NRC FORM 618
(8-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

# CERTIFICATE OF COMPLIANCE
## FOR RADIOACTIVE MATERIAL PACKAGES

| 1. a. CERTIFICATE NUMBER | b. REVISION NUMBER | c. DOCKET NUMBER | d. PACKAGE IDENTIFICATION NUMBER | PAGE | PAGES |
|---|---|---|---|---|---|
| 9342 | 16 | 71-9342 | USA/9342/AF-96 | 1 OF | 7 |

2. PREAMBLE
   a. This certificate is issued to certify that the package (packaging and contents) described in Item 5 below meets the applicable safety standards set forth in Title 10, *Code of Federal Regulations*, Part 71, "Packaging and Transportation of Radioactive Material."

   b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

   a. ISSUED TO *(Name and Address)*
   DAHER-TLI
   8161 Maple Lawn Boulevard
   Suite 480
   Fulton, MD 20759

   b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION
   Daher-TLI consolidated application dated February 17, 2021.

4. CONDITIONS

   This certificate is conditional upon fulfilling the requirements of 10 CFR Part 71, as applicable, and the conditions specified below.

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5.(a) Packaging

(1) Model No.: Versa-Pac in two configurations: VP-55 and VP-110.

(2) Description

The Model No. Versa-Pac is either a 55-gallon (Model No. VP-55) or a 110-gallon (Model No. VP-110) package for shipment of uranium oxides, uranium metal, uranyl nitrate crystals and other uranium compounds, e.g., uranium carbides, uranyl fluorides and uranyl carbonates, uranium hexafluoride in the 1S or 2S cylinders, and TRISO fuel. The 1S and 2S cylinders are ANSI N14.1 Standard compliant, which means that each cylinder (which includes new or re-certified cylinders) must be fabricated, inspected, tested, and maintained in accordance with ANSI N14.1-2012 or earlier version of ANSI N14.1 at the time of fabrication.

The exterior skin of the packaging is a UN1A2/Y425/S minimum, carbon steel material for the Model No. VP-55 and a UN1A2/Y409/S minimum, carbon steel for the Model No. VP-110.

All models use a bolted closure ring, ASTM A429 bolts and nuts, a silicone gasket, a drum cover reinforced by a 10-gauge thick plate with four or eight bolts depending upon the Model No. VP-55 or VP-110, respectively.

All models are strengthened with vertical stiffeners, two inner liners insulated by a ceramic fiber blanket and a ¼" carbon steel reinforcing plate on the bottom. The packaging's interior is completely insulated with layers of a ceramic fiber blanket around the containment cavity with rigid polyurethane foam disks on the top and bottom of the cavity.

5.(a)(2) Description (continued)

A ½" thick fiberglass ring is used as a thermal break at the payload cavity flange. The cavity blind flange is secured to the flange with twelve bolts.

The primary containment boundary for the Model Nos. VP-55 and VP-110 is defined as the payload cavity with its associated welds, the containment end plate, the inner flange ring, the silicone-coated fiberglass gasket, the cavity blind flange, and the bolts.

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.

When transporting 1S and 2S cylinders in the VP-55, a 9 lbs/ft$^3$ polyethylene foam liner is inserted into the package cavity, with a minimum thickness of 2 inches.

The approximate dimensions and weights of the packaging are as follows:

**Table 1 - Weight and Dimensions**

| Model No. | Packaging OD (in.) | Packaging Height (in.) | Payload Containment Cavity ID (in.) | Payload Containment Cavity Height (in.) | Packaging Tare Weight (lbs.) | Maximum gross weight (lbs.) |
|---|---|---|---|---|---|---|
| VP-55 | 23-3/16 | 34-3/4 | 15 | 25-7/8 | 390 | 750 |
| VP-110 | 30-7/16 | 42-3/4 | 21 | 29-3/4 | 705 | 965 |

(3) Drawings

The packaging is constructed and assembled in accordance with DAHER-TLI Drawing Nos.:

VP-55-LD, Rev. 4 (sheets 1 and 2) 55 Gallon Versa-Pac Shipping Container

VP-110-LD, Rev. 3 (sheets 1 and 2) 110 Gallon Versa-Pac Shipping Container

The 5-inch steel pipe inner container is constructed and assembled in accordance with Daher-TLI Drawing No. VP-55-2R Rev. 0, sheet 1 of 1.

5.(b) Contents

(1) Type and form of material

(i) Solid, homogeneous (powder or crystalline), or non-homogeneous, uranium materials with no free-standing liquids. Materials shall be stable and in a non-pyrophoric form. Density is not limited. Materials may include natural thorium in any form. Materials may include neutron poisons (e.g., boron, hafnium, erbium, and gadolinia).

Contents are limited to:

A. Uranium oxides ($U_xO_y$).

B. Uranyl nitrate crystals in the form of uranyl nitrate hexahydrate, trihydrate or dihydrate.

C. Other uranium compounds, e.g., uranyl fluorides and uranyl carbonates. Uranium compounds may also contain carbon or be mixed with carbon or graphite. Uranium carbide is authorized for shipment. However, uranium hydrites are not authorized for shipment.

D. Uranium metal or uranium alloys.

E. Natural thorium in any form.

(ii) TRISO fuel and compacts composed of uranium kernels encased within layers of carbon and SiC to form TRISO particles. The uranium may be in the form of uranium oxides, carbides, and/or nitrides. Uranium kernels and TRISO particles are of unrestricted size, density, and uranium content per kernel/particle. Uranium kernels and TRISO particles may be loose or mixed in a graphite matrix and pressed into compacts of various fuel forms (e.g., annular cylinders, planks, right circular cylinders, spheres, etc.). Pressed TRISO fuel compacts may include a graphite fuel free zone at the periphery of the component.

(iii) Uranium Hexafluoride is authorized for shipment when loaded into 1S or 2S cylinders, or in sample tubes when less than 0.1 kg in total quantity, utilizing a 9 PCF polyethylene foam liner with a thickness of at least 2 inches. Aside from the polyethylene foam liner, no hydrogenous packing materials are permitted when shipping 1S/2S cylinders.

5.(b)(1) Type and form of material (continued)

Contents may be pre-packaged in polyethylene, polytetrafluoroethylene, aluminum, and carbon steel, Aluminum Trihydrate, Sodium Borate (Borax, fused), perlite, paper labels, plastic tape, plastic bags, plastic bottles and desiccant such as “Quik-Solid” are also authorized as packing materials. The quantity of hydrogenous packing materials is unlimited unless otherwise specified. Materials with a hydrogen density greater than 0.141 g/cm$^3$ are not authorized.

Radioactive contents shall have an auto-ignition temperature and melting point greater than 600ºF.

(2) Maximum quantity of material per package:

The U-235 and uranium mass limits are determined by enrichment and are not to exceed the limits established below:

**Table 2 - Loading Table for Model Nos. VP-55 and VP-110**

| Weight Percent U-235 | U-235 Mass Limit (g) | |
|---|---|---|
| | Ground/Vessel | Air |
| ≤ 100% | 360 | 360 |
| ≤ 20% | 445 | 445 |
| ≤ 10% | 505 | 505 |
| ≤ 5% | 610 | 610 |
| ≤ 1.25% | 1,650 | -- |

For contents restricted by Table 2A, hydrogenous packing materials are not to exceed 1 lb (454 g) of material. Uranium compounds containing hydrogen (e.g., hydrates and hydrides) are not permissible under Table 2A. The bumper pads and insulation plug are not considered in the 1 lb. hydrogenous material limit.

**Table 2A - Loading Table for Model No. VP-55 With Limited Hydrogenous Packing Material**

| Weight Percent U-235 | U-235 Mass Limit (g) | |
|---|---|---|
| | CSI=0.7 | CSI=1.0 |
| ≤ 100% | 515 | -- |
| ≤ 20% | 605 | 635 |
| ≤ 10% | 685 | -- |
| ≤ 5% | 800 | -- |

For contents restricted by Table 3, all fissile contents shall be loaded into a single 5-inch pipe.

5(b)(2) Maximum quantity of material per package (continued)

**Table 3 - Loading Table for Model No. VP-55 with 5-inch pipe**

| Weight Percent U-235 | U-235 Mass Limit (g) | |
|---|---|---|
| | Ground/Vessel | Air |
| ≤ 100% | 695 | 395 |
| ≤ 20% | 1,215 | 495 |
| ≤ 10% | Unlimited [1] | 590 |
| ≤ 5% | Unlimited [1] | 790 |

[1] Contents ≤10 wt% are limited by the volume of the 5-inch pipe container (6.4 L). This corresponds to theoretical mass limits of 122 kg of U-metal, 60 kg $UO_2$, and 45 kg $U_3O_8$. Actual content mass will be lower due to material packing efficiency, secondary containers, shoring and package gross weight limit.

For contents restricted by Table 3A, all fissile contents shall be loaded into 5-inch pipe(s) and hydrogenous packing materials are not to exceed 1.25 lb (567 g) of material per pipe. Uranium compounds containing hydrogen (e.g., hydrates and hydrides) are not permissible under Table 3A.

**Table 3A - Loading Table for Model No. VP-55 with 5-inch pipe and Limited Hydrogenous Packing Material [1]**

| Weight Percent U-235 | Number of Pipes | CSI |
|---|---|---|
| ≤ 20% | 1 | CSI=1.0 for all compounds |
| ≤ 10% | 2 | CSI=1.0 for uranium oxides<br>CSI=1.4 for all other compounds |

[1] Contents are limited by the volume of the 5-inch pipe container (6.4 L). This corresponds to theoretical mass limits of 122 kg of U-metal, 60 kg $UO_2$, and 45 kg $U_3O_8$, per pipe. Actual content mass will be lower due to material packing efficiency, secondary containers, shoring and package gross weight limit.

For contents restricted by Tables 4 and 5, all fissile material shall be uranium hexafluoride loaded into 1S or 2S cylinders. If both 1S and 2S cylinders are transported in the same package and/or the number of cylinders exceeds the allowed quantity in Table 4, follow the mass limits of Table 2. If a package containing 1S/2S cylinders is transported by air, follow the mass limits of Table 2. For 1S or 2S cylinders with material exceeding 20 wt% U-235, each 1S or 2S cylinder shall be loaded into an individual 5-inch pipe.

5(b)(2) Maximum quantity of material per package (continued)

**Table 4: 1S/2S Cylinder Limits for the VP-55 (up to 20wt.% U-235)**

| Cylinder Type | Mass $UF_6$ per VP-55 (lb/g) | Weight percent U-235 | Number of Cylinders | U-235 Mass Limit per VP-55 (g) |
|---|---|---|---|---|
| 1S | 7.0 / 3,175 | ≤ 20 | 7 | 429.8 |
| 2S | 9.8 / 4,445 | ≤ 20 | 2 | 600.8 |

**Table 5: 1S/2S Cylinder Limits for the VP-55 with 5-inch Pipe (up to 100wt.% U-235)**

| Cylinder Type | Mass $UF_6$ per VP-55 (lb/g) | Weight percent U-235 (e is enrichment) | Number of Cylinders | U-235 Mass Limit per VP-55 (g) |
|---|---|---|---|---|
| 1S | 1.0 / 454 | 20 < e ≤ 100 | 1 | 306 |
| 2S | 4.9 / 2,223 | 20 < e ≤ 100 | 1 | 1497 |

The net weight of the authorized contents shall not exceed 350 lbs for the Model Nos. VP-55 and 260 lbs for the Model No. VP-110, including cribbing and dunnage.

(3) Contents are limited to normal form material. The radionuclide inventory of the loaded contents, including U-234 and U-236, shall be less than the calculated mixture $A_2$ value.

(4) Decay heat is limited to 11.4 W.

5.(c) Criticality Safety Index (CSI)

| | |
|---|---|
| (1) Contents Limited by Table 2 (VP-55 or VP-110): | 1.0 |
| (2) Contents Limited by Table 2A (VP-55): | As listed in Table 2A |
| (3) Contents Limited by Table 3 (VP-55): | 0.7 for material up to 10 wt% and 1.0 for material greater than 10 wt% and up to 100 wt%. |
| (4) Contents Limited by Table 3A (VP-55): | As listed in Table 3A |
| (5) Contents Limited by Table 4 (only VP-55): | 1.0 |
| (6) Contents Limited by Table 5 (only VP-55 with 5-inch pipe): | 1.0 |

6. In addition to the requirements of Subpart G of 10 CFR Part 71:

   (a) The package shall be prepared for shipment and operated in accordance with the Operating Procedures in Section No. 7 of the application.

   (b) Each packaging must meet the Acceptance Tests and Maintenance Program of Section No. 8 of the application.

7. Transport by air of fissile material is authorized, as limited by the ‘Air’ quantities in Table 2 and Table 3.

8. Transport of plutonium above minimum detectable quantities is not authorized.

9. Packages must be marked with the appropriate model number, i.e., VP-55 or VP-110, as applicable. Optional use of certain package components is listed in the licensing drawing notes.

10. Content forms may not be mixed in a single package.

11. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

12. Expiration date: May 31, 2024.

REFERENCES

Daher-TLI application, "Application for Certificate of Compliance for the Versa-Pac Shipping Package," Revision No.12, February 17, 2021.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

John B. McKirgan Digitally signed by John B. McKirgan
Date: 2021.09.03 12:55:06 -04'00'

John McKirgan, Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Date: 9/3/21

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 16**


**Summary**

By application dated February 17, 2021 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21049A135), as supplemented on July 14, 2021 (ADAMS Accession No. ML21195A282), Daher-TLI, (Transport Logistics International, Inc. [TLI] or the applicant) requested revision to Certificate of Compliance (CoC) No. 9342, for the Model No. Versa-Pac package.

The applicant proposed to consolidate all amendment contents to Revision 12 to the Versa-Pac safety analysis report (SAR) and provided the following submittals: (i) a summary table of the changes to the SAR, (ii) a list of the effective pages, and (iii) a copy of the SAR, Revision 12 for Versa-Pac.

The application includes clarifications for and expansion of current contents, additional licensed contents, and added package functionality through optional use of an inner cavity foam block. Additionally, this application revises the SAR to better prepare for foreign validations such that the package can allow for international shipments.

The staff used the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," as well as associated interim staff guidance documents to perform the review of the proposed package changes. Based on the statements and representations in the application, as supplemented, and the conditions listed in the following chapters, the staff concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.


## EVALUATION

## 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. No changes were made to the packaging.

### 1.2 Contents

The applicant requested to modify the CoC by adding limits for the hydrogen-limited contents at enrichments other than 20 wt% and hydrogen restricted loading table for the VP-55 with the 5-inch pipe. The applicant is also requesting the addition of details of neutron absorbers to the contents and sample tubes for shipping $UF_6$ in quantities less than 0.1 kg. Several content configurations and mass limits changes were requested. The changes consist of:

- Revision to the mass limits for each enrichment range for the standard configuration in CoC Table 2 for the VP-55 and VP-110, based on new criticality calculations with SCALE 6.1.3 and a revised benchmarking analysis in SAR Section 6.8,

- Addition of hydrogen limited content mass limits for 100, 10, and 5 weight percent (wt.%) enriched uranium to the existing limits for 20 wt.% enriched uranium in CoC Table 2A,

- Revision to the mass limits for 5 and 10 wt.% enriched uranium contents in the VP-55 with 5.0-inch pipe container in CoC Table 3, to be limited by the volume of the pipe container,

- Addition of a new content category consisting of hydrogen limited (less than 1.25 lb. (567 grams) of high density polyethylene (HDPE) equivalent) uranium contents enriched to a maximum of 10 wt.% and 20 wt.% in 5.0-inch pipe containers in the VP-55,

- Revision to, or addition of, air transport mass limits for several content categories, and

- Revision to the benchmarking analysis in SAR Section 6.8 to calculate enrichment-specific Upper Subcritical Limits (USLs) for the various package contents.

### 1.3 Drawings

The applicant revised one drawing, VP-55-LD, from Revision 3 to Revision 4. The drawing notes were updated to reflect optional use and details of several components, among them are the following:

- Certain inner containment pads made optional when shoring device is provided or when paint protection is not required,

- Tolerance for Drum lid gaskets for different drum lid depths, and

- Certain components made optional for configurations that include uranium oxides, metals, and TRISO fuel that are not temperature sensitive.

The changes in the revision have been reviewed and do not affect the packages ability to meet the requirements of 10 CFR Part 71.

### 1.4 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.

## 2.0 STRUCTURAL EVALUATION

The NRC staff reviewed the Versa-Pac application to verify that the structural performance of the package meets the requirements of 10 CFR Part 71.

The NRC staff reviewed the applicant's submittals and found that the proposed changes in SAR Chapter 2, "STRUCTURAL EVALUATION," are a complete consolidation and re-write of the chapter without changing or adding any technical contents. There are no changes to the design, analysis, and construction of the structural components of the Versa-Pac transportation package that are important to safety. Therefore, the proposed changes are acceptable.

### 2.1 Materials Evaluation

The application does not add any new materials to the packaging design. The staff verified that the proposed revisions to the package do not expose the existing packaging materials to thermal, structural, or corrosive service environments more severe than those that have been previously evaluated and found acceptable by the staff in prior amendments to the CoC. The staff also confirmed that the addition of neutron absorbers (e.g., boron, hafnium, erbia, and gadolinia) as allowable contents do not introduce chemical, galvanic, or other detrimental reactions, as these absorbers are common additions to the fissile uranium compounds transported in the package. Therefore, the staff finds the package materials to be acceptable.

### 2.2 Evaluation Findings

Based on review of the statements and presentations in the application, the NRC staff determined that the proposed changes are acceptable and concludes that the package maintains adequate structural integrity to meet the structural and materials requirements in 10 CFR Part 71.

## 3.0 THERMAL EVALUATION

Staff reviewed the application for changes to the Versa-Pac shipping package, as described below, in order to verify that the thermal performance of the package has been adequately evaluated for the tests specified for normal conditions of transport (NCT) and hypothetical accident conditions (HAC) and that the package design satisfies the thermal requirements of 10 CFR Part 71.

The applicant sought approval of the following changes:

1) Addition of Appendix 3.5.3 to provide temperature profiles for the package without the containment insulation plug (Stock Number IG) to support making this part optional.

2) Added pressure maximum NCT and HAC pressure calculations.

### 3.1 Thermal Evaluation under Normal Conditions of Transport

SAR Appendix 3.5.3 describes the Versa-Pac thermal model that the applicant used to perform the thermal evaluation of the package. Except for the removal of the containment insulation plug (Stock Number IG) as shown in SAR Figure 3-32, the thermal model (using ANSYS finite element code v19.1) of the Versa-Pac is the same as described in SAR Section 3.3, which the staff has previously reviewed. The applicant performed a steady state analysis during NCT of the Versa-Pac, without the containment insulation plug. SAR Table 3-20 shows predicted temperatures during NCT conditions. All predicted temperatures in Table 3-20 are below applicable limits. SAR Section 3.1.4 states that due to permeation in the silicone coating of the cavity seal, the maximum normal operating pressure is expected to be near atmospheric pressure which means the containment is not a pressurized package.

### 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 the SAR Appendix 3.5.3.4. 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[1]. However, the applicant showed that the temperature increase did not result in any allowable limits being exceeded, as a result of changing the convection heat transfer coefficient from 10 W/m$^2$-°C (used in 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.

### 3.3 Evaluation Findings

The staff reviewed the applicant's assumptions and analysis results, as presented in their application, to determine consistency with NUREG-1609. The staff agrees with the applicant that the removal of the insulation plug will have only a minor impact in predicted temperatures, and the results support making this part optional. The staff reviewed the pressure calculations and verified that the pressure increase is minor and does not approach the design pressure of the containment vessel. Based on its review of the application, the staff concludes that the thermal design has been adequately described and evaluated for the SAR changes proposed, as described in Section 3.0 of this SER, and that the thermal performance of the package meets the thermal requirements of 10 CFR Part 71.

## 6.0 CRITICALITY EVALUATION

Staff reviewed the application for changes to the Versa-Pac shipping package, as described below, in order to verify that the criticality performance of the package has been adequately evaluated and that the package design satisfies the criticality requirements of 10 CFR Part 71.

The following sections describe the staff's review of each of the proposed changes listed in SER Section 1.2 above.

### 6.1 Standard Configuration VP-55 and VP-110

The applicant recalculated $k_{eff}$ for all of the models previously evaluated for the standard configuration of various enrichment uranium contents in the VP-55 and VP-110 configurations, using SCALE 6.1.3, with KENO VI and the continuous-energy ENDF/B-VII.0 cross section library, and with the revised USLs determined in the benchmarking analysis in SAR Section 6.8. The applicant used the same NCT and HAC single package and array models previously used

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[1] "Thermal Measurements in a Series of Large Pool Fires", Sandia Report SAND85– 0196 TTC – 0659 UC 71, August 1971.

to determine system $k_{eff}$ with SCALE 4.4a and the 44-group ENDF/B-V cross section library. The results demonstrate that small increases in per-package $^{235}U$ mass, as shown in SAR Table 6.1.2-1, will maintain system $k_{eff}$ below the USL for 5, 10, 20, and 100 wt.% enrichments. For 1.25 wt.% enrichment, the results demonstrated that the mass limit would need to be decreased to maintain system $k_{eff}$ below the USL. All maximum $k_{eff}$ values calculated for each enrichment, shown in SAR Table 6.1.2-1, are below the corresponding USLs, which are summarized in SAR Table 6.1.2-8 for all content configurations.

The staff reviewed the applicant's revised calculations and agrees that there are no changes to the models other than the computer code and cross section library used, and the calculated USL. The applicant has shown and the staff agrees that the Model No. Versa-Pac, with revised standard configuration mass limits as shown in SAR Table 6.1.2-1, 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.

### 6.2 Hydrogen Limited Contents Including TRISO Fuels

The applicant requested the addition of hydrogen limited content mass limits for 100, 10, and 5 wt.% enriched uranium to the existing limits for 20 wt.% enriched uranium in CoC Table 2A. The mass limits for this content category also include TRISO fuels, consisting of uranium oxide, carbide, or nitride kernels encased within layers of carbon and silicon carbide, which may be loose or mixed in a graphite matrix and pressed into compacts of various fuel shapes. Hydrogenous packing material in the VP-55 cavity is limited to 1 lb. (454 grams) of HDPE equivalent. The applicant determined mass limits for the new enrichment values for hydrogen limited contents, shown in SAR Table 6.2.2-1, using the same configurations evaluated in the models for the previously approved 20 wt.% enriched uranium contents with a Criticality Safety Index (CSI) of 0.7, as described in SAR Section 6.3.4.2. Specifically, the applicant modeled homogeneous and heterogeneous configurations of uranium metal of varying enrichment, optimally moderated with 1 lb. of HDPE (NCT), and mixtures of 1 lb. HDPE and varying water densities (single package and HAC). In addition, the applicant determined the effect of varying amounts of graphite being present in the NCT array evaluation. Similar to the conclusions of the analysis for 20 wt.% enriched uranium, the $k_{eff}$ of the NCT array optimally moderated by HDPE and graphite is significantly lower than the HAC array optimally moderated by HDPE and water for all other enrichments evaluated. All maximum $k_{eff}$ values calculated for each enrichment, shown in SAR Table 6.1.2.2, are below the corresponding USLs, which are summarized in SAR Table 6.1.2-8 for all content configurations.

The staff reviewed the applicant's calculations for the 5, 10, and 100 wt.% enrichment mass limits for hydrogen limited contents in the VP-55, and agrees that the applicant has identified the most reactive condition for each enrichment for the single package, NCT array, and HAC array. The applicant has shown and the staff agrees that the Model No. Versa-Pac, with additional mass limits for 5, 10, and 100 wt.% enrichment hydrogen limited contents in the VP-55 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 VP-55 with 5-Inch Pipe Container

The applicant requested a revision to the mass limits for 10 wt.% enriched uranium contents in the VP-55 with 5-inch pipe container, and removal of the specific mass limits for 5 wt.% enriched uranium contents. For the previously approved mass limit for 10 wt.% enriched contents in the 5-inch pipe container, the applicant evaluated varying fissile mass and HDPE moderator within the pipe, and varying water density inside and outside the package cavity, and in between packages in the array. The previously approved analysis also evaluated partial filling of the 5-inch pipe, to determine if a lower quantity of fissile material would achieve optimum moderation at a higher $k_{eff}$. The applicant did not change any of the analysis parameters or assumptions, which demonstrated that for 10 wt.% uranium contents, the maximum $k_{eff}$ occurred at the maximum evaluated mass (1,605 grams $^{235}U$). For this amendment request, the applicant provided an additional analysis of optimally moderated fissile masses greater than 1,605 grams $^{235}U$, which demonstrated that $k_{eff}$ decreases with increasing mass, as shown in SAR Tables 6.5.3-3 and 6.6.3-3. This demonstrates that peak $k_{eff}$ is obtained with the previously evaluated mass limit, and that the mass of 10 wt.% enriched uranium contents can be limited by the volume of the 5-inch pipe container. This result is bounding for the 5 wt.% enrichment contents; therefore, the mass limits for 5 wt.% enriched uranium contents can be removed.

The staff reviewed the applicant's calculations for the 10 wt.% enrichment mass limits for VP-55 with 5-inch pipe container and agrees that the applicant has identified the most reactive condition for the single package, NCT array, and HAC array. The applicant has shown and the staff agrees that the Model No. Versa-Pac, with the mass limit for 10 wt.% enrichment uranium contents changed to be volume limited by the 5-inch pipe container, 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.

### 6.4 Hydrogen Limited Contents in 5-Inch Pipe Container in VP-55

The applicant requested to revise the CoC to add a new content category for hydrogen limited contents in a 5-inch pipe container in the VP-55. This content category consists of 10 or 20 wt.% enriched uranium contents contained within a 5-inch pipe container in the VP-55, with a maximum of 1.25 lb. of HDPE equivalent packing material in the pipe container. For 20 wt.% enriched contents, the VP-55 is limited to one 5-inch pipe container, while for 10 wt.% enriched contents, the VP-55 may contain up to two 5-inch pipe containers. Additionally, for 10 wt.% enriched contents, the applicant provided analyses to support two different CSIs: 1.0 for uranium oxides and 1.4 for all other permissible uranium forms. Similar to the previously approved hydrogen limited contents in the VP-55, uranium compounds containing hydrogen are not authorized, and graphite not chemically or mechanically bound to the uranium contents, not in the fuel-free zone of TRISO compacts, or not otherwise mixed with the uranium (i.e., loose graphite) is not allowed.

The applicant evaluated hydrogen limited contents in the 5-inch pipe container in the VP-55 similar to how the standard 5-inch pipe component contents were evaluated, but with HDPE moderator limited to 1.25 lbs. Similar to all of the other content categories, the applicant evaluated the single package with damage from HAC tests, fully flooded, and with full water reflection outside of the package (to satisfy 10 CFR 71.55(b), (d), and (e)). The applicant evaluated the NCT array of 360 packages with the 5-inch pipe optimally moderated with the limited HDPE material, without water flooding, and with full water reflection of the array. The applicant modeled the HAC array of 105 packages (for a CSI of 1.0) or 72 packages (for a CSI of 1.4) with damage from the HAC tests, with varying water density inside the pipe container, package cavity, and outer packaging, varying water density between packages, and full water reflection of the array. For the single package models, one (for 20 wt.% contents) or two (for 10 wt.% contents) pipe containers are modeled centered in the package cavity, as shown in SAR Figure 6.3.4-9. For array models, the applicant evaluated varying off-center configurations of the one or two pipe containers, to move fissile material in adjacent packages closer together to maximize system $k_{eff}$. The most reactive pipe container array configurations are shown in SAR Figures 6.3.4-10 and 6.3.4-11 for the dual and single pipe geometries, respectively.

The applicant modeled both homogeneous and heterogeneous configurations of contents withing the 5-inch pipe container. For the homogeneous configuration, the applicant started with the 5-inch pipe filled with uranium metal, then reduced the volume in subsequent analyses, first to allow up to the maximum 1.25 lbs. HDPE, then to allow increasing amounts of water. For the heterogeneous configuration, the applicant modeled the fissile content as varying size uranium metal spheres, with varying densities of moderator (HDPE and water) in between the particles. The evaluation begins with the particles close packed and evaluates increasing pitch for each particle size. The applicant performed heterogeneous evaluations for homogeneous configurations which resulted in system $k_{eff}$ values close to the calculated USL.

The applicant's results for the single package case, shown in SAR Table 6.4.4-1, demonstrate that the package remains subcritical for all volume fractions of fissile content evaluated in the 5-inch pipe container(s). The maximum $k_{eff}$ for the 10 and 20 wt.% contents are significantly below the USL determined for these contents in SAR Section 6.8. Note that the applicant did not perform a specific single package analysis for uranium oxide contents, as the uranium metal analysis is bounding for the single package.

For the NCT array, the applicant's calculated $k_{eff}$ results are shown in SAR Table 6.5.4-1. The maximum system $k_{eff}$ for both enrichments considered is with the maximum allowed HDPE content of 1.25 lbs., with no additional water moderator. For both enrichments considered, the maximum NCT array $k_{eff}$ is significantly less than the USL determined for these contents in SAR Section 6.8. Note that the applicant did not perform a specific NCT array analysis for uranium oxide contents, as the uranium metal analysis is bounding for the NCT array.

For the HAC array, the applicant's calculated $k_{eff}$ results for the homogeneous configuration are shown in SAR Table 6.6.4-1 for 10 and 20 wt.% uranium, and 10 wt.% uranium oxide contents. While the maximum $k_{eff}$ values for the three configurations are still well below the calculated USL for these contents, the applicant performed a heterogeneous analysis, as heterogeneous systems at low enrichment can potentially be more reactive than homogeneous systems. The heterogeneous analysis results are shown in Table 6.6.4-2 for 10 wt.% uranium metal, and in Table 6.6.4-3 for uranium oxide. These results show that heterogeneous configurations result in a higher $k_{eff}$ than homogeneous configurations, but still result in system $k_{eff}$ values that are less than the calculated USL for these contents. The heterogeneous analysis results for 20 wt.% uranium are shown in SAR Table 6.6.4-4, and show a much smaller increase in $k_{eff}$ than for 10 wt.% contents. This is expected, as heterogeneous effects are typically less pronounced as enrichment increases. The applicant performed an additional HAC package flooding study for the 10 wt.% uranium contents, since the $k_{eff}$ results for this content type were closest to the USL. The results of this study, summarized in SAR Table 6.6.4-5, show a small increase in $k_{eff}$ for cases where only the package cavity is flooded with low density water, with the maximum $k_{eff}$ still remaining below the USL.

In the single package, NCT array, and HAC array analyses, the applicant demonstrated that pipe containers with the uranium mass limited only by the volume of the pipe are subcritical under all conditions. These analyses support the applicant's request that there be no mass limit for hydrogen limited contents in the 5-inch pipe container, and that the only limit is the volume of the pipe container.

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 6.6 of this SER.

The staff reviewed the applicant's calculations for the hydrogen limited contents in 5-inch pipe containers in the VP-55 and agrees that the applicant has identified the most reactive configuration for all contents considered. The applicant has shown and the staff agrees that the Model No. Versa-Pac, with fissile mass of 10 and 20 wt.% enrichment uranium contents limited by the volume of the 5-inch pipe container, 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.

### 6.5 Air Transport Mass Limits

The applicant requested to revise the CoC to add or modify air transport mass limits for all content categories. The applicant did not change the previously approved analyses that support the air transport mass limits, or the resulting mass limits themselves. The applicant revised the application to apply the mass limits resulting from the air transport analysis consistently across all content categories.

The previously approved mass limits for air transport are:

- 395 grams for enrichments up to 100 wt.%,
- 495 grams for enrichments up to 20 wt.%,
- 590 grams for enrichments up to 10 wt.%, and
- 790 grams for enrichments up to 5 wt.%.

For the standard configuration with the VP-55 and VP-110, the applicant had previously limited the air transport mass limits to those determined for ground transport, since these mass limits are lower. Since this amendment increases the ground transport mass limits for the standard configuration based on updated analyses with new USLs, the air transport mass limits are also increased to be the same as the ground transport limits. These limits are still less than the air transport limits listed above and are therefore conservative.

The only other content category which previously had air transport mass limits was the VP-55 with a 5-inch pipe container. These air transport mass limits are requested to remain the same, with the exception that the enrichment mass limits for 5 wt.% enriched uranium are removed, as discussed in Section 6.3 of this SER. For the hydrogen limited contents in the VP-55, hydrogen limited contents in the VP-55 with 5-inch pipe container, and 1S/2S uranium hexafluoride ($UF_6$) cylinder contents, air transport mass limits are requested to be added. The air transport mass limits for these content categories are the lower of the mass limits determined in the air transport analysis in SAR Section 6.7, or the ground transport limits. This is conservative, since the analysis in SAR Section 6.7 supports the air transport limits for all content categories.

The staff reviewed the proposed revised or added air transport limits, and agrees that they are applied in a conservative manner. The applicant has shown and the staff agrees that the Model No. Versa-Pac, with the proposed air transport mass limits discussed above, will remain subcritical per the fissile material air transport requirements of 10 CFR 71.55(f).

## 6.6 Benchmarking Analysis

The applicant revised the benchmark analysis in SAR Section 6.8 to determine enrichment specific USLs for the use of SCALE 6.1.3, with KENO VI and the continuous energy ENDF/B-VII.0 cross section library, to determine $k_{eff}$ for all of the content category models. The analysis 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."

The applicant selected 252 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 Model No. Versa-Pac package. For each enrichment range, the applicant determined which of the selected benchmark experiments were most applicable using the SCALE TSUNAMI sensitivity and uncertainty analysis code. The applicant only used experiments at each enrichment that had a similarity coefficient ($c_k$) of greater than 0.9, indicating that the experiment is highly applicable to the package configuration being evaluated. For 1.25 wt.% enriched uranium contents, the $c_k$ criterion was reduced to 0.85 to ensure there were enough experiments for good validation statistics. The staff agrees that this is acceptable, as experiments with $c_k$ values 0.8 – 0.9 are considered applicable to the system being evaluated. The only content configuration that required addition of experiments outside of the $c_k$ range typically considered applicable was the 10 wt.% hydrogen limited contents in two 5-inch pipes. In order to capture the sensitivity of this configuration to iron in the steel pipes, additional experiment series with iron present were added, and the $c_k$ for this configuration was lowered to 0.7 to ensure adequate experiments for validation. The staff agrees that this reduction in $c_k$ criteria is acceptable, since the TSUNAMI selection process is an additional step taken to provide a more rigorous experiment selection, is not a step recommended in NUREG/CR-6361, and is not used directly in the generation of USL equations.

SAR Table 6.8-1 summarizes the critical experiments and their applicable qualitative and quantitative selection criteria, and SAR Table 6.8-2 provides the $k_{eff}$ and Monte Carlo uncertainty ($\sigma$) values for each experiment, as well as the $c_k$ value for each enrichment configuration in the Model No. Versa-Pac 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.

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 H/X. Therefore, all the USL equations are based on the H/X 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.

## 7.0 CONDITIONS

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

Condition No. 5(a)(2) was revised to reflect the new revision 4 of drawing VP-55-LD, which includes changes to the drawing notes depicting what packaging components are optional.

Condition No. 5(b)(1) was revised:

- to include a description of the neutron poisons which may be included in the approved contents,
- to include the ability to contain $UF_6$ sample tubes when in quantities of less than 0.1 kg and to restrict the use of hydrogenous packing materials when shipping 1S/2S cylinders, except for a polyethylene foam liner, and
- to allow for unlimited use of hydrogenous packing materials unless otherwise specified (e.g., restricted when shipping 1S/2S cylinders).

Condition No. 5(b)(2) was revised:

- to reflect new mass limits for both ground/vessel and air transport of U-235 (CoC Table 2),
- to reflect new mass limits for U-235 contents with a CSI of 0.7, which also includes these contents at: 5 wt.%, 10 wt.%, and 100 wt.%, (CoC Table 2A),
- to remove the mass limit for U-235 contents at 10 wt.% and less for ground/vessel transport in the 5-inch pipe container as the container (CoC Table 3), and
- to define the limits for U-235 contents in the 5-inch pipe with limited hydrogenous material (Table 3A).

Condition No. 5(c) was revised to point to CoC Table 3A when calculating allowable criticality safety indices for U-235 contents in the 5-inch pipe with limited hydrogenous material.

Condition No. 9 was revised to point to the revised licensing drawing notes to ascertain information about what package components are optional.

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. 16, for the Model No. Versa-Pac.