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

SAFETY EVALUATION REPORT

Docket No. 71-9225
Model No. NAC-LWT
Certificate of Compliance No. 9225

SUMMARY

By application dated December 28, 2012, as supplemented on March 14, 2013, and March 5, July 16, and October 17, 2014, NAC International (NAC or the applicant) requested a revision to Certificate of Compliance (CoC) No. 9225 for the Model No. NAC-LWT (NAC-LWT) transportation package. NAC requested the addition of high enriched uranyl nitrate liquid (HEUNL) as authorized contents to be transported in inner containers designed specifically for this material (HEUNL container). The U.S. Nuclear Regulatory Commission (NRC) staff performed its review of the application as supplemented using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Materials."

Based on the statements and representations in the application, as supplemented, the NRC staff agrees that these changes do not affect the ability of the package to meet the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 GENERAL INFORMATION

1.1 Packaging Description

The NAC-LWT package is a Type B(U)F-96 radioactive material transportation package. It is authorized to transport several types of contents, including light-water reactor and research reactor spent fuel. The NAC-LWT package is shipped by truck, boat or railcar and depending on the payload, within an international shipping organization (ISO) container.

1.2 Packaging Drawings

The applicant submitted four new licensing drawings that show the design of the HEUNL containers to transport the HEUNL, and its configuration within the NAC-LWT package.

The new drawings include:

LWT 315-40-180, Rev. 3P	LWT Transport Cask Assembly, HEUNL Contents
LWT 315-40-181, Rev. 5P (sheets 1 - 2)	Container Assembly, HEUNL
LWT 315-40-182, Rev. 2P	Container Spacer, HEUNL
LWT 315-40-183, Rev. 1P	Container Guide, HEUNL

1.3 Contents

NAC requested a revision to authorize shipment of HEUNL in the NAC-LWT. The HEUNL characteristics are shown in Table 1-1:

Table 1-1: HEUNL Characteristics

Liquid Parameter	Limiting Values
Maximum HEUNL Payload per HEUNL Container [1.]	58.1 L (15.35 gallons)
Maximum Package Heat Load	4.65 W
Maximum per HEUNL Container Heat Load	1.16 W
Maximum HEUNL Heat Load	0.02 W/L
Maximum Curie Content (gamma emitters)	9.0 Ci/L
Maximum ^{235}U content	7.4 g/L
Maximum ^{235}U enrichment	93.4 wt%

1. Each HEUNL container must also have a minimum of 1 gallon of headspace (ullage).

2.0 STRUCTURAL EVALUATION

The purpose of this amendment was to add HEUNL, its inner containers, and ancillary devices as authorized contents to the NAC-LWT transportation package.

2.1 Structural Design Criteria

Proprietary information removed.

2.1.1 Acceptance Criteria

Loads and load combinations were evaluated using the ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division I, Subsection NB for internal pressure and free drops, American National Standards Institute (ANSI) ANSI/ASME N45.2.15, “Hoisting, Rigging and Transporting Items for Nuclear Power Plants,” for handling loads, and 10 CFR Part 71 for normal conditions of transport and hypothetical accident condition loads.

2.1.2 Weights and Centers of Gravity

The safety analysis report (SAR) summarizes the HEUNL container, spacer and payload weights and centers of gravity, respectively.

2.2 Normal Conditions of Transport

The HEUNL container was evaluated for normal conditions of transport using classical, closed-formed calculations and finite element analyses and comparing stress output with allowable stresses from the ASME B&PV Code. Canister components were evaluated with static methods using equivalent G loadings.

2.2.1 Pressure

Design Pressure

The maximum expected pressure during normal conditions of transport was determined to be 100 psig. The HEUNL container was evaluated with an internal pressure of 150 psig which resulted in a margin of safety exceeding 5 for membrane and membrane plus bending stresses.

Closure Assembly

The closure assembly lid and attachment bolts were evaluated for the maximum calculated operating pressure for the HEUNL container of 100 psig. The evaluation included determination of the membrane and membrane plus bending stresses in the lid, calculation of bolt stresses, and calculation of thread shear stress. Positive margins of safety for all of these calculations were demonstrated with a minimum margin of safety exceeding 0.6. Further calculations were performed to verify that the contact pressure between the lid and inner seal remained intact under the pressure condition.

2.2.2 Free Drop

The HEUNL container was evaluated for a 1-ft foot drop on the side, bottom and top ends, and the combination of pressure and 1-ft drop stress intensities.

The side drop was specifically evaluated at 14 discreet sections and the reported minimum margin of safety was 5.98. In addition, bearing stresses were calculated between guide rails and the inner surface of the NAC-LWT package which demonstrated a margin of safety greater than 10.

The bottom end drops were specifically evaluated at 14 discreet sections and the reported minimum margin of safety was 3.73. In addition, bearing stresses were calculated between the bottom of the support ring and the bottom of the package and also the top-most HEUNL container and the closure lid for each of the end drop configurations. These evaluations demonstrated a margin of safety greater than 10.

The requirements of 10 CFR 71.71(c)(7) are satisfied.

2.2.3 Sloshing

Sloshing was evaluated in terms of amplification of damage resulting from free drops. The applicant determined that the time periods of the sloshing and that of the free drop were significantly out of phase to preclude additional structural damage.

2.2.4 Heat

The thermal load for HEUNL container is less than 5 Watts, which does not result in significant thermal stresses.

2.2.5 Cold

Closure Assembly

The closure assembly was evaluated for volumetric expansion due to ice and internal pressure during cold conditions. The minimum reported margin of safety for the closure lid was 1.08 and the minimum margin of safety reported for the closure bolts was 0.25.

Further calculations were performed to verify that the contact pressure between the lid and inner seal remained intact under the pressure condition.

Fill/Drain Port

Proprietary information removed.
The calculated minimum margin of safety was 3.10.

2.3 Hypothetical Accident Conditions

The HEUNL container was evaluated for hypothetical accident conditions using classical, closed-formed calculations and finite element analyses results and comparing stress output with allowable stresses from the ASME B&PV Code. HEUNL container components were evaluated with static methods using equivalent G loadings.

2.3.1 30-foot Free Drop

The HEUNL container was evaluated for a 30-foot side, bottom end and top drops.

The side drop was specifically evaluated at 14 discreet sections and the reported minimum margin of safety was 7.47.

The bottom end drop was specifically evaluated at 14 discreet sections and the reported minimum margin of safety was 3.50. In addition, buckling stresses were calculated with standard, closed-form methods and these evaluations demonstrated a margin of safety greater than 8.0.

The top end drop was specifically evaluated at 14 discreet sections and the reported minimum margin of safety was 2.98. In addition, buckling stresses were calculated with standard, closed-form methods and these evaluations demonstrated a margin of safety greater than 8.0.

Internal pressure plus stress intensities from the 30-foot drop were not considered by the applicant for hypothetical accident conditions. Inspection of the stress intensity magnitudes from either the normal operating pressure or the pressure due to the fire transient demonstrates that significant margins would still be present for this load condition.

The requirements of CFR 71.73(c)(1) are satisfied.

2.3.2 Pressure

HEUNL container

The HEUNL container was evaluated at an internal pressure of 200 psig due to the fire accident. The evaluations demonstrated a minimum margin of safety larger than 10.0.

Closure Assembly

The closure assembly lid and attachment bolts were evaluated for the maximum calculated accident pressure for the HEUNL container of 200 psig. The evaluation included determination of the membrane and membrane plus bending stresses in the lid, calculation of bolt stresses, and calculation of thread shear stress. Positive margins of safety for all of these calculations were demonstrated with a minimum margin of safety exceeding 1.74. Further calculations were performed to verify that the contact pressure between the lid and inner seal remained intact under the pressure condition.

2.3.3 Thermal Expansion

Comparisons of the radial and axial expansions due to the fire transient against baseline geometric clearances between the NAC-LWT package and the HEUNL container demonstrate that thermal expansion will not produce additional loadings on the HEUNL container.

Evaluation Findings

The NRC staff reviewed documentation provided by the applicant including detailed calculation packages and computational analysis results to verify that statements presented by the applicant are accurate and within acceptable engineering practices. Based on the review of the statements, representations, and supplemental calculations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

2.4 Materials Evaluation

This amendment is to add HEUNL as an approved content. The package itself has been previously reviewed and approved for many contents. Staff did not review the package since the liquid is contained in a stainless steel HEUNL container that is then placed in the package. Staff reviewed the following issues: 1) contents interactions with the HEUNL container, 2) adequacy of drawings, use of proper HEUNL container materials properties and 3) loading/unloading procedures. The containment reviewer evaluated the generation of hydrogen by the radiological decomposition of the water in the contents

The staff reviewed the specification of the content's chemical and physical composition and determined that it meets the requirements of 10 CFR 71.33(b)(3). There are four drawings of the HEUNL container and support spacers. The drawings specified welding procedures and qualifications, weld inspection methods and procedures, acceptance procedures for the welds, and appropriate materials lists. The requirements of 10 CFR 71.111 are met.

Proprietary information removed.

Proprietary information removed.

The requirements of 10 CFR 71.33(a)(5) on specification of materials of construction are met.

Proprietary information removed.

The staff determined that the requirements of 10 CFR 71.43(d) requiring no significant chemical, galvanic, or other reaction is met

Proprietary information removed.

The staff found that the acceptable operating temperature range for all materials bounded the expected temperature range during normal conditions of transport and hypothetical accident conditions thus suitable for use in this application and meet the thermal test requirements of 10 CFR 71.71 and 10 CFR 71.73.

The loading and unloading procedures in Chapter 7 were reviewed by the staff and found to have no materials issues.

3.0 THERMAL EVALUATION

The staff reviewed the thermal aspects of the NAC-LWT transportation package with four HEUNL containers that are partially filled with HEUNL contents, or empty, to verify that package performance has been adequately evaluated for the tests specified under normal conditions of transport, hypothetical accident conditions, and that the package design satisfies the thermal requirements of 10 CFR Part 71.

3.1 Description of the Thermal Design

3.1.1 Design Features

This amendment request is for four HEUNL containers either partially filled or empty to be loaded into the NAC-LWT package.
Proprietary information removed.
The HEUNL container pressure boundary has been identified in the application to include the HEUNL container shell, top end cap, bottom end cap, lid and lid inner O-ring seal, and lid port plug and O-ring seal. Although, the two quick

disconnect valves are not part of the pressure boundary, the staff ensured the applicant specified design aspects of the quick disconnect valves that prevent HEUNL contents from ingressing into the cavity between the quick disconnect valve and the HEUNL container lid were described on Drawing No. 315-40-181, note 17.

It is necessary to include at least 1 gallon of headspace, or ullage, in each HEUNL container during filling operations to ensure the HEUNL contents do not completely fill the HEUNL container during hot and cold normal conditions of transport, or hypothetical accident conditions as a result of the expansion of the contents as a function of temperature. The ullage satisfies 10 CFR 71.87(d) and prevents high pressures that would result due to constrained expansion of a completely filled liquid/solid HEUNL container during hot and cold normal conditions of transport, and hypothetical accident conditions. The headspace of at least 1 gallon is achieved by a vent tube (Type II HEUNL container) or siphon tube (Type I HEUNL container) that has a minimum length described on Drawing No. 315-40-181, note 11. The staff confirmed that the minimum vent or siphon tube length will provide at least 1 gallon of headspace based on the HEUNL container dimensions on the licensing drawings.

In order for the vent tube or siphon tube to provide the 1 gallon headspace during filling operations the following must occur. First, the pressure testing and leakage rate testing, in accordance with ANSI N14.5-1997, "Radioactive Materials - Leakage Tests on Packages for Shipment," is necessary for each HEUNL container as described in Section 8.1.4.4 of the application, as well as leakage rate testing of the quick disconnect valves and associated interfaces, which is described in Section 7.1.14.1, step 6, and Section 7.1.14.2, step 5 of the application. In addition, the HEUNL containers must be in vertical orientation with the quick disconnect valves facing up during filling operations, which is described in Section 7.1.14.1 of the application. Also during filling operations the temperature of the HEUNL contents must be greater than 68°F which is described in Section 7.1.14.2 step 4 of the application. After the filling process, the HEUNL container fill and vent lines are cleared with an inert gas purge, which is described in Section 7.1.14.2 step 4 of the application. Section 8.1.4.4.B of the application also describes a verification test that ensures each HEUNL container has a minimum of 1 gallon headspace based on the length of the vent tube or siphon tube. Based on the above activities from Chapters 7 and 8 of the application, 10 CFR 71.87(d) will be satisfied. The staff confirmed that headspace will be present in each HEUNL container during hot and cold normal conditions of transport, and hypothetical accident conditions based on the presence of at least 1 gallon of headspace during HEUNL container filling operations during which the contents are at 68°F.

3.1.2 Contents Decay Heat

The maximum heat load for a total of four HEUNL containers is a maximum of 4.65 Watts per NAC-LWT package. The maximum heat load in one HEUNL container is a maximum of 1.16 Watts. The staff notes, when each HEUNL container is limited to 1.16 Watts, a total of four HEUNL containers can only have a maximum heat load of 4.64 Watts per NAC-LWT. These values are bounded by the decay heat values used in the thermal analysis, 12.88 Watts per NAC-LWT package and 3.22 Watts per HEUNL container. The staff confirmed the decay heat values used in the thermal analysis are for bounding calculation purposes only. The 0.02 Watts/liter energy deposition rate used in the pressure and flammability analysis described in Sections 4.5.6.1 and 4.5.6.2 of the application limits the total decay heat in the NAC-LWT and the decay heat in each HEUNL container.

3.1.3 Summary Tables of Temperatures

The maximum temperatures of the package components for the materials test reactor (MTR) contents (Condition 1, Table 3.4-6 of the SAR) bound the maximum temperatures for the NAC-

LWT components for the HEUNL contents. The maximum calculated temperatures for normal conditions of transport and hypothetical accident conditions for the HEUNL contents and *(Proprietary information removed)* are provided in Table 3-1 of the safety evaluation report (SER) below.

Table 3-1: Maximum Calculated Temperature of HEUNL Contents

	Normal Conditions of Transport (°F)	Hypothetical Accident Conditions (°F)
HEUNL Contents	139	

Proprietary information removed from Table 3-1.

3.1.4 Summary Tables of Maximum Pressures in the Containment System

The maximum calculated pressures in the NAC-LWT containment vessel for normal conditions of transport and hypothetical accident conditions for the HEUNL contents are provided in Table 3-2 of the SER below.

The maximum calculated pressures in the NAC-LWT containment vessel takes into account the thermal expansion of the package cavity and HEUNL container, as well as package cavity gas temperature changes from loading to normal conditions of transport and hypothetical accident conditions.

The maximum pressures in the HEUNL container takes into account air initially present in the headspace of the HEUNL container, radiolytic gas generation, vapor pressure of water, temperature changes from the HEUNL filling temperature to the maximum HEUNL normal conditions of transport and hypothetical accident conditions temperatures, and the decrease in headspace due to expansion of the HEUNL contents.

Proprietary information removed.

The staff confirmed the headspace in the HEUNL container allows for the expansion of contents. Section 6.1 of the calculation package 65008500-3010, Rev. 1, provides additional description of the HEUNL container pressure calculations.

Proprietary information removed.

The HEUNL container was analyzed at 100 psig, which is greater than the normal conditions of transport pressure, in Table 3-2 of the SER below, and therefore captures the hydrostatic pressure effect. In a partially filled HEUNL container, sloshing calculations were included in the structural calculations for various fill levels. The applicant stated the sloshing frequencies calculated indicated that dynamic amplification due to sloshing was negligible compared to the accelerations due to the drop conditions.

The pressure in an HEUNL container with 1 gallon of headspace during filling operations bounds the pressure in an HEUNL container with headspace greater than 1 gallon as well as the pressure in an empty HEUNL container. The hydrostatic test described in Section 8.1.4.4 of the application will test the HEUNL container pressure boundary to a pressure of 140 +10/-0 psig which exceeds the pressure calculated for normal conditions of transport. The staff reviewed Calculation Package 65008500-3010, Rev. 1 and found the pressures in

Table 3-2 of the SER to be conservative based on the following two assumptions. The calculations assume a 1-year residency time compared to the lower 3 month one-way trip time in the certificate of compliance Condition 16(b), and a G value equal to

Proprietary information removed.

Although the HEUNL container volume used in the radiolytic gas generation pressure calculation was slightly less than the maximum volume of HEUNL allowed in the container, the other conservatisms in the radiolytic gas generation pressure calculation make up for this.

Table 3-2: Maximum Pressures in the Containment System

Volume	Normal Conditions of Transport (psia)	Hypothetical Accident Conditions (psia)
NAC-LWT Package Cavity		
HEUNL Container		

Proprietary information removed from Table 3-2.

3.2 Material Properties

Material properties for stainless steel and air were used in the analysis model, the HEUNL contents were assumed to have the properties of water. The staff reviewed the thermal conductivity values used in the HEUNL container analysis model and found the values to match references.

3.3 General Considerations

3.3.1 Evaluations by Analysis

The thermal analysis of the NAC-LWT with HEUNL containers was performed using the ANSYS computer code and 2D finite element models representing a 180 degree cross section of the NAC-LWT package and HEUNL containers. Figure 3.4-21 of the application illustrates the finite element model for HEUNL container. A uniform heat generation rate was applied to the liquid based on the total heat load and a constant temperature of 134°F was applied to the outer surface of the model for the HEUNL container. This temperature corresponds to the maximum inner shell temperature which was obtained using the 2D ANSYS MTR model for normal conditions of transport (Condition 1) from Section 3.4.1.3 of the application after deleting all elements inside the package inner shell and applying a uniform heat flux to the package inner shell corresponding to the analyzed total decay heat (12.88 Watts) of the HEUNL contents.

3.3.2 Evaluation by Test

Evaluation by thermal test of the package is not necessary because a thermal analysis has been performed.

3.4 Thermal Evaluation under Normal Conditions of Transport

3.4.1 Heat and Cold

At 100°F ambient conditions with solar insolation, the maximum temperatures of the package components for the MTR contents (Condition 1, Table 3.4-6 of the application) bound the maximum temperatures for the package components for the HEUNL contents. The analysis resulted in a maximum temperature of 139°F for the HEUNL contents during normal conditions of transport. The maximum HEUNL content temperature also bounds the *(Proprietary information removed)* maximum temperature. The staff confirmed this is below the maximum temperature limits for the stainless steel components of the HEUNL container and the *(Proprietary information removed)*.

The minimum temperatures in the package occur with a 0.0 kW decay heat load and the minimum ambient conditions. Under these conditions, a uniform temperature of -40°F will exist in the package. The applicant stated because the HEUNL containers are underfilled, the contents will start to freeze where the HEUNL contents are in contact with the HEUNL container, therefore freezing from the exterior to the interior of the contents. The applicant also stated that this will not result in a solid condition (when liquid contents completely fill a container); the frozen HEUNL cannot apply any additional load to the HEUNL container shell. The staff agrees with these statements.

Proprietary information removed.

3.4.2 Maximum Normal Operating Pressure

The maximum internal pressure within the containment system (i.e., the volume outside the HEUNL containers and within the NAC-LWT containment boundary) is due to temperature changes of the gas from loading to normal conditions of transport and dimensional changes due to temperature induced changes of the system. This resulted in a maximum internal pressure of the containment boundary during normal conditions of transport of 24 psia; the staff confirmed this value.

Proprietary information removed.

3.4.3 Maximum Thermal Stresses

The applicant's analysis assumed a maximum temperature for the entire HEUNL container. A significant difference is not expected between the minimum and maximum temperatures of the HEUNL container due to the low decay heat of the contents. Therefore significant thermal stresses are not expected during normal conditions of transport; the staff agrees with this conclusion.

3.5 Thermal Evaluation under Hypothetical Accident Conditions

3.5.1 Initial Conditions

The initial conditions were from the MTR analysis model, 100°F ambient with solar insolation and a maximum analyzed decay heat of 12.88 Watts. The NAC-LWT package is loaded with HEUNL containers inside an ISO container and the gas in the NAC-LWT package cavity is considered to be air.

3.5.2 Fire Test Conditions

The fire test conditions were from the MTR analysis model.

3.5.3 Maximum Temperature and Pressure

Two ANSYS 2D finite element models representing a 180 degree cross section of the NAC-LWT package and HEUNL containers were used for the fire transient analysis, one for the initial conditions and one for the fire transient. The model used for the initial condition is a combination of the HEUNL container model described in Section 3.4.1.18 of the application and the NAC-LWT package model described in Section 3.4.1.3.1 of the application with the ISO container and without the ribs/slide bars. At the start of the fire accident the NAC-LWT package is not in the ISO container, the steam pressure and/or the pin puncture will force the neutron shield to be empty, and the ribs/slide bars are added to allow more heat transfer; the staff agrees with these assumptions. Figure 3.5-14 of the application shows the fire transient model. The analysis resulted in a maximum temperature of for the HEUNL contents during hypothetical accident conditions, therefore the contents will not boil. The staff confirmed the stainless steel components of the HEUNL container, the *(Proprietary information removed)*, the alternate port cover Viton seals on the NAC-LWT package, and the lead gamma shield on the NAC-LWT package are also below their maximum temperature limits.

The maximum internal pressure within the containment system is due to temperature changes of the gas from loading to hypothetical accident conditions and dimensional changes due to temperature induced changes of the system.

Proprietary information removed.

The staff reviewed the Calculation Package 65008500-3010, Rev. 1, and found the HEUNL container pressure after the tests for hypothetical accident conditions to be acceptable.

Proprietary information removed.

3.5.4 Maximum Thermal Stresses

The applicant's analysis assumed a maximum temperature for the entire HEUNL container. A significant difference is not expected between the minimum and maximum temperatures of the HEUNL container due to the low decay heat of the contents. Therefore significant thermal stresses are not expected during hypothetical accident conditions; the staff agrees with this conclusion.

3.6 Evaluation Findings

Based on review of the thermal sections of this amendment application, the staff has reasonable assurance that the NAC-LWT package with the HEUNL content within individual HEUNL containers meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

The staff reviewed the application to verify that the effect of the HEUNL content and its inner containers on the package containment design was described and evaluated under normal conditions of transport and hypothetical accident conditions as required in 10 CFR Part 71. Regulations applicable to the containment review include 10 CFR 71.31, 71.33, 71.35, 71.43, and 71.51.

The NAC-LWT is a Type B package designed to transport various radioactive material content. There were no changes in the containment boundary with this amendment and the leakage testing of the NAC-LWT packaging remains as previously evaluated. Rather, the amendment dealt with the placement of four vessels containing HEUNL liquid within the NAC-LWT cavity. Therefore, this evaluation focused on the descriptions within the application that indicated the HEUNL containers under normal conditions of transport and hypothetical accident conditions would not affect the NAC-LWT containment boundary.

4.1 Description of Containment Design Features

The pressure boundary of the HEUNL container includes the container shell, top end cap, bottom end cap, lid, lid plug and O-ring seal, and lid inner O-ring seal. A number of design features and acceptance/maintenance procedures are in place to ensure the HEUNL container and contents would not affect the NAC-LWT containment boundary. A vent /siphon tube within each HEUNL vessel ensures there is a minimum 1 gallon headspace, within the 15.62 gallon (as-build nominal) HEUNL vessels. The ullage satisfies 10 CFR 71.87(d) and prevents high pressures that would result due to constrained expansion of a completely filled liquid/solid HUENL container during normal conditions of transport (hot and cold conditions) and hypothetical accident conditions. For example, the *(Proprietary information removed)* that the applicant measured for the condition of frozen content would be accommodated by the approximately 6% ullage. The vent and fill/drain quick disconnect valves are recessed within the vessel's top end cap and covered with a closure lid that compresses two concentric *(Proprietary information removed)*. The two lid plugs and O-ring seals located in the lid allow access to the interseal volume between concentric O-rings and the HEUNL container; the lid plugs/seals are designed to the SAE J1926 standard. These two O-rings, and the concentric Viton O-rings (alternate port cover design) that form part of the NAC-LWT boundary, are chemically compatible with the HEUNL content. The application's structural analyses conclude that the HEUNL plugs and closure assembly could withstand normal conditions of transport and hypothetical accident conditions and not leak. Structural welds are examined by dye-penetrant examination and ultrasonic examination in accordance with ASME B&PV Code, Section V, with acceptance criteria in accordance with ASME B&PV Code, Section III, Subsection NB, as denoted on the licensing drawings.

The applicant indicated that all of the components listed on Drawing No. 315-40-181 are Important to Safety (ITS) and their classification designations are included in proprietary Enclosure 2 to NAC submittal dated October 17, 2014, (see ADAMS Accession No. ML14294A230).

Proprietary Information Removed.

The applicant addressed the effect of normal conditions of transport and hypothetical accident conditions on the HEUNL container. For both normal conditions of transport and hypothetical accident conditions, the closure lid and its bolts were analyzed by the applicant assuming the lid was directly exposed to the liquid and vapor/gas pressure within the vessel. This analysis assumed there was leakage past the fill and drain quick-disconnect valves. Results from the stress analysis indicated that lid and bolt stresses were below allowable and there was full contact between the lid and seal. The O-rings were below their allowable temperatures during the thermal hypothetical accident conditions.

The applicant determined the maximum pressure within the HEUNL container during normal conditions of transport and hypothetical accident conditions to be *(Proprietary information removed)*, respectively. The HEUNL container is hydrostatically tested to 140 (+10/0) psig after fabrication to check the integrity of the HEUNL container. Following the hydrostatic tests, the HEUNL containers are helium leak tested in accordance with the approved methods of ANSI N14.5-1997 to confirm that the total leakage rate meets the “leaktight” criterion (1×10^{-7} ref cm^3/s). The concentration of helium gas in the HEUNL container during the test is accounted for in determining the test sensitivity. In addition, maintenance and periodic helium leakage tests are performed per ANSI N14.5-1997. Specifically, helium leakage testing, with a leaktight acceptance criterion, is performed after maintenance to the HEUNL container boundary, HEUNL container lid inner O-ring, and HEUNL container lid port plug/O-ring. Periodic helium leakage testing of the HEUNL container lid’s inner O-ring and port plug O-rings also has a leaktight acceptance criterion.

During filling of the HEUNL containers, the fill/drain and vent quick disconnect valves are cycled to seat the valves properly and confirmed to be closed by performing a functional verification. The HEUNL port plug and seal are leak tested to confirm no detectable leakage when tested to a sensitivity of 1×10^{-3} ref cm^3/s using a pressure rise test after the HEUNL container is filled. Similar criterion apply when leak testing the HEUNL closure lid/O-ring seal to a sensitivity of 1×10^{-3} ref cm^3/s using a pressure drop test.

The staff reviewed and accepted the applicant’s description of the HEUNL vessel’s pressure boundary, acceptance tests, and maintenance/periodic tests to show its content would remain contained and would not adversely affect the NAC-LWT containment boundary.

4.2 Combustible-Gas Generation

The applicant’s analysis of hydrogen generation within the HEUNL container was based on previous measurements of concentrated nitric acid solutions and *(Proprietary information removed)* . These measurements were based on there being no significant neutron or alpha emission from the solution.

Proprietary information removed.

Proprietary information removed.

This analysis was based on a decay heat of 0.02 W/liter of HEUNL solution and 1 gallon ullage within each HEUNL container. The applicant’s analysis conservatively assumed that all of the gamma and beta released was deposited in the solution for gas generation.

The staff reviewed and accepted the applicant’s description of the flammable gas generation within the HEUNL containers.

4.3 Containment under Normal Conditions of Transport and Hypothetical Accident Conditions

With the four HEUNL containers as contents, the pressure within the NAC-LWT package during normal conditions of transport and hypothetical accident conditions were analyzed by the applicant to be *(Proprietary information removed)* psia, respectively; these pressures are lower than the NAC-LWT package cavity’s 50 psig design pressure. The Alternate vent and drain port cover design Viton O-rings, which are required when transporting the HEUNL containers, were below their allowable temperatures during normal conditions of transport and hypothetical accident conditions, based on the O-ring temperatures being below their allowable values when transporting previously approved contents, that have much higher decay heats. As stated previously, the NAC-LWT containment boundary continues to be helium leak tested. The only change to the NAC-LWT leakage rate test for this amendment was to indicate that the NAC-LWT closure lid leakage rate test would have a minimum helium concentration greater than 98% in the package cavity.

4.4 Containment Evaluation Finding

Based on a review of the containment sections of this amendment application, the staff has reasonable assurance that the NAC-LWT package with the HEUNL content within individual containers meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING EVALUATION

The objective of this review is to verify that the NAC-LWT transportation package meets the external radiation requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions.

The staff shielding review evaluated the NAC-LWT shielding features to provide adequate protection from the radioactive contents within. This review evaluated the potential impact on external dose rates due to the addition of HEUNL as authorized contents to the NAC-LWT package.

5.1 Shielding Description

5.1.1 Design Features

The NAC-LWT package assembly is composed of a package that provides a containment vessel to prevent release of radioactive material. The containment boundary consists of a 4-inch-thick bottom plate, a 0.75-inch-thick, 13.375 inch diameter shell, and upper ring forging and an 11.3-inch-thick closure lid.

Gamma shielding is provided by a 5.75-inch-thick lead shield enclosed by a 1.2-inch-thick outer shell. Neutron shielding is provided by a 5-inch-thick shield tank with a 0.24-inch-thick outer wall containing a water/ethylene glycol mixture and a minimum of 1% boron by weight.

HEUNL will be loaded into a stainless steel container, with up to 58.1 L (15.35 gallons) of solution in each HEUNL container. The HEUNL container is comprised of a welded lid, shell, bottom plate structure with lid penetrations for filling and draining. Four HEUNL containers will be loaded into the containment vessel cavity.

5.1.2 Summary Table of Maximum Radiation Levels

The maximum dose rates after the tests for normal conditions of transport and hypothetical accident conditions are reported in SAR Table 5.3.20-16 with a more detailed dose rate summary in Table 5.3.20-15 in the SAR and are summarized in Table 5-1 below.

Table 5-1: Maximum Dose Rates

Transport Condition	Dose Rate Location	Maximum (mrem/hr)
Normal	Package Surface	6.05
	1 m (Transport Index)	1.5
Accident	1 m	3.13

5.2 Source Specification

Both neutron- and gamma-emitting nuclides were analyzed for HEUNL assuming a bulk density of 1.3 g/cm^3 and applying a bounding volume of 64.3 L per HEUNL container to determine the source strength. The applicant performed two ORIGEN-S calculations are used for source term calculation, one for fission products and a second for actinides and light elements. Composition of the HEUNL material is provided in Tables 5.3.20-1 through 5.3.20-6 in the SAR.

5.2.1 Gamma Source

A list of gamma-emitting nuclides is provided in SAR Table 5.3.20-3 and consists entirely of fission products. The actinides present are minor gamma source contributors. The expected gamma source term per liter is summarized in the SAR in Table 5.3.20-9.

5.2.2 Neutron Source

The actinides listed in Table 5.3.20-2 of the SAR are the only neutron source in HEUNL material. The expected neutron source term per liter is summarized in SAR Table 5.3.20-8.

5.3 Shielding Model

The applicant used a detailed MCNP model to conduct a three-dimensional shielding analysis. The HEUNL containers and packages are modeled as described in the licensing drawings. The applicant's model conservatively omits tube quick disconnect fittings, the bottom portion of the outer shell that rests on the shoulder and axially overlaps the HEUNL container and neck, and base plate. The HEUNL containers are conservatively shifted towards the top of the containment vessel cavity to position HEUNL material closest to the point of minimum gamma shielding.

Models for normal conditions of transport include a gap between the lead and outer shell, while the models for hypothetical accident conditions assume the loss of neutron shielding material and lead slump. The neutron shield shell and impact limiters are conservatively removed during hypothetical accident conditions shielding analysis.

The staff has determined that the shielding model is described in sufficient detail to conduct a review of the package shield design.

5.4 Shielding Evaluation

5.4.1 Methods

ORIGEN-S as used is an appropriate software package to determine nuclide inventory and evaluate the source terms. MCNP5 is a continuous-energy, Monte Carlo transport code. It is appropriate for use in this application.

5.4.2 Input and Output Data

Sample ORIGEN-S source term input files and MCNP files were provided.

5.4.3 Flux-to-Dose-Rate Conversion

The gamma and neutron flux-to-dose conversion factors from ANSI/ANS 6.1.1-1977, “Neutron and Gamma-Ray Flux to Dose Rate Factors,” were used in the analysis and are appropriate.

5.4.4 External Radiation Levels

A summary of the radiation levels on various package surfaces and 1 m from the package surface are presented in SAR Table 5.3.20-15 for both normal conditions of transport and hypothetical accident conditions.

5.4.5 Confirmatory Analyses

The staff reviewed the applicant’s shielding models and determined that the conservative assumptions and analysis methods are appropriate to this shielding design.

The staff performed dose-rate calculations with the MONACO/MAVRIC modules within the SCALE 6.1 code package to verify the dose rates resulting from the presence of HEUNL within the package. Staff verified that the peak does rates were at the side of the cylindrical shell of the package. Staff analysis conservatively ignored the components of the ends of the individual HEUNL containers and modeled the HEUNL material as a solid cylinder of equal liquid density and source strength throughout the packaging cavity. The HEUNL container side-walls were modeled as a single, full-length cylinder. Staff conducted analyses with HEUNL material occupying the annulus between the HEUNL containers and the inner wall of the packaging cavity. The dose rates calculated by the staff are in reasonable agreement with the applicant’s analysis.

The staff has determined that the design of the radiation shielding features of the NAC-LWT package is in compliance with 10 CFR Part 71 and the applicable design criteria have been satisfied. The evaluation of the shielding system provides reasonable assurance that the NAC-LWT will provide safe transportation of radioactive materials and do not affect the ability of the package to meet the dose rate limits in 10 CFR Part 71. This finding is based on staff confirmation of the external dose rates as well as considerations of the applicant’s conservative analyses and modeling assumptions in the SAR.

6.0 CRITICALITY EVALUATION

The objective of the criticality review is to verify that the NAC-LWT package design with HEUNL satisfies the criticality safety requirements of 10 CFR Part 71, including performance under the normal conditions of transport specified in 10 CFR 71.71 and the hypothetical accident conditions specified in 10 CFR 71.73. The staff's review considered the criticality safety requirements of the radioactive material transportation regulations in 10 CFR Part 71.

6.1 Description of the Criticality Design

The NRC staff reviewed the General Information section in Chapter 1 of the NAC-LWT SAR as well as any additional information in the Criticality Section, Chapter 6, of the NAC-LWT SAR. NRC staff determined that the description of the criticality safety features supporting their evaluation, including the figures, drawings, and tables provide enough detail to allow for an in-depth evaluation.

The proposed design allows for up to 4 HEUNL containers to be transported in a NAC-LWT package. The HEUNL material consists of uranyl nitrate, various other nitrates, and water. Composition of the HEUNL material is provided in SAR Table 6.7.2-1. The evaluated nitrate contents are further detailed in SAR Table 6.7.2-2. This amendment makes no changes to the packaging design already approved in previous amendments.

The applicant provided tables summarizing the results of the criticality evaluation for a single package and arrays of packages under normal conditions of transport and hypothetical accident conditions. SAR Tables 6.7.2-16 and 6.7.2-17 contain a summary of the final analysis results of the criticality safety analyses. The package or package array is considered to be subcritical if k_{safe} (or k_s) for each of the analysis cases is less than the upper subcritical limit (USL). The computed k_{safe} is equated as $k_s = k_{eff} + 2\sigma < USL$. The applicant's USL, including the administrative margin and bias, is 0.9366. Staff reviewed these tables and found that the applicant's calculated maximum k_{eff} values, including two standard deviations, are significantly less than the USL.

6.1.1 Packaging Design Features

The applicant provided drawings of the packaging and HEUNL containers in Section 1.4 of the NAC-LWT SAR. The staff reviewed these drawings and found that they sufficiently describe the locations, dimensions, and tolerances of the containment system and HEUNL containers. Therefore the staff found that the applicant meets the requirements of 10 CFR 71.31(a)(1) and 10 CFR 71.33(a)(5) with respect to the criticality evaluation.

For criticality control, the NAC-LWT design with HEUNL relies upon limiting the volume and concentration (and hence, the mass) of fissile material. The neutron multiplication factor (or k_{eff}) will be less than the USL, including all biases and uncertainties, after the tests for normal conditions of transport and hypothetical accident conditions.

6.1.2 Codes and Standards

The staff found that the applicant appropriately identified the regulations in 10 CFR Part 71 that are applicable to the criticality design of the package. In Section 6.5.4.1 of the NAC-LWT SAR, the applicant also identifies standards applicable to the validation and application of the criticality computer codes used.

6.1.3 Summary Table of Criticality Evaluations

Staff reviewed the summary tables for HEUNL in Tables 6.7.2-16 and 6.7.2-17 of the SAR to ensure that the Model No. NAC-LWT will continue to meet the requirements of 10 CFR 71.55(b), (d) and (e), 71.59(a)(1) and (2). The applicant performed an evaluation for a single package and an infinite array of packages considering the effects of the tests for normal conditions of transport and hypothetical accident conditions. In all instances, the calculated reactivity results were all well below the USL of 0.9366, with the highest calculated reactivity found to be 0.9071 for an infinite array of packages under hypothetical accident conditions.

Table 6-1: Summary of Criticality Evaluations

Normal Conditions of Transport	
Analysis Case	k_s
Single Package Maximum	0.8952
Array Maximum (infinite array)	0.8965
Hypothetical Accident Conditions	
Analysis Case	k_s
Single Package Maximum	0.8950
Array Maximum (infinite array)	0.9071
USL	0.9366

6.1.4 Criticality Safety Index

Section 6.7.2.5 of the NAC-LWT application states that the criticality safety index (CSI) is 0. Per 10 CFR 71.59(b) the value of "N" as defined in 10 CFR 71.59(a) is effectively infinity. The applicant calculated an infinite array for normal conditions of transport (5N) and an infinite array for hypothetical accident conditions (2N) using the maximum reactivity configuration defined for the 10 CFR 71.55 evaluation. The staff found that these array sizes are acceptable and meet the requirements of 10 CFR 71.59(a)(1) and 10 CFR 71.59(a)(2). In addition, the staff found that the licensee meets 10 CFR 71.59(a)(3) because the value of N is not less than 0.5.

6.2 Fissile Material Contents

The applicant described the proposed contents, which consist of a maximum of four HEUNL containers, in Section 6.7.2.5 of the application. A schematic of an HEUNL container is provided in Figure 6.7.2-6. The maximum content of each HEUNL container is limited to 58.1 L (15.35 gallons) of solution with a maximum concentration of 7.4 g ^{235}U per liter, which results in a maximum ^{235}U mass of 430 g. Therefore, the maximum ^{235}U in the package is limited to 1.72 kg. The analysis uses a bounding maximum content for each HEUNL container, which is 17 gallons (64.35 liters) of solution with a maximum concentration of 7.2 g ^{235}U per liter, and results in a maximum ^{235}U mass of 463 g. Therefore, the maximum analyzed ^{235}U in the package is 1.85 kg, which bounds the approved mass of 1.72. The maximum uranium enrichment analyzed in the criticality model is 93.4 wt.% ^{235}U. The staff finds this acceptable because it bounds the limits in the proposed CoC, which is 93.4% for HEUNL.

The NRC staff reviewed the dimensions provided by the applicant and finds them to be consistent with or bounded by those used in the applicant's analysis. The NRC staff also reviewed the fuel mixture mass and atom densities and finds them to be consistent based on the applicant's analysis and staff's confirmatory calculations, the staff finds that the applicant has defined adequately the type, maximum quantity, and chemical and physical form of the fissile material in compliance with the requirements of 10 CFR 71.31(a)(1), 10 CFR 71.33(b)(1), 10 CFR 71.33(b)(2), and 10 CFR 71.33(b)(3).

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configuration

The staff reviewed the applicant's model description in Section 6.7.2.2 of the SAR. This model takes into account the effects of the normal conditions of transport and hypothetical accident conditions tests specified in 10 CFR 71.71 and 10 CFR 71.73. The applicant used the contents and packaging tolerances that maximize reactivity and assumed full water reflection outside the containment system. Additionally, applicant analyses for a single package indicated that inclusion of moderator inside the package cavity containing the HEUNL containers reduces system reactivity. The applicant also assumed optimal moderation of the HEUNL solution and shifted contents in the HEUNL containers to produce optimal interaction.

The staff reviewed the applicant's analysis models, and, based upon the information provided by the applicant, as well as its own confirmatory calculations, the staff finds the model configurations and analysis to be acceptable.

6.3.2 Material Properties

The staff verified that the appropriate atom densities are provided for all materials used in the models of the packaging and contents by reviewing applicable tables in Chapter 6 of the SAR. The compositions and densities for the materials used in the computer models were reviewed by the staff and determined to be acceptable.

6.3.3 Computer Codes and Cross-Section Libraries

The applicant performed the criticality evaluations for the NAC-LWT using the three-dimensional Monte Carlo code MCNP5 (version v1.60) with continuous energy cross-sections. The applicant used the most up-to-date cross section libraries for the model materials that are available in MCNP. These libraries were derived from ENDF/B-V, VI, and VII cross section data. In addition, the applicant used the appropriate MCNP5 option (i.e., mt) to properly account for the hydrogen bound to water.

In Section 6.7.2.2 of the application, NAC states that it is using cross section data validated for highly enriched uranyl nitrates as specified in SAR Section 6.5.4. For isotopes without an ENDF/B-VII library, the latest and most applicable library set was used (i.e., ENDF/B-VI, ENDF/B-V, etc.). Section 6.5.4.1 of NAC-LWT application states that these are the same cross sections used to perform code validation. The ENDF data is considered acceptable per the guidance in Section 4.2, "Cross Sections and Cross Section Processing," of NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages." Therefore, the staff found the cross sections used are appropriate for use with the NAC-LWT HEUNL application.

The MCNP5 code is an industry standard for performing criticality analyses and is widely used in industry application for criticality calculations. As a result, the MCNP code and its associated cross-section sets have been extensively benchmarked against critical experiments. Thus, the staff agrees that the codes and cross-section sets used by the applicant are appropriate for this particular package design and contents.

The application contains sample input and output files, which staff reviewed to confirm that the model inputs and outputs were consistent with the descriptions in the application. The applicant included a sufficient number of particle histories in its calculations to achieve a statistical standard deviation of less than 0.001 in the calculated values of k_{eff}. The staff considers this to be sufficient for this application and finds the applicant's use of the code acceptable.

6.3.4 Demonstration of Maximum Reactivity

The applicant performed several calculations for the contents for both a single package and arrays of packages. Staff reviewed the applicant's analyses and finds reasonable assurance that the most reactive configuration of the package is considered. Optimum moderation conditions were identified. Further descriptions of these analyses and their results are provided in Sections 6.4 through 6.6 of this safety evaluation report.

6.3.5 Confirmatory Analyses

Staff performed confirmatory analyses on the most reactive configurations described by the applicant. The SCALE 6 computer software package was used as an alternate independent code to the MCNP code used by the applicant for the analyses of the NAC-LWT with HEUNL containers. Staff used the 238-group cross section libraries derived from ENDF/B-V data. Significant parameters were varied to ensure maximum reactivity peaks were adequately captured and in all instances staff calculations were bounded by or in close agreement with the applicant's results.

6.4 Single Package Evaluation

6.4.1 Configuration

The staff verified that the applicant's evaluation demonstrates that a single package is subcritical under both normal conditions of transport and hypothetical accident conditions. The fissile material was modeled in the most reactive credible configuration consistent with the condition of the packaging and contents. The most reactive credible configuration was determined by implementing a series of studies, which included package interior moderation, HEUNL moderation, HEUNL container configuration, and optimum container tolerances. These studies were designed to meet 10 CFR 71.55 (b) and (e) requirements for normal conditions of transport and hypothetical accident conditions for single packages. The single package analysis by regulation must consider a fully water reflected package and be at optimum physical configuration and moderation. Each study retained the maximum reactivity configuration from the previous study. The applicant relies on a series of pre-shipment leakage tests to ensure HEUNL contents do not leak from HEUNL containers (see SAR Chapter 7, Section 7.1.14, "Procedures for Vertical Filling of HEUNL Contents into HEUNL Containers.") as required by 10 CFR 71.55(b).

Per the requirements in 10 CFR 71.55(b)(3) the applicant performed an evaluation of the NAC-LWT with the containment system fully reflected by water. The containment for the NAC-LWT is the inner shell of the package. While no operating condition results in a removal of the package outer shell and lead gamma shield, the applicant re-evaluated the most reactive case by removing the lead and outer shells (including neutron shield), and reflecting the containment system by water at full density. Using this maximum reactivity configuration, the calculated keff+2σ was 0.86235, which is significantly below that of the full package water-reflected model (i.e., neutron reflection produced by the lead gamma shield and outer steel package shell produces a higher reactivity system than that produced by a water reflector), which resulted in a keff+2σ of 0.8952.

The NAC-LWT single package analyses included reflection of 20 cm water on all sides. "Full reflection" is 30 cm per the recommendations in NUREG/CR-5661; however, the applicant performed a sensitivity study that showed that the difference between 20 and 30 cm reflection for a fully flooded single package NAC-LWT model with HEUNL containers is within the uncertainty of the calculation and is therefore insignificant. The staff found that the 20-cm reflector meets the requirement in 10 CFR 71.55(b)(3).

The criticality evaluation considers damage to the package for both normal conditions of transport and hypothetical accident conditions when determining maximum system reactivities. The accident conditions of transport include the loss of neutron shielding material, the neutron shield shell, and the impact limiters.

6.4.2 Results

6.4.2.1 Normal Conditions of Transport

The staff confirmed that the results of the applicant's criticality calculations are consistent with the information presented in Table 6.7.2-16 of the application. The maximum k_{eff} for a single package under normal conditions of transport is 0.8952. Since the k_{eff} is less than the USL of 0.9366 after the tests specified in 10 CFR 71.71, the staff verified that this meets the requirements of 10 CFR 71.55(d)(1) which requires that the contents be subcritical.

Since the applicant performed criticality evaluations using optimum moderation of the HEUNL, the staff found that this is a reasonably bounding geometry of the fissile material, and therefore the staff found that the geometric form of the package contents could not be altered in such a way that would affect the conclusions from the criticality safety analyses. The staff found that the applicant meets the requirements in 10 CFR 71.55(d)(2).

The applicant performed calculations where moderation is present to such an extent to cause maximum reactivity consistent with the chemical and physical form of the material. The staff found that this meets the requirements of 10 CFR 71.55(d)(3).

Under the tests specified in 10 CFR 71.71, the staff verified that there will be no substantial reduction in the effectiveness of the packaging for criticality prevention including (1) the total volume of the packaging will not be reduced on which the criticality safety is assessed, (2) the effective spacing between the fissile contents and the outer surface of the packaging is not reduced by more than 5%, and (3) there is no occurrence of an aperture in the outer surface of the packaging large enough to permit the entry of a 10 cm cube. The staff found that this meets the requirements in 10 CFR 71.55(d)(4).

6.4.2.2 Hypothetical Accident Conditions

The staff confirmed that the results of the applicant's criticality calculations are consistent with the information presented in Table 6.7.2-16 of the application. The maximum k_{safe} for a single package after the tests for hypothetical accident conditions is 0.8950. Since the k_{eff} is less than the USL of 0.9366 under the tests specified in 10 CFR 71.73, the staff verified that this meets the requirements of 10 CFR 71.55(e), which requires that after the tests for hypothetical accident conditions the package be subcritical.

The staff verified that (1) the fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents, (2) water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents, and

(3) there is full reflection by water on all sides, as close as is consistent with the damaged condition of the package. This meets the requirements of 10 CFR 71.55(e)(1) through (3).

6.5 Evaluation of Package Arrays

After the single package analysis is complete, package array analysis is performed to meet 10 CFR 71.59 requirements. The requirements in 10 CFR 71.59 requirements are met by evaluating a package array with dry interior and exterior for normal condition and optimum interior and exterior moderated array for accident conditions. The analysis relies on the HEUNL container boundary to retain its HEUNL contents (i.e., no uranyl nitrate transfer between HEUNL containers).

The most reactive single package case is used as the basis for the normal conditions of transport array model.

6.5.1 Configuration

The applicant specified a CSI of 0. For normal conditions of transport and hypothetical accident conditions, the applicant modeled an infinite array by applying a reflective boundary condition at the surface. The normal conditions of transport configuration assumes no in-leakage of water and nothing between the packages. The applicant used the optimally moderated HEUNL container model for this evaluation. This model was determined to be most reactive under wet conditions.

Similar to the evaluation for normal conditions of transport, the NAC-LWT package hypothetical accident conditions analysis used the bounding conditions identified above, including the removal of the neutron shielding well as the neutron shield tank and the package impact limiters.

6.5.2 Results

6.5.2.1 Normal Conditions of Transport

The maximum k_{eff} for the normal conditions of transport array analyses is 0.8965. Since k_{eff} for an infinite array is less than the USL of 0.9366 under the tests specified in 10 CFR 71.71, the staff verified that this meets the requirements of 10 CFR 71.59(a)(1) which requires that an array size 5N of undamaged packages be subcritical.

6.5.2.2 Hypothetical Accident Conditions

Similar to the evaluation for normal conditions of transport, the NAC-LWT package under hypothetical accident conditions analysis used the bounding conditions identified above, including the removal of the neutron shielding well as the neutron shield tank and the package impact limiters. The maximum k_{eff} for the hypothetical accident conditions array analyses is 0.9071. Since k_{eff} for an infinite array is less than the USL of 0.9366 under the tests specified in 10 CFR 71.73, the staff verified that this meets the requirements of 10 CFR 71.59(a)(2) which requires that an array size 2N of packages under hypothetical accident conditions be subcritical.

6.6 Fissile Material Packages for Air Transport

Air transport for the NAC-LWT was not sought by the applicant and is not authorized.

6.7 Benchmark Evaluations

The applicant examined critical experiment cases from the "International Handbook of Evaluated Criticality Safety Benchmark Experiments" based upon their similarity to the HEUNL container contents. The important selection parameter was HEU nitrate fuels with a thermal spectrum, which resulted in a total of 106 critical experiments available for benchmarking.

The applicant performed the criticality evaluations using the MCNP5 v1.60 three-dimensional Monte Carlo code and continuous energy cross sections. The applicant performed benchmarks with the same computer code and cross section set.

6.7.1 Experiments and Applicability

The applicant performed benchmark comparisons and determined a USL based on the guidance published in NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages." The staff found the use of this guidance acceptable.

The applicant uses experiments from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. The experiments are listed in Table 6.5.4-1 of the NAC-LWT SAR. The staff found that these are appropriately referenced.

Materials selected by the applicant were solutions of uranyl nitrate. Experiments were selected for compatibility of materials and geometry with the spent fuel packages. As such, experiments containing significant neutron absorber in the form of plates, rods, or soluble poison were eliminated. Also removed were experiments containing non-light water moderator. Further review eliminated experiments if they did not contain a primarily thermal neutron spectrum causing fission.

The staff verified that the following important design parameters for the HEUNL in the NAC-LWT system were within the benchmark experiments cited by the applicant:

- Enrichment, and
- Energy of the Average Lethargy Causing Fission (EALCF).

The applicant analyzed 93.4% enriched fuel, while the maximum enrichment in the experiments was 93.2%. Although the evaluated enrichment of the maximum reactivity case for the HEUNL fuel is slightly above the maximum enrichment benchmark evaluated for the Uranyl Nitrates benchmark evaluation performed in Section 6.5.4 of the SAR (i.e., 93.4 wt.% for HEUNL vs. 93.2 wt.% in the critical set), the EALCF of 0.04 eV is within the area of applicability, and the applied USL of 0.9366 based on the EALCF, bounds the use of this fuel.

The staff verified that the selected critical experiments include HEU nitrate fuels with a thermal spectrum. The EALCF for the most reactive HEUNL case (i.e., 0.04 eV) is within the range of selected benchmarking experiments (i.e, 0.0306 eV to 0.526 eV).

6.7.2 Bias Determination

The USLSTATS tool in SCALE provides trending analysis for bias assessment. The USL and bias were determined using USLSTATS for two trending parameters: (1) EALCF and (2) ^{235}U enrichment. However, the applicant found no statistically significant trends for either parameter.

As all experiments contain primarily U-235 (92.78 wt.% to 93.22 wt.%) with minor impurities, the consistent attribute to trend analysis was the EALCF. Based on all the independent variable correlations, the applicant calculated a USL of 0.9366.

The criticality evaluation used the same cross section set, fuel materials, and similar material/geometry options that were used in the benchmark calculations. The staff reviewed the benchmark comparisons in the SAR and agrees that the Monte Carlo computer program MCNP5 v1.60 used for the analysis was adequately benchmarked to representative critical experiments relevant to the package design and contents specified.

6.8 Evaluation Findings

Based on the review of the statements and representations in the application, supplemental information supplied by the applicant, and staff confirmatory analyses, the staff has reasonable assurance that the nuclear criticality safety design has been adequately described and evaluated by the applicant and that the package meets the criticality safety requirements of 10 CFR Part 71.

7.0 OPERATING PROCEDURES EVALUATION

The staff reviewed Chapter 7 of the application to verify that it meets the requirements of 10 CFR Part 71 and is adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

The chapter includes the procedures for package loading, unloading, and preparation of the empty package for transport. To support this revision request, NAC added Sections 7.1.13 and 7.1.14 of the application to include the procedures for loading HEUNL contents into an HEUNL container and loading of four inner containers in the NAC-LWT package using a dry transfer system. Section 7.2.7 was added to include procedures for unloading the HEUNL contents from the NAC-LWT package.

During filling operations, the HEUNL container must be in the vertical orientation (disconnect valves up), in order to ensure proper ullage within the HEUNL container. The ullage satisfies 10 CFR 71.87(d) and prevents high pressures that would result due to constrained expansion of a completely filled liquid/solid HEUNL container as a result of the expansion of the contents as a function of temperature during hot and cold normal conditions of transport, and hypothetical accident conditions. The headspace of at least 1 gallon is achieved by a vent tube (Type II HEUNL container) or siphon tube (Type I HEUNL container) that has a minimum length described on Drawing No. 315-40-181, note 11.

In order for the vent tube or siphon tube to provide the 1 gallon headspace during filling operations the following must occur. First, the pressure testing and ANSI N14.5 leakage rate testing is necessary for each HEUNL container as described in Section 8.1.4.4 of the application, as well as leakage rate testing of the quick disconnect valves and associated interfaces, which is described in Section 7.1.14.1, step 6, and Section 7.1.14.2, step 5, of the application. In addition, the HEUNL containers must be in vertical orientation with the quick disconnect valves facing up during filling operations, which is described in Section 7.1.14.1 of the application. Also during filling operations the temperature of the HEUNL contents must be greater than 68°F which is described in Section 7.1.14.2, step 4, of the application. After the filling process, the HEUNL container fill and vent lines are cleared with an inert gas purge, which is described in Section 7.1.14.2, step 4, of the application. The fill/drain and vent quick disconnect valves are cycled to seat the valves properly and confirmed to be closed by performing a functional verification.

Section 8.1.4.4.B of the application also describes the verification test that will be used to ensure each HEUNL container has a minimum of 1 gallon headspace based on the length of the vent tube or siphon tube. Based on the above activities from Chapters 7 and 8 of the application, 10 CFR 71.87(d) will be satisfied.

For pre-shipment, the HEUNL port plug and seal are leak tested to confirm there is no detectable leakage when tested to a sensitivity of at least 1×10^{-3} ref cm^3/s using a pressure rise test after the HEUNL container is filled. Similar criterion apply when leak testing the HEUNL closure lid/O-ring seal to a sensitivity of 1×10^{-3} ref cm^3/s using a pressure drop test. The pre-shipment leakage test procedures are prepared and approved by personnel certified to the American Society of Non-destructive Testing as a Level III examiner for leakage testing.

In order to limit the concentration of hydrogen to less than 5% by volume within the HEUNL container, the shipment must be within a 3-month period between filling the HEUNL container and the end of the transport period.

The staff reviewed and evaluated the proposed loading and unloading procedures of the HEUNL contents and its containers. Based on the statements and representations in the application, the staff concluded that the package operations meet the requirements of 10 CFR Part 71, and that they are adequate to assure the package will be operated 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 Operating Procedures in Chapter 7 of the SAR, as supplemented.

8.0 ACCEPTANCE TESTS AND MAINTENANCE REVIEW

The staff reviewed Chapter 8 of the application to verify that it meets the requirements of 10 CFR Part 71 and is adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

The chapter includes the acceptance tests and maintenance procedures for the HEUNL containers. To support this revision request, the applicant added Section 8.1.4.4 to provide component tests of the HEUNL container.

The HEUNL container is hydrostatically tested to 140 (+10/0) psig after fabrication, in accordance with the ASME B&PV Code, Section III, Subsection NB, to confirm the integrity of the HEUNL container. Following the hydrostatic tests, the HEUNL containers are helium leak tested in accordance with the approved methods of ANSI N14.5-1997 to confirm that the total leakage rate meets the “leaktight” criterion (1×10^{-7} ref cm^3/s). The concentration of helium gas in the HEUNL container during the test is accounted for in determining the test sensitivity. In addition, maintenance and periodic helium leakage tests are performed in accordance with the approved methods of ANSI N14.5-1997. Specifically, the HEUNL container boundary is helium leakage tested after maintenance to the HEUNL container, its lid inner O-ring, and lid port plug/O-ring with a leaktight acceptance criterion. Periodic helium leakage testing of the HEUNL container lid’s inner O-ring and port plug O-rings also is to a leaktight acceptance criterion. The helium leakage test procedures are prepared and approved by personnel certified to the American Society of Non-destructive Testing as a Level III examiner for leakage testing.

The applicant revised the NAC-LWT package closure lid leakage rate test to require a minimum helium concentration in the package cavity to be greater than 98%. In order to ensure this condition, the package cavity is back-filled with 99.9% (minimum) pure helium, evacuated to a pressure that is less than 100 torr, and then backfilled with 99.9% (minimum) pure helium.

The staff reviewed and evaluated the acceptance tests and maintenance procedures. Based on the statements and representations in the application, the staff concluded that the acceptance tests and maintenance procedures meet the requirements of 10 CFR Part 71, and that they are adequate to assure the package will be constructed and maintained 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 Chapter 8 of the SAR, as amended.

CONDITIONS

In addition to the new and revised drawings in Condition 5.(a)(3)(ii), the following changes have been made to the Certificate:

Condition 5.(a)(3)(iii) was added to include the following drawings:

LWT 315-40-180, Rev. 3P	LWT Transport Cask Assembly, HEUNL Contents
LWT 315-40-181, Rev. 5P (sheets 1 - 2)	Container Assembly, HEUNL
LWT 315-40-182, Rev. 2P	Container Spacer, HEUNL
LWT 315-40-183, Rev. 1P	Container Guide, HEUNL

Conditions 5.(b)(1)(xx) was added to specify the type and form of the HEUNL contents.

Condition 5.(b)(2)(xxi) was added to specify the quantity of material per package and per HEUNL container, and specify conditions of transport for the contents.

Condition 5.(c) was revised to add a CSI of 0.0 for transport of the HEUNL contents.

Condition 16 was added as follows:

For shipment of HEUNL contents:

a. Hydrogen concentration can be assumed to be less than 5% provided the package shipment is completed within 3 months of closure of the HEUNL containers.

b. The maximum cumulative time (service life) an HEUNL container shall contain the HEUNL solution is 15 months.

c. An HEUNL container that has a cumulative time containing HEUNL solution greater than 12 months is not authorized to be loaded with HEUNL solution.

Condition 16 has been renumbered to be Condition 17.

Condition 17 has been renumbered to be Condition 18.

Condition 18 has been renumbered to be Condition 19.

Condition 19 has been renumbered to be Condition 20.

Condition 20 has been renumbered to be Condition 22.

Condition 21 was added to authorize continued use of the NAC-LWT for approximately 1 year.

CONCLUSION

CoC No. 9225 has been revised to authorize shipment of HEUNL as specified above in the Model No. NAC-LWT package. Based on the statements and representations in the application, and with the conditions listed above, the staff agrees that this authorization does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued on December 24, 2014.