be substantially altered and there will be no loss or dispersal of the contents under the tests for NCT.

3.0 THERMAL EVALUATION

Staff reviewed the application for changes to the Versa-Pac shipping package, as described below, to verify that the thermal performance of the package has been adequately evaluated for the tests specified for NCT and HAC and that the package design satisfies the thermal requirements of 10 CFR Part 71. The application was also reviewed to determine whether the package is consistent with the acceptance criteria listed in Section 3 of NUREG-2216.

The applicant sought approval of the following change:

1) Addition of Appendix 3.5.4 for a supporting thermal analysis for the HCB.

3.1 Thermal Evaluation under Normal Conditions of Transport

SAR Appendix 3.5.4 describes the Versa-Pac thermal model for the HCB that the applicant used to perform the thermal evaluation of the package. The HCB is built using aluminum plates, insulation material and isolation pipes and separator plate. SAR Figure 3-42 shows the applicant's ANSYS finite element thermal model of Versa-Pac 55 with the HCB that is used to perform analysis under both NCT and HAC.

The applicant performed a steady state analysis during NCT of the Versa-Pac 55 with the HCB, as described in SAR Section 3.5.4.4. SAR Table 3-22 provides corresponding boundary conditions that are consistent with 10 CFR Part 71. Material properties that are specific to the HCB are provided in the SAR. These properties cover the temperature range expected during the analyzed conditions of NCT. SAR Table 3-27 shows predicted temperatures during NCT conditions. The staff verified that all applicant's predicted temperatures in SAR Table 3-27 are below the allowable limits provided in SAR Table 3-10. The VP-55 transport package with the

HCB is not a pressurized package. Therefore, the maximum normal operating pressure is expected to be near atmospheric pressure.

3.2 Thermal Evaluation under Hypothetical Accident Conditions

The applicant performed a transient thermal analysis to evaluate the package under HAC. The initial conditions of the package, prior to the start of the fire accident, are based on the NCT temperature distribution, as described in SAR Appendix 3.5.4.4. The applicant's thermal model for fire analysis assumes an emissivity coefficient of 0.9, a flame temperature of 800°C (1475°F) and a forced convection heat transfer convection coefficient ranging between 15.6 and 17.4 W/m^2-°C. The forced convection coefficient values used in the HAC analysis are lower than a measured value of about 25.5 W/m^2-°C which is typical for this type of fires, per the report "Thermal Measurements in a Series of Large Pool Fires", Sandia Report SAND85– 0196 TTC – 0659 UC 71, (August 1971). However, the applicant showed that the temperature increase did not result in any allowable limits being exceed, because of changing the convection heat transfer coefficient from 10 W/m^2-°C (used in the original SAR Revision 12) to a maximum value of 17.4 W/m^2-°C. The staff reviewed the predicted results and observed that, in some cases, the temperature increase was noticeable, but margins were still large, and the staff had no concern about the overall thermal performance of the package. SAR Table 3-28 shows predicted temperatures during HAC conditions. This table shows that maximum temperature for each package component and the time when the maximum temperature is reached for a specific component. The staff verified that all applicant's predicted temperatures are below the allowable limits provided in SAR Table 3-10.

3.3 Evaluation Findings

The staff reviewed the applicant's assumptions and analysis results, as presented in their application, to determine consistency with NUREG-2216. The staff reviewed the thermal model, material properties, boundary conditions, and initial conditions used by the applicant to perform the thermal analysis of the Versa-Pac shipping package during NCT and HAC. The staff finds the analyses acceptable because the information provided in the SAR is consistent with NUREG-2216. Based on its review of the application, the staff concludes that the Versa-Pac shipping package thermal design has been adequately described and evaluated for the SAR changes proposed, as described in SAR Section 3.0, and that the thermal performance of the package meets the thermal requirements of 10 CFR Part 71.

F3-1 The staff has reviewed the package description and evaluation and concludes that they satisfy the thermal requirements of 10 CFR Part 71.

F3-2 The staff has reviewed the material properties and component specifications used in the thermal evaluation and concludes that they are sufficient to provide a basis for evaluation of the package against the thermal requirements of 10 CFR Part 71.

F3-3 The staff has reviewed the methods used in the thermal evaluation and concludes that they are described in sufficient detail to permit an independent review, with confirmatory calculations, of the package thermal design.

F3-4 The staff has reviewed the accessible surface temperatures of the package as it will be prepared for shipment and concludes that they satisfy 10 CFR 71.43(g) for packages transported by exclusive-use vehicle.

F3-5 The staff has reviewed the package design, construction, and preparations for shipment and concludes that the package material and component temperatures will not extend beyond the specified allowable limits during NCT consistent with the tests specified in 10 CFR 71.71.

F3-6 The staff has reviewed the package design, construction, and preparations for shipment and concludes that the package material and component temperatures will not exceed the specified allowable short-term limits during HAC consistent with the tests specified in 10 CFR 71.73.

6.0 CRITICALITY EVALUATION

The objective of this NRC criticality evaluation is to verify that the transportation package design meets the nuclear criticality safety requirements in 10 CFR Part 71.

The applicant requested to modify the CoC for the Versa-Pac package to add the HCB with hydrogen-limited contents. The following sections describe the staff's review of each of the proposed change.

6.1 Addition of the HCB with Hydrogen-Limited Contents

The packaging design features the HCB with hydrogen-limited contents consist of an aluminum structure within which allows for two (2) 5-inch pipes to be loaded with unlimited uranium compound contents enriched to no more than 20-wt.% U-235. The HCB is modeled in the criticality safety analysis as two moderator pipes and one separator plate. The two neutron moderator pipes and the separator plate are made with CPVC. The rest of the space in the HCB is filled with thermal insulation. The applicant stated that CPVC was chosen for its hydrogen and chlorine content, as the scattering with hydrogen and neutron capture in chlorine reduce the system reactivity. Additionally, CPVC has a higher allowable temperature and ability to retain hydrogen and chlorine at elevated temperatures.

In SAR Section 6.2.6, the applicant provided the HCB fissile content description and some restrictions. According to the applicant, the VP-55 HCB with hydrogen-limited contents configuration is derivative of the 5-inch pipe with hydrogen-limited contents with the exception that criticality control additionally relies upon the HCB for HAC. Criticality control relies on the HCB's moderator pipes and separator plate, its positioning inside the package, and the 5-inch pipe's geometry. SAR Table 6.2.6-1 provides the Uranium Mass Limits for the VP-55 with the HCB hydrogen-limited contents.

The staff reviewed all uranium compounds modeled for the HCB analysis. These compounds are listed in SAR Table 6.3.2-3 for the bounding uranium compounds for the HCB configuration and SAR Table 6.3.2-4 for the HCB CPVC properties. Most compounds are built-in SCALE code materials.

For this configuration, the applicant analyzed the contents for a criticality safety index (CSI) of 1.4 or 0.7, corresponding to HAC array sizes of 72 or 144 packages, respectively. All contents have a maximum enrichment of 20 wt.% and are split into uranium carbide (UC) with CSI=1.4 contents and uranium oxide (U_3O_8) with CSI=0.7 contents. The NCT package array is modeled with ≥5N packages, no flooding, and with water reflection in all directions. The HAC package array is modeled with 2N packages, no flooding in the initial studies, and with water reflection in all directions (to satisfy 10 CFR 71.55(b), (d), and (e)).

The applicant analyzed the HCB as Safety Category B. Safety Category B states that a system shall be designed so that a single fault in any of its parts does not lead to the loss of safety function. So, for the HCB, the analysis proves that the failure of any one of the moderators and the separator components of the HCB basket will not negatively impact criticality safety. Also, the applicant modeled adjacent packages of the HCB rotated such that three adjacent moderating pipes are as close together as possible, the closest moderating pipe is the one removed in this study to bound any combination of HCB orientation and pipe removal. Additionally, the NCT evaluation shows that both moderator pipes and the separator plate may all be missing and be acceptable. In the same study, the 5-inch pipes are also modeled as displaced axially out of their moderating pipes limited in their displacement by the containment foam plug. This study is done by the applicant to verify the bounding position of the 5-inch pipe inside the Versa-Pac.

Geometries for the single package and HAC package array are shown in SAR Figures 6.3.4-20 and 6.3.4-21, respectively, showing the general positioning of the HCB and fissile material. The NCT array is like the HAC array except larger to match the CSI and without any flooding, with water reflection around the array.

The applicant performed criticality safety analysis for the combination of CPVC resin and additives used in the two moderator pipes and a separator plate that are designed to reduce neutron communication between the 5-inch pipes in a single Versa-Pac and between multiple Versa-Pac packages in an array. As mentioned in previous sections of this SER, CPVC was chosen for its hydrogen and chlorine content, as the scattering with hydrogen and neutron capture in chlorine reduce the system reactivity. For this analysis, a maximum of 5 wt.% carbon black additive bounds all other compound additives.

The staff finds that the specifications for the contents used in the criticality evaluation are consistent with information provided in the General Information section of this application. Also, the staff finds acceptable the material descriptions based on the facts that the specifications relevant to the criticality evaluation include fissile material mass, dimensions, uranium enrichment(s), fissile nuclides present and their concentrations, physical and chemical composition and form, density, internal moderation.

The staff evaluated the uranium mass limits for the VP-55 with the HCB hydrogen-limited contents in SAR Table 6.2.6-1 and found them acceptable taking in consideration some of the restrictions established in SAR Section 6.2.6. One of the restriction states that for UC enriched up to 20 wt.% U-235, unlimited UC contents are allowed in two 5-inch pipes with the HCB with CSI=1.4. Per SAR Section 6.6.6.2, UC has been determined to bound uranium carbides, fluorides, nitrides, and oxides. These uranium compounds may be loaded per the UC limits in SAR Table 6.2.6-1.

The staff verified with the thermal and structural technical reviewers that the structural and thermal integrity of the HCB under HAC will resist deformation, maintain positioning of the 5-inch pipes, and retain its hydrogen and chlorine content post-HAC fire. Thus, the HCB model is identical under NCT and HAC. The relevant dimensions of the HCB are the inner and outer diameters of the CPVC pipes, the width and thickness of the CPVC plate, and the overall heights of each component, as listed on the HCB licensing drawing provided in SAR Section 1.4.9. The components are all modeled as shown in SAR Figure 6.3.1-7, so the center to center spacing of the pipes is based on the outer diameters of the pipes and thickness of the plate.

The staff reviewed the applicant's packaging design features and found them acceptable. The staff also confirmed that sketches describing the criticality design features were consistent with each other; with the information in the General Evaluation section, including the engineering drawings; and with the models used in the criticality evaluation.

6.2 HCB with Hydrogen-Limited Contents

The applicant stated that the VP-55 HCB with hydrogen-limited contents configuration is derivative of the 5-inch pipe with hydrogen-limited contents with the exception that criticality control additionally relies upon the HCB for HAC. The applicant provided in SAR Table 6.1.2-8 a summary of the results of the limiting cases from the VP-55 with HCB hydrogen-limited contents evaluation. In SAR Section 6.3.2.11, the applicant listed the moderator pipes and separator plate of the HCB model with their respective bounding CPVC compounds. The applicant shows that uranium carbide (UC) bounds all uranium compounds analyzed. Thus, UC was used as the overall bounding compound for the CSI=1.4 content. As UC bounds U_3O_8, only one single package evaluation was done with UC as the bounding fissile material. One NCT array evaluation was done that combined the bounding fissile material of UC (CSI=1.4) with the U_3O_8 (CSI=0.7) bounding array size of 5N=360. Thus, the single NCT array evaluation bounds both the UC (CSI=1.4) and U_3O_8 (CSI=0.7) contents. The contents were determined to be subcritical and below the upper subcritical limit (USL) for all package evaluations.

The staff reviewed SAR Table 6.1.3-1. This table provides the CSIs for all contents for the Versa-Pac. The staff performed confirmatory calculations regarding the HCB hydrogen-limited contents and confirmed that the CSI for 20 wt% U-235 UC is 1.4 and for 20 wt% U-235 U_3O_8 is 0.7. The staff found this CSI acceptable based on the number of packages evaluated in the arrays. The staff also verified that the applicant has determined the appropriate value of N and calculated the CSI correctly. The appropriate value of N selected by the applicant was the smaller of values determined from the arrays evaluated according to 10 CFR 71.59(a)(1) and (a)(2).

The staff reviewed the applicant's calculations for the 20-wt.% enrichment mass limits for hydrogen limited contents in the VP-55 and agrees that the applicant has identified the most reactive condition for the 20-wt% of U-235 enrichment for the single package, NCT array, and HAC array. The applicant has shown, and the staff agrees that the VP-55, with additional HCB mass limits for 20 wt.% enrichment hydrogen limited contents, will remain subcritical under NCT and HAC in single package and array configurations per the requirements of 10 CFR 71.55 and 10 CFR 71.59.

6.3 HCB Neutron History Specification

SAR Section 6.3.3 shows the computer codes and the cross-section libraries. SCALE 6.1.3 was used to complete the criticality analysis for all contents using the Criticality Safety Analysis Sequence with KENO-VI (CSAS6). The continuous energy cross-section library *ce_v7_endf* was used, which compiles data from the ENDF/B-VII.0 data library.

SAR Table 6.3.3-1 shows the typical neutron history specification used for each content. Some cases or studies of a content analysis required more neutron histories to achieve convergence. Convergence of k_{eff} was determined through visual inspection of the plot of *Average k-effective* by *Generation Run* that is included in each output file. For the HCB, the number of generations was 250, neutrons per generation was 20,000, number of skipped generations was 50 and the active neutron histories was 4.0×10^6. HCB generations are the same for the standard contents as previously approved by NRC for this package.

The staff revised and found this HCB neutron history specification acceptable based on the facts that the applicant used an appropriate cross section library. The applicant used multigroup cross sections, appropriately considered the neutron spectrum of the package for collapsing the group structure and properly processed the cross sections to account for resonance absorption and self-shielding. The use of KENO as part of the SCALE sequence directly enabled such processing.

6.4 Benchmark Analysis (Determination of Upper Subcritical Limits)

All benchmark selected was modeled and k_{eff} was calculated using the SCALE 6.1.3 CSAS6 and *ce_v7_endf* continuous energy cross section library. The applicant added two series with higher EALF values to the benchmark analysis to accommodate an extended USL equation for the 20 wt% U-235 enrichment HCB hydrogen-limited content analysis. The analysis presented in SAR Section 6.8 follows the guidance in NUREG/CR-6361, “Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages.”

SAR Section 6.8 was updated to include a new HCB USL equation and to add supplemental benchmarks (HCT-011 and LCT-058) and corrected a transpositional error in SAR Table 6.8.1-2 where similarity index (c_k) values listed for experiment series LST-002 and LST-003 were incorrectly ordered. The transpositional error affected the cases included in the USL generation and the corrections made resulted in very small changes in USLs for the given contents.

The applicant selected 264 critical benchmark experiments from the *International Handbook of Criticality Safety Benchmark Experiments*, based on qualitative parameters such as fissile and moderating species, structural and reflector material, as well as quantitative parameters such as enrichment, hydrogen to fissile ratio (H/X), and energy of the average neutron lethargy causing fission (EALF). These experiments were selected to cover a wide range of enrichments and H/X, consistent with the variation of configurations of the package. Two additional series with higher EALF values were added to accommodate an extended USL equation for the 20-wt% U-235 enrichment HCB hydrogen-limited content analysis. For the 20-wt.% enrichment, the applicant determined which of the selected benchmark experiments were most applicable using the SCALE TSUNAMI sensitivity and uncertainty analysis code. The correlation coefficients between each benchmark and the application case for each enrichment are listed in SAR Table 6.8.1-2. In this table, the column labeled ‘20 (HCB)’ is the extended 20 wt% for the higher EALF values of the HCB analysis. The criterion for being considered applicable for the validation is $c_k \geq 0.9$ for all enrichments ≥5 wt%.

The staff reviewed the benchmark analysis and found it acceptable, since this is to a certain degree of a deviation from guidance (usually 0.8 is the c_k cutoff). The extended 20-wt.% validation under ’20 (HCB)’ use lowered requirements of $c_k \geq 0.75$. The applicant stated that the added benchmark series include more steel materials to help fill this gap in benchmarks, but to have sufficient benchmarks for the validation, the lower c_k value criterion was necessary. Also, it is important to recognize at this point that the TSUNAMI selection criterion is an additional step not included in the standard validation process, as outlined in NUREG/CR-6361, to provide a more rigorous selection process for applicable benchmarks and the c_k values are not used for the generation of the USL equations.

SAR Table 6.8.1-1 summarizes the critical experiments and their applicable qualitative and quantitative selection criteria, and SAR Table 6.8.1-2 provides the k_{eff} and Monte Carlo uncertainty (σ) values for each experiment, as well as the c_k value for each enrichment configuration of the package. The applicant used the USLSTATS computer code to generate USL equations for each enrichment considered in the package criticality analysis. The USLSTATS code is a generic parameter trending analysis code developed at Oak Ridge National Laboratory that uses the results of benchmark experiments to estimate code bias and bias uncertainty. This code is a standard in the industry for code validation and is acceptable for determining USLs for the package. The applicant also used the USLSTATS code to test k_{eff} data for normality. This test indicated that the k_{eff} data were normal for each enrichment evaluated, indicating that the standard validation statistics recommended in NUREG/CR-6361 can be used.

For the HCB, the resulting USL equations for each enrichment are shown in SAR Table 6.8.2-1, along with the calculated USL. Trending analysis performed by the USLSTATS code indicated that the trending parameter with the highest correlation coefficient with k_{eff} for all enrichments was EALF. Therefore, for the HCB USL equations are based on the EALF trending parameter.

The staff reviewed the applicant’s revised benchmarking analysis in SAR Section 6.8. The staff agrees that the enrichment specific USLs are determined in a conservative manner, consistent with the recommendations of NUREG/CR-6361 and are therefore acceptable.

The staff reviewed the applicant’s requested changes to the CoC, initial assumptions, model configurations, analyses, and results. The staff finds that the applicant has identified the most reactive configurations of the Model No. Versa-Pac package with the requested contents, and that the criticality results are conservative. Therefore, the staff finds with reasonable assurance that the package, with the requested contents, will meet the criticality safety requirements of 10 CFR Part 71.

6.5 HCB Single Package Analysis

The applicant evaluated the single package for the HCB with hydrogen-limited contents. SAR Table 6.4.6-1 shows the “HCB Hydrogen-Limited Content Single Package Criticality Evaluation”. In this evaluation, the applicant models the HCB with two (2) 5-inch pipes resting against the bottom surface of, and centered in, the inner cavity. This series of cases analyzes a full range of moderation and determines the peak in k_{eff}, which was 0.71524, demonstrating that for the single package with the HCB configuration, there is a large margin to the USL (0.9400) for all cases.

For all analyses of the hydrogen limited 5-inch pipe container in the VP-55, the applicant used the SCALE 6.1.3 code system, with the KENO VI three-dimensional Monte Carlo criticality code and the continuous-energy ENDF/B-VII.0 cross section library. This is the same code and cross section library used in all other analyses for the Model No. Versa-Pac package. The staff’s review of the applicant’s benchmarking analysis for all configurations in the package is discussed in Section 6.3 of this SER.

6.6 HCB NCT Array Analysis

For the NCT arrays analysis for the HCB with hydrogen-limited contents, the results are presented in SAR Table 6.5.6-3. The applicant modeled the cases of the HCB of each package rotated such that one pipe is as close as possible to another pipe of the surrounding packages. The applicant modeled the moderator pipe and separator plate with their respective bounding

CPVC composition listed in SAR Section 6.3.2.11. The analysis starts with the pipes entirely filled with UC. Then, the quantity of UC in the 5-inch pipes in each of the cases was reduced and replaced with graphite to analyze a full range of moderation ratios and determine the peak value of k_{eff}, which was 0.88187, demonstrating that for the NCT array evaluation there is a large margin to the USL for all cases. NCT Array HCB Homogeneous Case Summary at 20 wt.% U-235 are plotted in SAR Figure 6.5.6-3.

The staff reviewed the applicant's calculations for the three different configurations of the HCB. Based on the k_{eff} results of the HCB configurations in this NCT array study, the staff finds that the applicant has identified the most reactive configuration for all contents considered. Also, the staff agree to allow the moderator/separator components of the HCB to be classified as Category B safety items, as the failure of any individual component would not result in a condition adversely affecting public health and safety.

The applicant has shown, and the staff agrees that the package, using the HCB with hydrogen-limited contents, will remain subcritical under NCT and HAC in single package and array configurations per the requirements of 10 CFR 71.55 and 10 CFR 71.59.

6.7 Updated to specify ANSI N14.1 effective at the time of manufacturing

The applicant stated in SAR Section 6.2.5 that the cylinders must conform to the standards presented in the version of ANSI N14.1 effective at the time of manufacturing. No packing materials with a hydrogen density greater than that of light water (0.1119 g/cm^3) are allowed in the VP-55 1S/2S cylinder configuration. The staff found this update acceptable since criticality control relies only on these cylinders' geometry and not their positioning inside the package. The payload for the 1S/2S cylinders is limited by mass per ANSI N14.1, as shown in Table 6.2.5-1.

6.8 Evaluation Findings

The staff reviewed the applicant's requested changes to the CoC, initial assumptions, model configurations, analyses, and results. The staff finds that the applicant has identified the most reactive configurations of the Model No. Versa-Pac package with the requested contents, and that the criticality results are conservative. Therefore, the staff finds with reasonable assurance that the package, with the requested contents, will meet the criticality safety requirements of 10 CFR Part 71.

F6-1 The staff has reviewed the package and concludes that the application adequately describes the package contents and the package design features that affect nuclear criticality safety in compliance with 10 CFR 71.31(a)(1), 71.33(a), and 71.33(b) and provides an appropriate and bounding evaluation of the package's criticality safety performance in compliance with 10 CFR 71.31(a)(2), 71.31(b), and 71.35(a).

F6-2 The staff has reviewed the package and concludes that the application identifies the codes and standards used in the package's criticality safety design in compliance with 10 CFR 71.31(c).

F6-3 The staff has reviewed the package and concludes that the application specifies the number of packages that may be transported in the same vehicle through provision of an appropriate CSI in compliance with 10 CFR 71.35(b). The applicant specifies an appropriate CSI for each type of fissile content.

F6-4 The staff has reviewed the package and concludes that the applicant used packaging features and package contents configurations and materials properties in the criticality safety analyses that are consistent with and bounding for the package's design basis, including the effects of the NCT and the relevant accident conditions in 10 CFR 71.55(f) and 71.73. The applicant has adequately identified the package configurations and material properties that result in the maximum reactivity for the single package and package array analyses.

F6-5 The staff has reviewed the package and concludes that the criticality evaluations in the application of a single package demonstrate that it is subcritical under the most reactive credible conditions, in compliance with 10 CFR 71.55(b), 71.55(d), 71.55(e), and 10 CFR 71.55(f). The evaluations in the application also demonstrate that the effects of the NCT tests do not result in a significant reduction in the packaging's effectiveness in terms of criticality safety, in compliance with 10 CFR 71.43(f) and 10 CFR 71.55(d)(4). The evaluations in the application also demonstrate that the geometric form of the contents is not substantially altered under the normal conditions of transport tests, in compliance with 10 CFR 71.55(d)(2).

F6-6 The staff has reviewed the package and concludes that the criticality evaluation in the application of the most reactive array of 5N undamaged packages demonstrates that the array of 5N packages is subcritical under normal conditions of transport to meet the requirements in 10 CFR 71.59(a)(1).

F6-7 The staff has reviewed the package and concludes that the criticality evaluation in the application of the most reactive array of 2N packages subjected to the tests in 10 CFR 71.73 demonstrates that the array of 2N packages is subcritical under HAC in 10 CFR 71.73 to meet the requirements in 10 CFR 71.59(a)(2).

F6-8 The staff has reviewed the package and concludes that the applicant's evaluations include an adequate benchmark evaluation of the calculations. The applicant identified and evaluated experiments that are relevant and appropriate for the package analyses and performed appropriate trending analyses of the benchmark calculation results. The applicant has determined an appropriate bias and bias uncertainties for the criticality evaluation of the package.

F6-9 The staff has reviewed the package and concludes that the application identifies the necessary special controls and precautions for transport, loading, unloading, and handling and, in case of accidents, compliance with 10 CFR 71.35(c). These controls include additional contents specifications (e.g., fuel loading curve(s), reactor operating parameters) and administrative procedures to prevent package misloads.

F6-10 The staff has reviewed the package and concludes that the evaluations in the application assume unknown properties of the fissile contents are at credible values that maximize neutron multiplication consistent with 10 CFR 71.83.

7.0 PACKAGE OPERATIONS

The purpose of this evaluation is to verify that the proposed changes to the operating controls and procedures of the Versa-Pac transport package meet the requirements of 10 CFR Part 71.

The applicant revised the operations procedures to include inspecting, loading, and handling of the HCB. In addition, minor improvements to the existing operating procedures were incorporated.

Based on the review of the statements and representations in the application and conditions imposed in the CoC for the Versa-Pac transport package, the staff concludes that the revised operating controls and procedures for the package to accommodate the new contents meet the requirements of 10 CFR Part 71, and that these controls and procedures are adequate to ensure the safe use of the package.

F7-1 The NRC staff has reviewed the description of the operating procedures and finds that the package will be prepared, loaded, transported, received, and unloaded in a manner consistent with its design and evaluation for approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

Chapter 8 of the application identifies the acceptance tests and maintenance programs to be conducted on the Model Versa-Pac package to ensure compliance with the requirements of 10 CFR Part 71.

The staff reviewed and evaluated the revised acceptance tests. The revised acceptance tests incorporate visual inspections of the HCB when it is used in the package.

Based on the statements and representations in the application, the staff concluded that the revised acceptance tests meet the requirements of 10 CFR Part 71, and that they are adequate to assure the package will be constructed in a manner consistent with its evaluation for approval. Further, the certificate is conditioned to specify that the package must be prepared for shipment and operated in accordance with the Acceptance Tests and Maintenance Procedures in Section 8 of the application.

F8-1 The staff has reviewed the identification of the codes, standards, and provisions of the QA program applicable to the package design and finds that they meet the requirements specified in 10 CFR 71.31(c) and 10 CFR 71.37(b).

F8-2 The staff has reviewed the description of the preliminary determinations for the package before first use and finds that it meets the requirements of 10 CFR 71.85 and 10 CFR 71.87(g).

F8-3 The staff has reviewed the identification of the codes, standards, and provisions of the QA program applicable to maintenance of the packaging and finds that it meets the requirements specified in 10 CFR 71.31(c) and 10 CFR 71.37(b).

F8-4 The staff has reviewed the description of the routine determinations for package use preceding transport and finds that they meet the requirements of 10 CFR 71.87(b) and 10 CFR 71.87(g).

9.0 CONDITIONS

In addition to the HCB addition and the content changes, the staff made editorial changes to improve the readability of the CoC. The CoC now includes the following condition(s) of approval:

The CoC holder is now Orano-TLI. The CoC was revised to reflect that throughout.

Condition No. 5(a)(2), “Description,” was revised to refer to the “latest revision” of ANSI N14.1 effective at the time of fabrication and to provide a description of the newly added HCB.

Condition No. 5(a)(3), “Drawings,” was revised to reflect the following revised drawings:

- Drawing VP-55-LD, Revision 6,
- Drawing VP-55-2R, Revision 1, and
- addition of the new Drawing VP-55-HCB, Revision 1.

Condition No. 5(b)(2), “Maximum quantity of material per package,“ was revised:

- to remove reference to “uranium mass” when referring to the U-235 limits in CoC Table 2 and
- to make edits to CoC Table 3A:
    - add load limits for applicable contents utilizing the HCB,
    - include uranium metal in the CSI with other compounds in the ≤ 10 wt.% U-235 with 2 pipes,
    - remove the fissile mass limit from the from this configuration (that in Table 3A), and
    - to add a note clarifying restrictions on the HCB.

Condition 12 was revised to allow use of the previous certificate, CoC, Revision 16, until its current expiration date of May 31, 2024.

Condition 13 was revised to reflect a new expiration date of the current certificate of October 31, 2027.

The references section has been updated to include reference to this request.

8.0 CONCLUSIONS

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Versa-Pac package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9342, Revision No. 17, for the Model No. Versa-Pac.

Revision No. 17 of Certificate of Compliance No. 9342 for the Model No. Versa-Pac Transportation Package DATE November 7, 2022

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