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

November 7, 2019

Mr. Wes Stilwell
Global Packaging and Regulatory Compliance Manager
Westinghouse Electric Company LLC
Columbia Fuel Fabrication Facility
5801 Bluff Road
Hopkins, South Carolina 29061

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9380, REVISION NO. 0, FOR THE MODEL NO. TRAVELLER STD & XL PACKAGE

Dear Mr. Stilwell:

As requested by your application dated September 2018, supplemented August 30 and October 14, 2019, enclosed is Certificate of Compliance No. 9380, Revision No. 0, for the Model No. TRAVELLER STD & XL package. The U.S. Nuclear Regulatory Commission (NRC) staff (the staff's) safety evaluation report is also enclosed.

Westinghouse Electric Company, LLC, has been registered as a user of the package under the general license provisions of Title 10 of the *Code of Federal Regulations* 10 CFR 71.17 or 49 CFR 173.471. The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact Pierre Saverot of my staff at (301) 415-7505.

Sincerely,

/RA/

Daniel I. Doyle, Acting Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9380
EPID No. L-2018-NEW-0006

Enclosures:
1. Certificate of Compliance No. 9380, Rev. No. 0
2. Safety Evaluation Report

cc w/encls. 1&2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy, c/o L. Gelder

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9380, REVISION NO. 0, FOR THE MODEL NO. TRAVELLER STD & XL PACKAGE

DATED: November 7, 2019

DISTRIBUTION:
SFST r/f
AKock, NMSS
ADimitriadis, RI
BBonser, RII
MKunowski, RIII
GWarnick, RIV

(Closes EPID - L-2018-NEW-0006)

Filename: G:/SFST/PART 71 CASEWORK/Model Traveller Docket 71-9380/9380.R0.doc; 9380.R0.LETTER&SER.doc

ADAMS Package Accession No.: ML19311C541 (Pkg) ML19311C542 (Ltr) ML19311C543 (Encl 2)

OFC	DFM	E	DFM	C	DFM	|	DFM	C	DFM	C	DFM	
NAME	PSaverot		VWilson		JBorowski		RRodriguez		JChang			
DATE	06/06/2019		07/19/19		09/06/2019		09/12/2019		05/19/19			
OFC	DFM	C	DFM	C	DFM	|	DFM	C				
NAME	TTate		YDiaz-Sanabria		SFigueroa		DDoyle					
DATE	10/23/19		10/18/19		10/25/19		11/7/19					

E=With attachment/enclosure N=No copy C=Without attachment/enclosure

OFFICIAL RECORD COPY

SAFETY EVALUATION REPORT
WESTINGHOUSE ELECTRIC COMPANY LLC
Model No. Traveller STD & XL Package
Certificate of Compliance No. 9380
Revision No. 0

SUMMARY

By letter dated December 19, 2018, Westinghouse Electric Company LLC (the applicant) submitted an application for Certificate of Compliance No. 9380, Revision No. 0, for the Model No. Traveller STD & XL as B(U)F-96 packages. The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) issued a request for additional information (RAI) letter dated April 18, 2019, for which responses were received on July 8, 2019. On August 30, 2019, the applicant supplemented its RAI responses. On November 4, 2019, the applicant provided a final revised application.

The Traveller is a shipping package designed to transport both Type A and Type B fissile material in the form of uranium fuel assemblies or fuel rods with enrichments up to 5.0 weight percent (wt.%) ^{235}U. Several types of pressurized water reactor (PWR) fuel assemblies, as well as either PWR or boiling water reactor (BWR) fuel rods, can be shipped in the package which is designed to carry a single fuel assembly or a single Rod Pipe for loose fuel rods.

There are two packaging variants, the Traveller Standard (STD) and Traveller XL (XL), depending upon the length of the fuel assembly.

The packaging is made up of two basic components, an Outerpack and a Clamshell, which are connected together with shock absorbing rubber mounts to minimize the forces applied to the contents during transport. The Outerpack is a structural component that serves as the primary impact and thermal protection for the contents, while the Clamshell restrains the fuel assembly or Rod Pipe contents during all transport conditions.

During accident transport conditions, the Clamshell remains closed and its design limits any possible rearrangement of the fuel assembly. Neutron absorber plates are installed on the inside surface of the Clamshell along the full length of each side. Some fuel assemblies require an axial or lateral spacer to ensure a proper axial fit into the Clamshell.

A weather gasket, set between the mating surfaces of the upper and lower Outerpack, is used to mitigate water and debris from entering the package.

NRC staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material." The analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, shielding, and criticality protection under normal and accident conditions.

Based on the statements and representations in the application, and the conditions listed in the Certificate of Compliance, the staff concludes that the package meets the requirements of 10 CFR Part 71.

References

Application for Certificate of Compliance for the Traveller PWR Fuel Shipping Package, Revision No. 1, dated November 2019.

1.0 GENERAL INFORMATION

1.1 Packaging

The Traveller is a shipping package designed to transport Type A and Type B fissile material in the form of uranium fuel assemblies or fuel rods with enrichments up to 5.0 weight percent (wt.%) ^{235}U. The Traveller package is designed to carry one pressurized water reactor (PWR) fuel assembly as well as either PWR or boiling water reactor (BWR) fuel rods or one Rod Pipe for loose fuel rods.

There are two packaging variants, the Traveller Standard (STD) and Traveller XL (XL) depending upon the length of the fuel assembly. The Traveller STD has a gross weight of 4,500 lb (2,041 kg), a tare Weight of 2,850 lb (1,293 kg) and has the following outer dimensions: 197.0 in. x 27.1 in. x 39.3 in. (5004 mm x 688 mm x 998 mm). The STD version accommodates standard length fuel assemblies and Rod Pipe.

The Traveller XL has a gross weight of 5,230 lb (2,372 kg), a tare weight of 3,260 lb (1,479 kg) and the following outer dimensions: 226.0 in. x 27.1 in. x 39.3 in. (5740 mm x 688 mm x 998 mm)

The packaging is made up of two basic components: an Outerpack and a Clamshell:

> The Outerpack is a structural component that serves as the primary impact and thermal protection for the contents. It also includes specific components for lifting, stacking, and tie down during transportation. The Outerpack consists of a top and bottom half, each half consisting of a stainless steel outer shell, a layer of rigid 10-pcf polyurethane foam, and an inner stainless steel shell. The stainless steel provides structural strength and acts as a protective covering to the foam. The Outerpack also has independent impact limiters at its top and lower ends.
>
> The Clamshell restrains the fuel assembly or Rod Pipe contents during all transport conditions. During accident transport conditions, the Clamshell remains closed and its structure limits any rearrangement of the fuel assembly. Neutron absorber plates are installed on the inside surface of the Clamshell along the full length of each side. Some fuel assemblies require an axial or lateral spacer to ensure a proper fit into the Clamshell. The Clamshell is fastened to the lower Outerpack with shock absorbing rubber mounts.

Rubber pads are positioned at axial locations, matching the structural grid locations for each fuel assembly type, along the inside of the Clamshell doors, to restrain lateral movement.

Foam is inserted between the Clamshell and the lower Outerpack to minimize shocks experienced during transport. The foam is a rigid, closed-cell polyurethane foam used for both its impact absorbing and thermal insulation properties. The steel-foam-steel “sandwich” is the primary fire protection for this package.

A weather gasket between the mating surfaces of the upper and lower Outerpack is used to mitigate water and debris from entering the package.

The Traveller packaging does not contain neutron or gamma shielding features because neutron and gamma radiations emitted from the allowable contents are negligible. However, the Traveller package features a flux trap system, with BORAL® neutron absorber plates located at each lateral side of the Clamshell, in addition to the ultra-high molecular weight (UHMW) polyethylene moderator blocks, which are affixed to the walls of the Outerpack inner cavity.

1.2 Contents

The contents of the packaging consist of either a single PWR fuel assembly or loose fuel rods. Fissile material is in the form of ^{235}U, with a maximum enrichment of 5.0 wt.%. A single fuel assembly or a single Rod Pipe is transported in a package.

Any number of loose fuel rods may be transported in a Rod Pipe. Fuel rods in the Rod Pipe include designs for both PWR and BWR. The theoretical maximum number of fuel rods that can fit inside the Rod Pipe is approximately 250 fuel rods.

The PWR fuel assembly may be transported with non-fissile, non-radioactive reactor core components, as discussed in Section 1.2.2.1.3 of the application.

The maximum weight of the contents is 1,650 lb (748 kg) for the Traveller STD and 1,971 lb (894 kg) for the Traveller XL

1.3 Materials

The materials of the Traveller package are well specified in the application, and are identical to those approved for the Traveller package under Docket No. 71-9297.

1.4 Drawings

The Model No. Traveller packaging is fabricated in accordance with the following drawings:

Traveller Type A Design – Licensing Drawings 10004E58, Rev. 9 (Sheets 1-9)

Traveller Type B Design – Licensing Drawings 10071E36, Rev. 2 (Sheets 1-9)

Rod Pipe – Licensing Drawing 10006E58, Rev. 6

1.5 Evaluation Findings

A general description of the Model No. Traveller package is presented in Section 1 of the package application, with special attention to design and operating characteristics and principal safety considerations. Drawings for structures, systems, and components important to safety are included in the application.

The application identifies the Westinghouse Quality Assurance Program and the applicable codes and standards for the design, fabrication, assembly, testing, operation, and maintenance of the package.

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. Traveller package against 10 CFR Part 71 requirements for each technical discipline.

2.0 STRUCTURAL AND MATERIALS EVALUATION

The objective of the structural review is to determine that the information presented in the application, including the description of the packaging, design and fabrication criteria, structural material properties, and structural performance of the package design for the tests under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), is complete and meets the requirements of 10 CFR Part 71.

2.1 Description of Structural Design

Section 2.1.1 of the application discusses the structural design for the Traveller packaging which consists of two principal structural components: the Outerpack and the Clamshell.

The Outerpack, which provides impact and thermal protection for either the fuel assembly or the rod pipe, is a long circular tubular construction with top and bottom halves held together by hinge-and-bolt assemblies. Each half is made of an inner and outer stainless-steel shell and a layer of rigid polyurethane foam in between. There are two impact limiters, integral to the packaging, located at the top and lower ends. Both impact limiters consist of 6 pcf (0.096 g/cm^3) foam.

The Clamshell, which protects the contents during routing handling and limits rearrangement of the contents in the event of a transportation accident, resides inside the Outerpack cavity on a series of rubber shock mounts. It is comprised of a long rectangular aluminum container designed to carry one fuel assembly or one rod pipe with a lower aluminum “v” extrusion, two aluminum door extrusions, a bottom base plate, a small access door assembly, and several mechanical ancillaries, including a continuous hinge to fasten each door to the “v” extrusion and the door latches.

The Clamshell provides structural support for either the fuel assembly or the rod pipe by mechanical restraining devices:

> Axial restraint at the top is provided through a threaded rod-clamping device which depends on the top plate configuration and fuel assembly type.
>
> Rubber pads are located axially to restrict lateral movement.
>
> A bottom spacer is located to ensure a proper fit for shorter fuel assemblies.
>
> A bottom support spacer and a top axial restraint are always required for Type B packages.

A rod pipe designed to carry loose fuel rods can be placed inside the Clamshell structure by a positive restraining device. Axial restraint is provided by an axial clamp assembly for the XL model and by a shipping spacer in the Clamshell top plate for the STD model.

2.2 Structural Design Criteria

Section 2.1.2 of the application discusses the structural design criteria for the Traveller package. The applicant evaluated the package primarily by a series of drop tests of full-scale Traveller XL specimens to demonstrate that the package maintains its structural functions through both NCT and HAC scenarios.

Additional drop testing was performed for ascertaining the structural adequacy of Type B package components, such as the Clamshell and bottom spacers. In addition, finite element analyses (FEA) were performed to assess the performance of some of the Type B components, as explained in Sections 2.12.2 and 2.12.3 of the application.

The structural design criteria require that the test results must support the assumptions used in the criticality evaluation, in that there is no release of material, no loss of moderator or neutron absorber, no gross decrease in the Outerpack geometry, and no gross increase in the Clamshell geometry

Evaluations to ascertain the behavior of miscellaneous package components, including lifting attachments and tie-down devices, were performed with typical mechanical design calculations. Other structural failure modes such as brittle fracture, fatigue, and buckling were also considered.

2.3 Weights and Centers of Gravity

Section 2.1.3 of the application discusses the weights and centers of gravity for the Traveller package. The package is evaluated for two configurations, which vary primarily in overall length: Traveller Standard (STD) at 500 cm (197 in.) and Traveller XL at 574 cm (226 in.).

The maximum gross weights of Traveller STD and Traveller XL are 2,041 kg (4,500 lbs.) and 2,372 kg (5,230 lbs.), respectively. The center of gravity (CG) for both configurations is approximately at the geometric center of the Outerpack, which is about 58.4 cm (23 in.) above the ground level, considering the support legs, circumferential stiffeners on the upper Outerpack, and forklift pockets.

Table 2.1-3 of the application lists the weights summary, including a maximum fuel assembly weight of 748 kg (1,650 lbs.) and 894 kg (1,971 lbs.) for the Traveller STD and XL packages, respectively.

2.4 General Standards

The smallest overall dimension of the package is the outer shell diameter, approximately 68.8 cm (27.1 in.). This is greater than the minimum dimension of 10 cm (4 in.) specified in 10 CFR 71.43. Therefore, the package meets the requirements of 10 CFR 71.43(a) for minimum size.

Two tamper indicating seals are attached between the upper and lower Outerpack halves to provide visual evidence that the closure was not tampered with. This satisfies the requirements of 10 CFR 71.43(b).

The Traveller package cannot be opened inadvertently. Positive closure of the package is provided by high strength Allen type threaded rods and nuts. Thus, the requirements of 10 CFR 71.43(c) are satisfied.

2.5 Lifting and Tie-Down Standards for All Packages

Section 2.5 of the application discusses criteria including design loads used for lifting and tie-down devices.

2.5.1 Lifting Devices

For both types of packages, the applicant evaluated the attachment points and their related structural details. A total bounding weight of 69.79 kN (15,690 lbf) and 120.0 kN (27,000 lbf) was used for the Traveller XL and Traveller STD designs, respectively. For the latter, the applicant analyzed a stacked lifting configuration consisting of two canisters. For both cases, the total bounding loads analyzed was three times the weight of each respective design.

For both the Traveller XL and Traveller STD designs, the applicant discussed a 4-point lifting configuration with attachment points located on stacking brackets (see figure 2.5-1 and figure 2.5-5 of the application). Two different failure models were considered, namely, hole tear-out of the lifting eye plate and weld strength of the lift plates attached to the Outerpack.

For both models, the calculated maximum stresses were less than the allowable stresses. Section 2.5.1 presents additional mechanical design considerations including forklift handling, among others. Similarly, in all situations considered, all stress results were less than the allowable yield stresses.

The staff notes that, since the lifting device analyses assumed conservative bounding loads (i.e., 3 times the total weight of each design) and the calculated stresses were less than the allowable in all situations, the requirements of 10 CFR 71.45(a) for lifting devices are met.

2.5.2 Tie-Down Devices

The packages are secured to the transportation conveyance by a strap across the top of the packages and a chain inboard from the welded plate at the package legs. The applicant noted that there are no structural devices designed for tie-down; however, the possibility of the leg assembly or of the eight (8) lift eyes being inadvertently used as tie-down devices was analyzed.

Per the requirements of 10 CFR 71.45, the applicant calculated the following series of forces acting on the center of gravity:

- Vertical: 2 g = 46.5.3 kN (10,460 lbf)
- Axial: 10 g = 232.6 kN (52,300 lbf)
- Transverse: 5 g = 116.3 kN (26,150 lbf)

For the leg assembly, the applicant calculated the resulting loads acting on each leg and analyzed the cross-member welds that attach the leg to the Outerpack. The calculated weld shear stress was less than the allowable shear stress.

For the lift eyes, the applicant conservatively assumed that only six lift eyes are load-bearing and calculated the resultant force on each eye. The applicant noted that the lift eyes are fillet welded to the Outerpack and, therefore, weld stresses were analyzed. The applicant further calculated vertical and combined shear weld stresses.

For both cases, the calculated weld shear stresses were less than the allowable shear stresses.

The staff ascertained that there are no structural devices that are designed exclusively to be tie-down devices. In addition, the staff evaluated the additional analysis performed by the applicant and notes that the methods of evaluation provide additional conservatism to the tie-down analysis and, in aggregate, comply with the requirements of 10 CFR 71.45(b).

2.6 Normal Conditions of Transport

2.6.1 Heat

The application considered temperatures between -40°C (-40°F) and 70°C (158°F) to evaluate the thermal stress and the differential thermal expansion (DTE) for the package. Because the packages are not sealed to the environment, no pressure induced stress is considered.

The applicant stated that effects of DTE for the package is negligible. A DTE of 0.58 cm (0.23 in.) is calculated between the aluminum Clamshell and the fuel assembly, which can be accommodated by the combined thickness of the base and the axial clamp cork rubber of 1.27 cm (0.5 in.).

Because of a difference in thermal expansion coefficient between the UHMW polyethylene and the Type 304 stainless steel, special design features are introduced to the moderator panels attached to the inner face of the Outerpack. This includes oversized panel attachment holes and a nominal panel-to-panel gap of 0.66 cm (0.26 in.) to accommodate DTE between the moderator panel and the inner stainless-steel shells of the Outerpack.

The staff reviewed the DTE evaluation in the application and concludes that the effects associated with DTE on various package components are negligible. Thus, the requirements of 10 CFR 71.71(c)(1) are satisfied.

2.6.2 Cold

The materials used in constructing the packages are not degraded by cold at -40°C (-40°F). Since the load bearing components are made of stainless steel and aluminum, materials that do not exhibit brittle fracture at cold temperature, the requirements of 10 CFR 71.71(c)(2) are satisfied.

2.6.3 Reduced External Pressure

The Traveller package is not designed to form an airtight pressure boundary. Thus, the reduced external pressure will not impact the structural integrity of the package, and the requirements of 10 CFR 71.71(c)(3) are satisfied.

2.6.4 Increased External Pressure

The Traveller package is not designed to form an airtight pressure boundary. Thus, the increased external pressure will not impact the structural integrity of the package, and the requirements of 10 CFR 71.71(c)(4) are satisfied.

2.6.5 Vibration

By comparing natural frequencies of typical transportation vehicles to that of the fundamental mode of vibration of the tied-down package, the applicant determined that the Outerpack would not undergo resonance vibration.

Considering typical Clamshell acceleration time history, as shown in Figure 2.6-1 of the application and measured during a 483-kilometer (300-mile) trip road test, the applicant states that the rubber shock mounts effectively isolate and dampen loads and vibrations to the Clamshell and its contents.

Thus, the staff agrees with the applicant's conclusion that no resonance vibration conditions which could fatigue the Clamshell will occur during NCT.

This satisfies the requirements of 10 CFR 71.71(c)(5).

2.6.6 Water Spray

The Traveller packaging materials of construction are not affected by the water spray test. The staff agrees with the applicant that the water spray tests of 10 CFR 71.71(c)(6) have negligible effects on the package.

2.6.7 Free Drop

The applicant performed a 1.2-m (meter) (4-ft) low angle slap-down drop test on the Traveller XL certification test unit (CTU) specimen as an initial condition for subsequent HAC drops. The package axis, with the support legs pointing up, was aligned at an angle approximately 10 degrees with the horizontal plane.

Section 2.6.7 of the application discusses the drop orientation selection for structural integrity evaluation of welded joints. The staff reviewed the discussion and agrees with the applicant's evaluation that both structural and criticality control integrities will be maintained, meeting the requirements of 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

The corner drop test does not apply since the gross weight of the package exceeds 50 kg (110 lbs.), in accordance with 10 CFR 71.71(c)(8).

2.6.9 Compression

The applicant presented an analysis of the package for the compression test by considering a bounding stacking load of 11,340 kN (26,150 lbf), which is 5 times the weight of the Traveller XL.

The applicant assumed the load path to follow through the welds of the stacking brackets, through the Outerpack side, and to the leg supports. Stresses and other pertinent forces were calculated for each of the sections and compared to their respective allowable values. In all cases considered, the calculated values were less than the allowables.

The staff reviewed the analysis and concludes that the stipulated loading path is representative for this test. In addition, the results show that the structural performance for all load-bearing components is acceptable. This satisfies the requirements of 10 CFR 71.71(c)(9).

2.6.10 Penetration

The applicant stated that the penetration test has negligible consequence on the performance of the package because it was designed to withstand the most limiting case of the puncture test.

This evaluation was demonstrated by calculating the impact energies between both tests. The applicant stated that the puncture drop test bounds the pin penetration by a factor of 400.

The staff reviewed the evaluation and agrees with the applicant's conclusion that the puncture test is bounded by the penetration test.

Thus, the penetration is not expected to result in any significant structural damage to the Outerpack. This satisfies the requirements of 10 CFR 71.71(c)(10).

2.7 Hypothetical Accident Conditions

2.7.1 30 ft Free Drop

Qualification consisted of four full scale test campaigns of the Traveller XL, as shown in Table 2.7.1 of the application. The applicant stated that the Traveller XL bounds the shorter Traveller STD design due to its greater weight and size and, therefore, was used for all drop tests. The drop campaigns were designed to challenge fuel rod integrity, thermal protection, and criticality control.

Ten 30 ft free drops were performed using full-scale prototypes, Qualification Test Units (QTU) and a final Certification Test Unit (CTU). For the Type B configuration, a free drop test of the Clamshell, to demonstrate fuel clad leaktight capabilities, was performed.

The initial drop campaign consisted of QTU and CTU drop tests. This campaign demonstrated that the Outerpack performed adequately with localized damages. The applicant identified that the 30 ft bottom end drop, and the 30 ft top end CG-forward-of-the-corner drop onto drop were the most challenging for the package.

After the fire test which followed the puncture-pin drop, the Clamshell was examined and found intact and closed. The applicant noted that (i) the simulated poison plates maintained their position, (ii) the axial location of the fuel rods stayed between the bottom and top nozzles, and (iii) the moderator blocks remained intact and essentially undamaged. Tables 2-7-4 through 2-7-8 of the application list the measured pre- and post-test fuel envelope, gap, and pitch.

Lateral deformation of a single rod was predominant in causing fuel geometry change. Fracture was observed at the end plug locations for 20 fuel rods with an average width of approximately 0.03 in. and an average length of about 50 percent of the rod diameter. The applicant determined the post-test geometry of the fuel assembly acceptable in that only local rod expansion was noted in the lower 20 in. of the bottom nozzle region and the cracked rod gaps were all less than a pellet diameter.

Notable results for the initial campaign confirmed that the test fuel assembly experienced some lattice expansion and cracked fuel rods in the bottom nozzle end cap region of the fuel assembly.

However, the staff notes that (i) the Clamshell was not breached, (ii) the Outerpack remained closed, (iii) the end plugs did not separate from the rods and (iv) pellet material was not lost from the cracked rods. Overall, for the Type A configuration, the fissile package configuration criticality safe geometry was maintained.

<u>Type B configuration</u>

In order to demonstrate that all fuel rods meet the leaktight criterion, the applicant performed an additional 30-ft drop test for the Type B package configuration. This additional drop test consisted on a full-scale prototype with a W-NSSS 17X17 XL lead filled helium backfilled fuel assembly loaded onto a Traveller XL Clamshell. The Clamshell was modified by adding an axial bottom support spacer and a top axial restraint. Sections 2.12.2 and 2.12.3 provide a validation and additional FEA on these two modifications.

The Type B configuration was consequently bottom dropped onto the Traveler XL with the impact limiter in place. The Outerpack was not included in the test. The applicant stated that the Type B configuration Outerpack is uncoupled from the Traveller Clamshell by the shock mounts during a drop event and, therefore, was not necessary to be included in the drop test. The applicant justified the uncoupled behavior based on the drop testing and FEA results.

During drop testing, the applicant stated that the Outerpack impacted the surface in a significantly inelastic manner before the Clamshell impact. Similar behavior is also observed in the FEA simulation discussed in Section 2.12.3 of the application. Based on both scenarios, the applicant concludes that the Outerpack is at rest the moment the Clamshell hits it; therefore, loads associated with the Outerpack are zero at the moment of impact, demonstrating that an uncoupled behavior exists.

The staff reviewed the claims and concludes, based on the information presented, that there is reasonable assurance that the Outerpack and Clamshell behavior during this drop even represents an uncoupled system.

Since the cladding of the fuel rods is part of the package's containment capabilities and given that this package is intended to carry different types of fuel assemblies, the staff reviewed how this full scale prototype W-NSSS 17x17XL particular fuel assembly bounds other assemblies that have different cladding arrays in terms of buckling potential.

In its supplemental information dated August 30, 2019, the applicant provided additional details regarding some of the cladding material properties for the W-NSSS 17X17 XL fuel assembly. Of note, of all the zirconium alloys considered for cladding, the applicant selected Standard Zirconium Alloy, with an elastic modulus of 1.47×10^7 psi, for the drop test because it has the least ductility and failure occurs at a much lower strain than for other alloys, as presented in Section 2.2.1.8 of the application.

Using the elastic modulus of Standard Zirconium Alloy ($E = 1.47 \times 10^7$ psi), the applicant calculated the critical buckling loads for various fuel assemblies with different cladding arrays and dimensions. The applicant concluded that the W-NSSS 17X17 XL provided the lowest critical buckling value.

The staff reviewed the approach and agrees that the selection of the Standard Zirconium Alloy for the drop tests bounds other alloys considered for cladding because it has the lowest total energy absorption capabilities. Concurrently, the staff agrees that the W-NSSS 17X17 XL fuel array bounds other fuel arrays as it has the lowest critical buckling load, as shown in Table 1 of the August 30, 2019, supplement, and demonstrated to be successful during the Type B configuration drop test.

Tables 2.7-12 and 2.7-13 of the application list the measured pre- and post-test fuel envelope and gap characterization dimensions. Notable results for the Type B testing confirmed that all fuel rods remained leak tight (see Section 6.3.2 of the application for additional details), with no measurable change in fuel rod diameter and the Clamshell remained closed and structurally intact.

Rod Pipe

Section 2.11.3 of the application discusses rod pipe testing and validation. The function of the rod pipe is to transport loose fuel rods. Details of the rod pipe are included in license drawing 10006E58. The applicant stated that the structural capability of the rod pipe to survive both NCT and HAC conditions is demonstrated by the HAC 30.5 ft (9 m) drop test. The drop test consisted of a full-length rod pipe filled with 1650 lb. (748 kg) of ballast with a lower impact pillow and rubber spacer.

The applicant stated that welds were uncompromised and that there were no measurable changes in pipe dimensions. Regarding the rubber spacer and lower impact pillow, both items suffered minor expected damages but were able to provide adequate protection to the rod pipe.

The staff reviewed the applicant's claims and assumptions and finds that the drop testing provides reasonable assurance that the rod pipe will maintain its structural integrity.

The free drop tests, in aggregate, satisfy the requirements of 10 CFR 71.73(c)(1).

2.7.2 Crush

The Traveller package weighs more than 500 kg (1,100 lbs.). Therefore, the dynamic crush test of 10 CFR 71.73(c)(2) does not apply.

2.7.3 Puncture

A 1-m (40-in.) puncture-pin drop test each was performed on all five full-scale Traveller XL specimens. Except for the puncture-pin drop of the second PTU, which preceded a 9-m (30-ft) free drop, all other puncture-pin drops were administered after the corresponding 9-m (30-ft) free drops to ensure that the most severe drop orientations and locations had been covered.

Section 2.7.3.2 of the application summarizes the test results. The applicant noted additional minor damage to the Outerpack and determined that the puncture-pin drops did not affect thermal performance of the package.

The criticality control capabilities of the package were also demonstrated in that the tests had revealed no evidence of loss of contents from the Clamshell or deterioration of the polyethylene sheeting and neutron absorber sheeting in the subsequent fire test events.

On this basis, the staff agrees that the tests that were performed satisfied the intent of 10 CFR 71.73(c)(3).

2.7.4 Thermal

See Section 3.0 of this safety evaluation report for the thermal performance of the Traveller package.

2.7.5 Immersion - Fissile Material

The Traveller package is not leak-tight under external pressure and, under the immersion test, water will fill all internal void space. Therefore, the packaging structure is not subject to the loading of the water immersion test and the requirements of 10 CFR 71.73(c)(5) are met.

2.7.6 Immersion - All Packages

The application notes that the water is assumed to fill all internal void space and the criticality analysis assumes the worst-case flooding scenarios. Therefore, the packaging structure is not subject to the loading of the water immersion test and the requirements of 10 CFR 71.73(c)(6) are met.

2.7.7 Summary of Results for Accident Sequence

In the most damaging bottom-end drop, the CTU test, without the use of the conforming shipping spacers, demonstrated that, because of the buckled bottom nozzle, the 17x17 XL fuel assembly experienced a small percentage of fuel rod cracks at the bottom end plug. The average crack size was deemed insufficient for fuel pellets to escape, thereby ensuring the containment function of the fuel cladding.

The test also demonstrated a slight change of the fuel assembly geometry due to localized fuel rod buckling. The applicant determined that the resulting fuel assembly geometry was acceptable for maintaining critical control of the package.

Regarding the Type B configuration, the addition of the axial bottom support spacer and top axial restraint in conjunction with the drop testing satisfied the leak tight requirement.

2.8 Materials Evaluation

The package materials have been evaluated under the Traveller Type AF package Docket No. 71-9297. A short summary of the materials evaluation is below for reference.

The Outerpack shell is made of ASTM A240 or A276 Type 304 stainless steel, and is filled with closed-cell polyurethane foam. The mechanical and thermal properties of the 304 stainless steel have been checked against the ASME B&PV code Section II, Part B and found to be correct. The foam crush strength was provided as a function of temperature and strain for all foam densities and found to be in agreement with publicly available data for similar closed-cell polyurethane foams. The foam thermal properties were also checked and found to be in agreement with publicly available data for similar closed-cell polyurethane foams.

A weather gasket is used between the upper and lower portions of the Outerpack to prevent rain, water spray, and debris from entering the package. The weather gasket is made of either fiberglass or silicone rubber. These gaskets have no structural or thermal function, thus only their melting temperature is provided. The melting temperatures of the weather gasket materials have been checked against publicly available data and found to be correct.

Neutron moderation is ensured by the Ultra High Molecular Weight (UHMW) polyethylene (PE) attached to the upper and lower sections of the Outerpack. The density, melt temperature, and thermal properties of the UHMW PE blocks provided in the application have been checked against publicly available data and found to be correct.

The Clamshell components and the removable top plate (RTP) or fixed top plate (FTP) are made of ASTM B221 or ASTM B209 aluminum alloy 6005-T5 or 6061-T6. These alloys are very similar in chemical composition, and have very similar mechanical and thermal properties.

Rubber pads cover the inside of the Clamshell to protect the contents in NCT but have no structural function. The 304 stainless steel fasteners are used to attach various Clamshell components. The mechanical and thermal properties of ASTM B221 or ASTM B209 aluminum alloy 6005-T5 or 6061-T6 have been checked against the ASME B&PV code Section II, Part B – Nonferrous Material Specifications, SB-221 - and found to be correct.

Borated 1100 series aluminum (BORAL, proprietary material) plates cover the inside wall of the clamshell over the entire fuel length and serve as a thermal neutron absorber for criticality control. The 1100 series aluminum used to fabricate BORAL is a ductile, corrosion resistant material. BORAL is acceptable for use in the Model No. Traveller package. In addition, the melting point of 1100 series aluminum used for the BORAL is high enough to preclude melting from occurring during hypothetical accident conditions.

The mechanical and thermal properties of the axial spacer's aluminum alloy 6063-T6, 6082-T6 and 6061-T6 have been checked against the ASME B&PV code Section II, Part D and found to be correct. The mechanical properties of the rubber pad, placed between the axial spacer and the Clamshell for additional shock absorption, were checked against publicly available data and the shear modulus was found to be higher than published data by a factor of 2 to 5. However, Westinghouse proprietary report SFAD-10-72 Rev. 2 shows that, even if the shear modulus is reduced by a factor of 10, the axial spacer behavior is not significantly affected; thus, the choice of a high shear modulus in the model has no impact on safety. The staff finds this conclusion to be acceptable.

No chemical interactions are expected between the metallic and the non-metallic materials in the package. The Outerpack and Clamshell are made of dissimilar metals but the Clamshell is held away from the Outerpack with rubber pads; thus, they are never in contact and no galvanic reactions are expected under normal operations.

The fasteners in the clamshell are in contact with aluminum, and the galvanic potential difference between these two dissimilar metals is too high to completely preclude any galvanic interaction, but the surface of the aluminum is much greater than that of the fasteners. As a result, the cathode-to-anode ratio is very small, and significant degradation of the aluminum is precluded.

Finally, neither the Outerpack 304 stainless steel nor the clamshell aluminum (physically isolated inside the Outerpack) has any significant chemical or galvanic reaction with air or water.

Radiation levels under normal handling and transport conditions are negligible for the package; thus, no materials will be adversely affected by radiation.

The staff asked the applicant to define the relevant zirconium alloy properties (e.g., total strain absorption energy, yield stress, ultimate stress) that would ensure that the fuel rod/cladding would survive the HAC tests (30 ft drop, thermal, etc.) to have confidence that the fabricated fuel rods, which act as containment boundary, will have the required structural integrity.

The individual properties (e.g., total strain absorption energy, yield stress, ultimate stress) vary per alloy and it is the evaluation of them together to calculate the total minimum strain energy to failure that defines the performance of a cladding alloy as the containment boundary and as bounded by the as-tested cladding configuration.

Westinghouse provided a write-up of the evaluation of total strain energy to failure and the staff included Condition No. 6(d) in the CoC: all zirconium alloy cladding must have at least a total minimum strain energy of 263 psi–in/in when considering tensile yield strength, ultimate strength and elongation at failure.

2.9 Evaluation Findings

Based on the review of the statements and representations 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.

3.0 THERMAL EVALUATION

The purpose of this thermal evaluation is to verify that the thermal design of the Traveller shipping package provides adequate protection against the thermal tests specified in 10 CFR 71, and meets the thermal performance requirements of 10 CFR 71 under NCT and HAC. The following sections summarize the staff's thermal evaluation.

3.1 Description of Thermal Design

The applicant described that the Traveller package utilizes an aluminum Clamshell, with Boral neutron poison plates, holding a single fuel assembly and that the clamshell is mounted within a cylindrical Outerpack fabricated from 304 stainless steel and flame-retardant polyurethane foam.

The stainless steel/foam composite provides thermal insulation during NCT and HAC, and most of the heat capacity is within the Outerpack, provided by the polyethylene moderator, the aluminum Clamshell and the fuel assembly itself, to reduce the peak temperatures within the package.

The applicant discussed in Section 3.1.2, Contents Decay Heat, that the content is a fresh fuel assembly or fuel rod, and the decay heat is insignificant (< 1 Watt) and not applicable for the Traveller package.

The staff reviewed the thermal design described in Section 3.1 to ensure that the package is designed to safely dissipate heat under passive conditions and that the temperature of the package and its contents will remain within their allowable values or criteria for NCT and HAC, as required in 10 CFR 71. The staff determined that the description of the thermal design is appropriate for a thermal evaluation.

3.2 Material Properties and Component Specifications

The applicant noted in Section 3.2.1, Material Properties, that the Traveller package is fabricated primarily from stainless steel, aluminum, Ultra-High Molecular Weight (UHMW) polyethylene, and flame-retardant polyurethane foam:

(a) the Outerpack is fabricated from stainless steel and polyurethane foam,

(b) the interior Clamshell holding the fuel assembly is fabricated from aluminum with BORAL neutron poison plates attached,

(c) the UMHW polyethylene is used as a neutron moderator and is located on the inside walls of the Outerpack, between the Outerpack and Clamshell.

The applicant provided the thermal properties of package materials in Table 3.2-1 and the thermal properties of fuel assembly materials in Table 3.2-2.

The staff reviewed Section 3.2.1 and Tables 3.2-1 and 3.2-2 for the thermal properties of the packaging components and fuel assembly, and finds the thermal properties (including melt temperatures and service temperature ranges) used for the thermal analysis to be acceptable.

3.3 Thermal Evaluation under NCT

3.3.1 Heat and Cold

The applicant stated in Section 3.3.1, Heat and Cold, that a steady state thermal analysis was performed with boundary conditions, including an ambient temperature of 38°C (100°F) and solar insolation of 400 W/m^2. As presented in Table 3.1-1, the applicant calculated a uniform package surface temperature of 48°C and stated that the accessible surfaces of the package do not exceed 50°C for non-exclusive use shipment.

The staff reviewed Section 3.3.1 and Figures 1.2 and 2.2-1 and agrees with the boundary conditions used for the NCT thermal analysis. The staff confirmed that the use of 400 W/m^2 as solar insolation is acceptable, given that the exterior of the Traveller package is composed of the curved surfaces and the flat surfaces are not transported horizontally.

The applicant stated in Section 3.3.2, Maximum Normal Operating Pressure, that with insignificant heat generated by the contents, the normal condition pressure in the rod will only increase based on the increased temperature from NCT insolation. The maximum NCT pressure, based on the ideal gas law, is calculated as 304.6 psig (319.4 psia).

The applicant stated, in Section 3.3.1, that the minimum temperature of the Traveller package is -40°C (-40°F) under an extreme ambient temperature of -40°C (-40°F), per 10 CFR 71.71(c)(2) and all materials used in the package are capable of sustained use at -40°C (-40°F), as shown in Table 3.2-1.

The staff reviewed Tables 3.1-1, 3.2-1 and 3.2-2 and finds that the NCT thermal evaluation of the Traveller package is acceptable because

(a) The maximum NCT fuel and component temperatures are within their corresponding service temperature ranges,

(b) The maximum NCT pressure is below the design limit for reactor fuel, and

(c) All materials used in the package are capable of sustained use at an extreme cold condition of -40°C (-40°F).

The staff determined that the Traveller package meets the thermal requirements as specified by 10 CFR 71.71.

3.3.2 Differential Thermal Expansion (DTE)

The applicant stated in Section 2.6.1.2, Differential Thermal Expansion, that the effects of differential thermal expansion (DTE) for the Traveller series of packages is negligible due to the design of the package:

(a) The DTE is expected to only impact the fuel assembly and the Clamshell interface. The Outerpack is not under physical constraints and can accommodate thermal growth.

(b) The most significant DTE is between the aluminum Clamshell and the fuel assembly, which is less than 0.25 in (6.35 mm). The DTE is accommodated by rubber-cork spacers between the Clamshell and fuel assembly, or by rubber spacers on the axial or lateral spacers.

(c) The DTE between the foam and the stainless steel shells of the Outerpack is easily accommodated by the elastic properties (low modulus value) of the foam.

(d) The Ultra-High Molecular Weight (UHMW) polyethylene does have a significantly higher coefficient of thermal expansion compared to 304 stainless steel.

The staff reviewed the licensing drawing No. 10004E58 and Figure 1-2 for the Outerpack and Clamshell cross-sectional view and discussed the elastic properties of the foam and the thermal expansion coefficients of aluminum Clamshell, fuel assembly, Outerpack (304 stainless steel) and UHMW polyethylene. The staff finds the applicant's statements, listed above in (a), (b), (c) and (d), to be acceptable.

The applicant performed calculations of differential thermal growth between the Clamshell and the fuel assembly, as well as between the Outerpack and the UHMW polyethylene for the Traveller XL version, and presented the results in Section 2.6.1.2.

The applicant stated that (1) the combined thickness of the space rubbers can accommodate the growth between the Clamshell and the fuel assembly due to DTE and (2) the DTE is not a concern for the Traveller XL and STD versions because the total differential growth associated with the XL Clamshell is greater than the STD Clamshell and the calculation for XL version, presented in Section 2.6.1.2, is the bounding calculation.

The staff reviewed the calculations of differential thermal growth presented in Section 2.6.1.2 of the application, and the Traveller STD and XL outer dimensions shown in Section 1.2.1.1. The staff confirmed that the calculations are acceptable and the DTE is not a concern for both the Traveller XL and Traveller STD versions.

3.4 Thermal Evaluation under HAC

3.4.1. Initial Conditions and Fire Test Conditions

The applicant stated in Section 3.4.1, Initial Conditions, and Section 3.4.2, Fire Test Conditions, that the primary verification of the package performance under HAC was demonstrated in the fire test of a full-scale Traveller XL package loaded with a simulated fuel assembly and identified as the certification test unit (CTU).

The fire test setup, thermocouple locations, and orientation of CTU are shown in Figures 3.4-1, 3.4-2 and 3.4-3.

The applicant stated in Section 3.4.1, Initial Conditions, that:

(a) the Outerpack and fuel assembly suffered minor damage during the impact test sequence, but the Clamshell including BORAL neutron poison plates and UHMW polyethylene moderator were essentially undamaged,

(b) the CTU was initially pre-heated and the air temperatures around the package prior to testing averaged 50°C (122°F), approximately 16 hours before the fire test, and

(c) the air temperature and outside surface temperature dropped to approximately 5°C (41°F) prior to testing, and the interior of the package remained above 38°C.

The staff finds the fire test setup shown in Figures 3.4-1, 3.4-2 and 3.4-3 to be acceptable because the "average" temperature of the fire is at least 800°C (1475°F).

The staff confirmed that the applicant's fire test setup is appropriate for the regulation's initial conditions of 38°C (100 °F) ambient and the NCT maximum temperature of 48°C, as summarized in Table 3.1-1 of the application.

3.4.2. Maximum HAC Temperatures and Pressure

The applicant described the fire test setup and fire testing in Section 3.4.2, Fire Test Conditions. The fire test was performed, in accordance with 10 CFR 71.73, with the 30-minute average temperatures of 904°C on the package skin, 895°C within the flame, and 833°C, as measured by the directional flame thermometers (DFTs), and 958°C as measured by the optical thermometers. The applicant summarized the recorded temperatures of the thermocouples and thermometers during the fire test in Tables 3.4-1, 3.4-2 and 3.4-3.

The staff reviewed Tables 3.4-1, 3.4-1 and 3.4-3 for the recorded temperatures during the fire tests and Figures 3.4-9 ~ 3.4-14 for the fire temperatures measured at the pool, test temperatures from DFTs and fire/skin temperatures from CTU.

The staff confirmed that the Traveller package has HAC maximum temperatures either within the service ranges or below the melting points, as shown in Tables 3.2-1 and 3.2-2 of the application, and therefore meets the thermal requirements of 10 CFR 71.73(c)(4).

3.4.3 Thermal Evaluation by Analysis

The applicant evaluated the HAC performance of the Traveller package with a simplified computer model. The model was developed using the HEATING7.2 code and was built in cylindrical coordinates using the simplified geometry described in Section 3.5.2, Traveller Thermal Evaluation by Analysis. The applicant presented the calculated radial temperature distribution for a 30-minute fire (800°C) in Figure 3.5-2.

The staff reviewed Section 3.4.3 for its simplified geometry, material properties, boundary conditions, and methodology used in the model. The staff determined that this analysis cannot be used to demonstrate the regulatory compliance of the package's thermal performance because of the simplified geometry (e.g. the Clamshell and fuel assembly region were modeled as a heat sink) which is unable to provide the temperature of each component in detail.

However, the staff confirms that the package's HAC thermal performance is adequate, based on the full-scale fire test.

3.4.3. Moderator Block Examination

The applicant stated in Section 3.4.2.4, Moderator Block Examination, that an examination of the moderator blocks after the burn test revealed no significant damage. The applicant compared the moderator block weights before and after the fire tests and presented the results in Table 3.4-4.

The staff reviewed Section 3.4.2.4 and Table 3.4-3 for the moderator block conditions and weights before and after the fire test and confirmed that, with a total weight change less than 0.06%, there is no significant weight loss for all blocks and therefore all blocks kept a sufficient hydrogen content.

The applicant stated in Section 3.4.2.4 that (1) the ultra-high molecular weight (UHMW) polyethylene was selected as neutron moderator for the Traveller package because of its high hydrogen content, its ductility at very low temperatures and its high viscosity at temperatures above its melting point (125~138°C); (2) the UHMW polyethylene does not liquefy above its melt temperature and has excellent stability at temperatures as high as 450°C; and (3) the moderator of the Traveller package is encapsulated with stainless steel to prevent oxidation and distortion at high temperatures.

The staff reviewed Section 3.2.4.2 and the high hydrogen content, the ductility at very low temperatures, the high viscosity at temperatures above its melt point, the non-liquefaction above its melt point, and the stability, at higher temperatures, of the UHMW polyethylene.

The staff confirmed that (1) the UHMW polyethylene encapsulated within stainless steel container will prevent oxidation and distortion, and (2) the UHWM has a maximum HAC temperature of 177°C, which is lower than its melt point (125~138°C), a vaporization temperature of ~349°C and process temperatures of 450°C.

Therefore, the neutron moderator, made of UHMW polyethylene, keeps its function during HAC.

3.5 Evaluation Findings

Based on the review of the statements and representations in the application, the staff concludes that the Traveller package thermal design has been adequately described and evaluated, and that the package meets the thermal requirements of 10 CFR Part 71.

4.0 CONTAINMENT EVALUATION

The Traveller package transporting Type A fissile content was certified under Docket 71-9297. The package described in the current application is similar to the Type A(F) package but allows for transport of fresh fuel with a Type B quantity. Specifically, the Traveller is a Type B(U)F-96 package for ground transport of fissile content consisting of a single fresh fuel (UO_2) PWR assembly or loose fresh PWR/BWR fuel rods (UO_2 or U_3Si_2) in a single Rod Pipe.

The details of the contents and contents composition are listed in Sections 1.2.2 and 1.2.2.2 of the application. According to Section 1.2.1.2, the contents consist of uranium dioxide (UO_2) or uranium silicide (U_3Si_2) pellets (i.e., not in powdered form).

According to Table 1-1 and Section 1.2.2.2, the single fresh fuel assembly may consist of either a Type A or Type B quantity; individual fuel rods placed within a Rod Pipe, in total, are limited to a Type A quantity. There is no air shipment according to Section 3.4.5. In addition, Section 3.3.1 noted the package uses non-exclusive use shipment.

The staff reviewed the application using NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material,” to verify the package containment design was described and evaluated for normal conditions of transport and hypothetical accident conditions, per 10 CFR Part 71. Regulations applicable to the containment review include 10 CFR 71.31, 71.33, 71.35, 71.43, and 71.51.

4.1 Description of the Package and Containment System

The package has two variants, designated as Traveller STD or XL depending on the length of the fuel assembly; dimensions and weights of each packaging are provided in Section 1.2.1.1. Section 1.2.1.5.2 of the application stated that the fuel assembly or Rod Pipe is secured to an inner Clamshell structure that limits rearrangement of the content.

According to Section 1.2.1.5.1, the Clamshell is secured into an Outerpack that provides the primary impact and thermal protection of the contents. Likewise, Section 1.2.1.5 indicated that thermal protection is provided by 10 pounds per cubic foot (pcf) polyurethane foam (rigid and closed cell) between the inner and outer shells of the Outerpack. It was also noted that 20 pcf polyurethane foam is included in the impact limiters.

According to Section 3.4.3.2, acetate plugs are provided for every internal foam compartment within the Outerpack. During a fire, these plugs would melt to vent the internal compartment containing the foam and prevent over-pressurization. According to Section 1.2.1.5.2 and Section 7.1.2.1, a number of features exist to prevent the inadvertent opening of the package. For example, the Clamshell is secured by multi-point cammed latches and hinge pins and the Outerpack is secured by bolts that are torqued to 60 +/- 5 ft-lb (81.3 +/- 6.8 N-m).

According to Section 1.2.1.2, the containment boundary consists of zirconium alloy cladding, end plugs of the individual fuel rods, and the weld between the cladding and end plugs. Fuel rod specifications, including the zirconium alloy cladding, are found in the document PDFROD00 referenced in LTR-LCPT-19-09 Appendix B (dated July 8, 2019). Detailed material properties of the six standard fuel rod zirconium alloy claddings were presented in Section 2.2.1.8 Table 2.2-5, Table 2.2-6, and Table 2.2-7 (Rev. 0, 9/2018).

Likewise, the strength associated with the zirconium alloy cladding is represented in Figure 3.4-17, pages 22 and 23 of LTR-LCPT-19-09 Appendix A (dated July 8, 2019) and page 2/6 of LTR-LCPT-19-21 Appendix A (dated August 30, 2019), which refer to burst internal pressure and temperature tests.

Type A and Type B fuel rods are back-filled with helium up to 460 psig and 275 psig, respectively. Section 1.2.2.1.1 stated there is no pressure relief device and Section 1.2.1.2 noted that the end plug/cladding seal welds meet the requirements of 10 CFR 71.43(c). Section 1.2.2.1.1 of the application stated that the ASME Boiler and Pressure Vessel Code, Section III, is used in the fuel rod’s mechanical design and stress analysis. Section 4.0 stated each Type B fuel rod undergoes 100% visual, radiographic, and ultrasonic inspections on the top and bottom end plug welds; Type A rods undergo these inspections on a sampling basis.

Section 8.1 and the RAI responses provided in Appendix A of LTR-LCPT-19-09 (dated July 8, 2019) provided details, including acceptance criteria, for the visual, radiographic, and ultrasonic inspections. For example, radiographic inspections ensure there are no unacceptable weld defects, such as lack of penetration.

Appendix B of Document LTR-LCPT-19-09 (dated July 8, 2019) mentioned that fuel assembly fabrication and inspection requirements and fuel rod specifications, including weld acceptance criteria, were defined in document PDFASY00, “Nuclear Fuel Assemblies,” and document PDFROD00, “Fuel Rod Assemblies.” In addition, weld acceptance criteria associated with ultrasonic and radiographic inspections were per QCI-920103, “Ultrasonic Testing of Fuel Rod Welds,” and QCI-920101, “Weld Radiograph Inspection.” Finally, helium leakage rate testing of fabricated fuel rods is based on QCI-922102, “Fuel Rod Automated In-Line Helium Leak Test.”

4.2 General Considerations

Section 1.2.1 of the application indicated that the content is secured within the Clamshell and Outerpack and, according to Section 4.1, the containment boundary is seal-welded and there are no valves. These measures would preclude dispersal of the content during normal conditions of transport.

In addition, Section 2.7.1.4 and Section 2.11.3 of the application indicated that the content was not dispersed during the accident condition tests. It is also noted that the cammed latches and hinge bolts mentioned earlier are positive fastening devices that prevent unintentional opening of the package.

The response to RAI 4-5 provided in Appendix A of LTR-LCPT-19-09 (dated July 8, 2019) indicated that hydrogen generation associated with hydrocarbon materials is not an issue with the Traveller package. It was stated that the Clamshell and Outerpack are not sealed systems and, therefore, flammable gases, if generated, would not accumulate. It was also mentioned that radiation levels are too low to result in radiolytic decomposition and that temperatures at normal conditions of transport and hypothetical accident conditions, as reported in Section 3, are below the hydrocarbon thermal decomposition temperatures.

It is noted that there are no filters or mechanical cooling associated with the package, thus satisfying 10 CFR 71.51(c).

Detailed containment release calculations were not necessary to demonstrate meeting 10 CFR 71.51 because, according to Section 8.1.4, the containment boundary is tested to the ANSI N14.5-2014 “leaktight” criterion (10^{-7} ref cm^3/sec).

4.3 Containment under Normal Conditions of Transport

As noted above, the content is secured within the Clamshell and Outerpack and the containment boundary is seal-welded. These measures would preclude dispersal of the content during normal conditions of transport.

Likewise, Section 2.7.1.1.1 indicated that results from the test units undergoing the NCT drop tests showed that the Clamshell maintained its shape and positioning within the Outerpack, which demonstrated that content would not be dispersed during normal conditions of transport. In addition, Section 4.2 stated that the structural effects of the normal conditions of transport tests are covered by the bounding hypothetical accident condition tests.

Section 2.7.1.4 and Section 2.11.3 indicated that there was no dispersal of content during the more rigorous accident condition tests. Finally, normal conditions of transport thermal analyses indicated that the containment boundary temperatures were below the allowable limits.

As mentioned above, detailed containment release calculations for normal conditions of transport were not necessary to demonstrate meeting 10 CFR 71.51 because the containment boundary is tested to the ANSI N14.5-2014 “leaktight” criterion.

4.4 Containment under Hypothetical Accident Conditions

Section 2.7.1.4 stated that the fuel rods did not have cracks and successfully met the “leaktight” acceptance criterion (as defined by ANSI N14.5) after the hypothetical accident condition drop test. In addition, RAI response 4-11 provided in Appendix A of LTR-LCPT-19-09 (dated July 8, 2019) indicated that the fuel rods would maintain their integrity after the thermal hypothetical accident condition based on results of fuel rod burst testing at elevated temperatures.

Specifically, the applicant noted that the calculated fuel assembly temperature at the thermal hypothetical accident condition was 219°F (104°C), which corresponded to an internal pressure of 385 psig. This was well below the experimentally derived burst test results shown in Figure 3.4-17 (from PDT-09-121 Zirlo Single Rod Burst Test Report, as noted in LTR-LCPT-19-21, Appendix A, dated August 30, 2019) and the RAI response (LTR-LCPT-19-09, Appendix A, dated July 8, 2019) which indicated an 1800°F fuel rod burst temperature when the rod was at an internal pressure of 358 psig.

It was also noted that post-fire test results did not indicate any fuel rod thermal-mechanically induced buckling along the length of the fuel rod (LTR-LCPT-19-21, Appendix A, dated August 30, 2019). In addition, the applicant discussed in Section 2.7.1.4 that, after the hypothetical accident condition drop test, the 264 rods were helium leak rate tested using a detector probe method to ensure there was no leakage approximately 30 minutes after the drop test. Subsequently, the rods were leak tested using an evacuated envelope methodology with an acceptance criterion of 10^{-7} ref. air. cm^3/sec.

It also was noted that a test rod was pierced before the start of the evacuated envelope leakage rate testing of the 264 rods and then placed in the evacuated envelope after the final 264 rods were tested to demonstrate that a rod leaking helium would have been detected after the lengthy leakage rate test procedure. The applicant stated that a conclusion of the drop test was that the fuel rods were “leaktight” after fabrication, prior to the drop test, and after the drop test.

Section 2.11.3 of the application and the response to RAI 2-1 in Appendix A of LTR-LCPT-19-09 (dated July 8, 2019) described tests that demonstrated the structural response of the Rod Pipe to withstand normal conditions and hypothetical accident conditions drop test: the end flanges remained secured to the extent that content was not dispersed.

Appendix B of Document LTR-LCPT-19-09 (dated July 8, 2019) described the details associated with the 17x17 XL Type B drop test assembly. It mentioned that the design, fabrication, and inspection of the fuel rods and assembly were based on standard, production quality processes and procedures, including being backfilled with helium, although the content was filled with lead slugs.

It was noted that fuel assembly fabrication and inspection requirements and fuel rod specifications, including weld acceptance criteria, were defined in document PDFASY00 “Nuclear Fuel Assemblies” and document PDFROD00 “Fuel Rod Assemblies.” In addition, the weld acceptance criteria associated with ultrasonic and radiographic inspections were per QCI-920103, “Ultrasonic Testing of Fuel Rod Welds,” and QCI-920101, “Weld Radiograph Inspection.” The helium leakage rate testing of fabricated fuel rods is based on QCI-922102, “Fuel Rod Automated In-Line Helium Leak Test.”

In order for the fuel rods in the fuel assembly to meet the “leaktight” acceptance criterion, Sections 1.2.1.5.2, 1.2.1.5.3, and 7.1.2.1 of the application noted that relevant axial fuel restraints, including bottom support spacer, bottom fuel axial spacer, bottom support plate, top axial restraint (with axial clamping studs), and circular/square base plate with clamping stud, are to be utilized for shipment. It was noted, in Section 4.0, that the lengths of the above-mentioned components are specific to each fuel assembly content and that the design results in the proper fit between the fuel assembly and Clamshell.

As stated above, detailed containment release calculations at hypothetical accident conditions were not necessary to demonstrate meeting 10 CFR 71.51 because the containment boundary is tested to the ANSI N14.5-2014 “leaktight” criterion.

4.5 Leakage Rate Testing

Section 8.1.4 of the application indicated that 100% of the Type B fuel rods undergo a fabrication leak test to 10^{-7} ref cm^3/sec (air) acceptance criterion with a sensitivity of 5x 10^{-8} ref cm^3/sec or less; the tests are in compliance with ANSI N14.5-2014.

Section 4.4 of the application stated that the Evacuated Envelope – Gas Detector method per Section A.5.4 of ANSI N14.5-2014 is used for the helium leak testing of the fuel rods. Since the rods are fabricated and then shipped, Section 4.1 and Section 4.4 indicated that the fabrication leakage rate test also serves as the pre-shipment leakage rate test.

According to Section 4.1 and Section 8.1.4, these rod fabrication acceptance tests are performed under the quality assurance program using qualified processes.

4.6 Evaluation Findings

Based on the review of the containment-related sections of the application, the staff concludes that the containment design has been adequately described and evaluated and has reasonable assurance that the package meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING EVALUATION

Westinghouse submitted an application for a Type B(U)F certificate of compliance for the Traveller transportation package design. The proposed contents of the Traveller are fissile material in the form of a uranium fuel assembly or fuel rods with enrichments up to 5.0 weight percent (wt.%) ^{235}U. The package will carry several types of PWR fuel assemblies, as well as either PWR or BWR fuel rods. The Traveller package is designed to carry one fuel assembly or one Rod Pipe for loose fuel rods. The loose rods contents will be transported inside a Rod Pipe and are limited to a Type A quantity; therefore, this evaluation of the shielding design only accounts for the PWR assembly.

Although the proposed contents consist only of unirradiated uranium, the applicant proposes the shipment of fuel that has contaminants that exceed the Type A quantity of ^{232}U, ^{234}U and ^{236}U from Table A-1 of 10 CFR Part 71. These values are shown in Table 1-2 and are repeated in Table 5.2-1 of the application. In addition to the concentration limits within this table, there are additional restrictions for contents that are to be acceptable for shipment as a Type A material that separately requires that there be less than a Type A quantity of material.

The package consists of three components: 1) an Outerpack, 2) a Clamshell, and 3) a fuel assembly or rod container. The Outerpack serves as the primary impact and thermal protection for the fuel contents and also provides for lifting, stacking, and tie down during transportation. Two independent impact limiters consisting of foam that is sandwiched between three layers of sheet metal are part of the Outerpack.

The purpose of the Clamshell is to protect the contents during routine handling and limit rearrangement of the contents in the event of a transport accident. The Traveller does not have gamma and neutron shielding as the proposed contents emit a very low level of neutron and gamma radiation as discussed in the following subsections.
The staff reviewed the package's shielding design using the guidance in Section 5 of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," March 1999.

5.1 Description of the Shielding Design

5.1.1 Packaging Design Features

The staff reviewed the information on the shielding design and evaluation in Chapter 5 of the application, "Shielding Evaluation." The staff determined that all figures, drawings, and tables describing the shielding features are sufficiently detailed to support an in-depth evaluation. The applicant provided drawings of the package in Section 1.3.2 in the proprietary version of the application.

The staff reviewed these drawings and found that it specified all dimensions of all components considered within the shielding evaluation. Therefore, the staff finds that the applicant meets the requirements of 10 CFR 71.31(a)(1) and 10 CFR 71.33(a)(5) with respect to the shielding design.

The applicant did not include tolerances for all packaging features; however, the design features of the Traveller are for structural, thermal, and criticality safety purposes as the applicant did not design it to ship any significant radiological source. There are metal and foam components that would act as shielding; however, since this is not their design purpose, the applicant did not credit any of the materials within the Traveller package for the shielding analysis. The only component credited for purposes of calculating radiation levels is the distance to the package surface.

As this is conservative, and there is a lot of margin to regulatory limits, the staff found the use of nominal dimensions acceptable for this package.

5.1.2 Summary Table of Maximum Radiation Levels

The applicant evaluated the maximum radiation level under NCT and showed the results in Table 5.1-1 of the application. The maximum surface radiation level is on the side of the package and it is 1.356 mrem/hr. This meets the regulatory limit of 200 mrem/hr in 10 CFR 71.47(a).

At 1 meter, the maximum radiation level is on the side of the package and it is 0.2329 mrem/hr. This meets the Transport Index (TI) of 10 in 10 CFR 71.47(a).

Under HAC, the limiting radiation level is also the side of the package and, since the applicant uses the same model as NCT, this is also 0.2329 mrem/hr at 1 meter, which meets the regulatory limit of 1 rem/hr in 10 CFR 71.51(a)(2).

5.2 Source Specification

The nuclides in Table 5.2-1 of the application are based on a 640 kg allowable quantity of uranium. The applicant used ORIGEN-S from SCALE 6.1.2 to calculate the grouped gamma and neutron spectra from the nuclides in Table 5.2-1 of the application. The results are shown in Tables 5.2-3 and 5.2-4 of the application, respectively.

As stated in Section 5.2 of the application, nuclide quantity limits are applicable at the time of shipment to prevent significant buildup of daughter products. This is especially important for the decay of ^{232}U from which ^{208}Tl is a daughter. ^{208}Tl reaches a peak activity at about 10 years decay time (Figure 2 of IAEA-TECDOC-1529, “Management of Reprocessed Uranium, Current Status and Future Prospects,” February 2007). ^{208}Tl has a significant gamma emission at about 2.6 MeV.

The staff performed an independent calculation using ORIGEN-S from SCALE 6.2.3 to verify the gamma and neutron spectra resulting from the nuclides in Table 5.2.1 of the application with zero decay time. The gamma and neutron sources calculated by the staff agree with that in Tables 5.2-3 and 5.2-4 of the application, respectively. Therefore, the staff has reasonable assurance that the applicant has evaluated the correct radiological source term. The staff also found that the group structure in these tables is reasonable given the important gamma energies for the nuclides involved.

The gamma source in Table 5.2-3 of the application also includes the “total gamma activity” of 4.4×10^5 MeV Bq/kg uranium from Table 5.2-1 of the application. This source term will account for gammas emitted with any fission product contaminants as well as account for any reasonable amount of decay from the uranium isotopes in Table 5.2-1 of the application as it is impossible to maintain radionuclides at a specific amount given the nature of their radioactive decay into daughter products.

Normalizing the allowable activity in this way means that the energy of the gammas is not specified and allows for a lower activity of higher energy gammas and a higher activity of lower energy gammas. The applicant models this as all being 0.8 MeV gammas. The applicant stated that this energy was chosen to represent the largest mean gamma energy of fission products from ASTM C1295-15 which is 0.766 MeV. The staff finds this to be non-conservative, as maximum energies tend to be more limiting for radiation level contributions even when converting to energy activity (e.g. MeV/s).

Since the most significant gamma will be the 2.6 MeV from the decay of ^{208}Tl, a nuclide in the decay chain of ^{232}U, using MICROSHIELD, the staff compared the radiation level from 0.8 MeV gammas and 3.0 MeV gammas using an activity for each gamma energy that meets the 4.4×10^5 MeV Bq/kg uranium from Table 5.2-1 of the application (i.e. lower energy gamma has a higher activity, and higher energy gamma has lower activity). The staff’s calculation shows that the 3.0 MeV gamma source results in about a 26% increase in radiation level over that of the 0.8 MeV gamma source.

This is well within the margin to the regulatory radiation level limit discussed in Section 5.1.2 of this SER; therefore, the staff found that the applicant’s analysis is reasonably representative of the allowable gamma source from fission products and uranium decay progeny and is acceptable.

5.3 Model Specification

The staff reviewed Sections 2 (structural evaluation) and 3 (thermal evaluation) of the application to determine the effects of the NCT and HAC tests and conditions on the packaging and its contents.

The applicant did not credit any of the packaging material. It only credits the distance occupied by the packaging for choosing a location for calculating radiation levels. Since the applicant did not credit any of the packaging material, the applicant used the same model for NCT as it did for HAC.

As discussed in Section 2.7.1 of the application, there is some deformation of the Outerpack as a result of the drop tests, but since this change is very small, the applicant did not change the Outerpack dimensions to account for this effect. Since the applicant does not model any of the materials within the Traveller packaging, any loss of material due to the HAC fire is already accounted for within the NCT evaluation.

The staff found this to be conservative and found the modeling assumptions with respect to the packaging acceptable given the large margins to the radiation level limits as discussed in Section 5.1.2 of this SER.

5.3.1 Configuration of Source and Shielding

The applicant did credit the self-shielding of the UO_2. The applicant created a cylinder with the height of the shortest allowable assembly and adjusted the diameter to be equivalent to that of the maximum mass of uranium with a uranium density of 10.96 g/cm^3 and placed it against the side of the inner package cavity to minimize the distance to the detector.

The applicant assumed that the source was uniformly distributed throughout the UO_2 cylinder. The staff found this to be a reasonable and acceptable representation of the source material, especially given the large margin to the regulatory radiation levels.

5.3.2 Material Properties

The applicant listed the material properties it used within the radiation level evaluations in Section 5.3.2 of the application. The only material credited within the shielding evaluation is that of UO_2. The applicant used a density of 10.96 g/cm^3. This is consistent with the published theoretical density of UO_2. The staff found it acceptable.

5.4 Evaluation

5.4.1 Codes

The applicant used the MCNP6 code to calculate the radiation levels. MCNP is a transport theory-based three dimensional code that employs the Monte Carlo solution method. The applicant used the photon transport library MCPLIB84, which compiles data from the ENDF/B-VI.8 library, and the neutron transport library ENDF71x, which compiles data from the ENDF/V-VII.1 library. These libraries are listed in LA-UR-13-21822, “Listing of Available ACE Data Tables,” Nuclear Data Team, XCP-5 Los Alamos National Laboratory, June 26, 2014, as the most recent applicable photon and neutron transport libraries; therefore, the staff found them appropriate to use with this code. This code and these libraries have been used across a wide range of applications and are well benchmarked and tested.

Based on the above, the staff found the use of this code and cross sections to be acceptable for performing this evaluation.

5.4.2 Flux-to-Dose-Rate Conversion

The applicant states that it used the ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors for both neutrons and gammas in all the shielding evaluations. The staff finds this acceptable per Section 5.5.4.3 of NUREG-1609.

5.4.3 Tallies

To demonstrate that the package design meets the regulatory radiation level limits at the locations prescribed in the regulation for NCT and HAC, the applicant is required to determine the maximum radiation level considering all points on the surface. Also, tally sizes should be appropriately sized for the geometry of the source and package features such that a maximum value can be computed considering source and package feature variations (e.g., tally size is such that contributions to the package surface radiation level tally in a given location do not include contributions from multiple areas having different shielding properties).

The applicant used tallies directly above the center of the fuel to calculate the axial radiation level and at the centerline of the fuel for the radiation level on the side of the package. The applicant does not state the size of the tallies but shows their relative size in Figure 5.4-1 of the application.

The staff found the tally specification to be reasonable and acceptable given the large margin to the regulatory limit as stated in Section 5.1.2 of this SER.

5.5 Evaluation Findings

The staff reviewed the package shielding design, calculated radiation levels, material specifications, and models for radiation level calculations. The staff found the applicant used dimensions and material compositions consistent with the package drawings.

The applicant's radiation level calculations, including source term and shielding model assumptions, are conservative. The calculated radiation levels meet the radiation level limits prescribed in 10 CFR 71.47 for a package under conditions normally incident to transportation; 10 CFR 71.43(f) and, for Type B packages, 10 CFR 71.51(a)(1) for a package under NCT; and 10 CFR 71.51(a)(2) for a package under HAC.

Based on its review of the information and representations provided in the application, the staff has reasonable assurance that the proposed package design and contents satisfy the shielding requirements and radiation level limits in 10 CFR Part 71.

6.0 CRITICALITY EVALUATION

The staff reviewed the criticality safety evaluation of the package using the guidance in Chapter 6 and Appendix A3 of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," March 1999. The staff's evaluation of the applicant's criticality safety evaluation follows.

6.1 Description of Criticality Design

The staff reviewed the General Information section in Chapter 1 of the application as well as any additional information in the Criticality Section, Chapter 6, of the application. The staff verified that the information is consistent as well as all descriptions, drawings, figures and tables are sufficiently detailed to support an in-depth staff evaluation.

The criticality safety features of the Traveller consists of neutron absorber plates, and a flux trap system that reduces neutron communication between packages in an array. This system features BORAL® neutron absorber plates located at each lateral side of the Clamshell that act in conjunction with ultra-high molecular weight (UHMW) polyethylene moderator blocks, which are affixed to the walls of the Outerpack inner cavity.

Neutrons leaving one package must pass through two regions of moderator blocks and then BORAL neutron absorber plates before reaching the contents of another package.

In addition, the applicant takes credit for the neutron absorption from the structural materials of the Traveller within the criticality safety analysis.

6.1.1 Packaging Design Features

The applicant provided drawings of the package in Section 1.3.2 in the proprietary version of the application. The staff reviewed these drawings and found that they sufficiently describe the locations, dimensions and tolerances of the containment system, basket, and neutron absorbing material.

Therefore, the staff finds 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.

6.1.2 Summary Table of Criticality Evaluations

The applicant provided a summary table of the criticality evaluations in Table 6-2 of the application. This includes criticality safety calculations for the fuel Groups 1 and 2 for a single package, Groups 1 and 2 in an array, and the rod pipe loaded with UO_2 or SiO_3 in a single package and in arrays. The applicant analyzed all of these configurations under both NCT and HAC.

The applicant shows that the limiting condition with respect to criticality safety is with the Group 2 fuel assemblies in an array configuration under HAC. For this configuration, the applicant calculated a maximum k_{eff} of 0.93783 and includes two times the standard deviation (2σ). The applicant calculates the highest k_{eff} for the Group 1 fuel assemblies in an array configuration under HAC at 0.93945; however, there is more margin to the USL for this configuration.

The applicant calculated the upper subcriticality limit (USL) for each configuration and summarizes these values in Table 6-1 of the application. The applicant shows that all of the k_{eff} values in Table 6-2 of the application are below that of their respective USL values in Table 6-1 of the application.

The staff finds that this meets the requirements of 10 CFR 71.55(b), (d) and (e).

6.1.3 Criticality Safety Index

The applicant has calculated a different CSI for 3 package configurations. This includes (1) Group 1 assemblies, (2) Group 2 assemblies and (3) the rod pipe. The applicant summarizes the CSI for each configuration in Table 6-3 of the application. For Group 1, the CSI is 1.0 for Group 2 the CSI is 4.2 and for the rod pipe the CSI is 0.7.

Per 10 CFR 71.59(b) the value of N is 50, 12 and 75, respectively. The applicant used appropriate array sizes for NCT (5N) and a single cask for HAC (2N).

The staff finds 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 finds that the CoC holder meets 10 CFR 71.59(a)(3) because the value of N is not less than 0.5.

6.2 Fissile Contents

The proposed contents of the Traveller is fissile material in the form of unirradiated uranium fuel assemblies or fuel rods with enrichments up to 5.0 weight percent (wt.%) U-235. It will carry several types of pressurized water reactor (PWR) fuel assemblies which are made of UO_2. These are categorized into two groups based on similar parameters as well as either PWR or boiling water reactor (BWR) fuel rods in the rod pipe.

The Group 1 configuration is applicable to the STD and XL and includes fuel array sizes of 14x14, 15x15, 16x16 and 17x17 as specified in Tables 6-5, 6-6 and 6-7 of the application and rod patterns shown in Figures 6-2, 6-3 and 6-4 of the application. Other fuel parameters applicable to Group 1, including cladding material, restrictions on annular blankets, number of stainless steel replacement rods, and amount of polyethylene packing materials are specified in Section 6.2.1 of the application.

The Group 2 configuration is only applicable to the XL variant and includes fuel array sizes of 16x16 and 18x18 as specified in Table 6-8 of the application with rod patterns in Figure 6-5 of the application. The Tables 6-5 through 6-8 include specifications and tolerances, where applicable, for array size, fuel rods, non-fuel holes, nominal pitch, minimum fuel pellet OD, minimum cladding ID, minimum cladding thickness, and maximum active fuel length. Other fuel parameters applicable to Group 2 are specified in Section 6.2.2 of the application.

Non-fissile non-radioactive reactor core components may be shipped with the fuel assembly contents of the Traveller. These components would displace moderator within the guide tubes and, therefore, the applicant did not model them within the criticality safety evaluation. The staff found that this is a conservative assumption, and that inclusion of these components is acceptable.

Loose PWR or BWR rods are allowed in the rod pipe as specified in Drawing 10006E58. These are either UO_2 or U_3Si_2. UO_2 rods can be transported in either the STD or XL configuration, while the U_3Si_2 rods are only transported in the STD configuration. Both UO_2 and U_3Si_2 rods have a maximum ^{235}U enrichment of 5.0 wt. %. Other specifications including fuel pellet diameter, maximum stack length, maximum number of rods per pipe, cladding material, allowable integral absorbers, limits on annular fuel pellet blanket length and wrapping, sleeving and other packing materials are specified in Section 6.2.3 of the application.

The staff finds that this meets 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) because the package and contents are adequately defined.

6.3 General Considerations for Criticality Evaluations

6.3.1 Model Configuration

The applicant's criticality safety model of the package includes the Outerpack shell and the Outerpack inner shell. The applicant also includes the moderator blocks and the Clamshell within the Outerpack inner cavity. The applicant discussed the modeling and assumptions made with respect to the packaging components for both the STD and XL variants in Section 6.3.1 of the application.

The staff reviewed this information and found the modeling of the packaging is consistent or conservative with respect to the drawing of the packaging in Drawing 10071E36 and assumptions made by the applicant with respect to the packaging are either conservative or have a negligible impact on the criticality safety of the package, because the packaging is external to the fuel assembly it has very little impact on its reactivity.

The applicant took into consideration the outer diameter tolerance as it affects the spacing of the packages as discussed Section 6.3.4.3.4 of the application and displays the results in Table 6-57 of the application. The staff found that the applicant's modeling of the outer packaging is conservative and acceptable.

The applicant discussed the modeling and assumptions made with respect to the rod pipe for both the STD and XL variants in Section 6.3.1.1 of the application. The staff found that the modeling of the rod pipe is consistent or conservative with respect to the Drawing of the rod pipe and assumptions made by the applicant with respect to the rod pipe are conservative on the criticality safety of the package. The applicant neglected the pipe end bolts and end caps. These are external to the fuel inside and would have a negligible impact on reactivity.

The staff reviewed Section 2 (structural evaluation) and Section 3 (thermal evaluation) of the application to determine the effects of the normal conditions of transport and hypothetical accident conditions on the packaging and its contents.

6.3.2 Normal Conditions of Transport

Under NCT, the applicant models no Outerpack deformation and moderator blocks are modeled at full density. The fuel assembly is modeled as a heterogeneous model for each fuel rod which is at nominal pitch placed against the bottom inner surface of the Clamshell.

For the single package the applicant modeled it as fully flooded including the fuel-clad gap, for an array the package is dry, except for the rod pipe, which is fully flooded.

For the rod pipe contents fuel rods are modeled with no lattice expansion. The applicant modeled a 20 cm water reflector at the boundary.

Although NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," states that full reflection is 30 cm, the staff found that 20 cm is sufficient to fully reflect the package as two times the diffusion length is considered fully reflected (Chapter 5, Bennet, Thompson, *The Elements of Nuclear Power*, 1981). The diffusion length of thermal neutrons in water is about 3 cm (Table 5.2, Lamarsh, *Introduction to Nuclear Engineering*, 1983). The diffusion length would be larger for higher energy neutrons, but it is the staff's judgment that the neutrons being reflected would be thermal-based on the amount of moderator present; therefore, the staff finds that the diffusion length for the system would not exceed 10 cm for the Traveller system.

The staff found that these modeling assumptions are conservative and consistent with the effects of the NCT tests, as discussed in Section 2 and 3 of the application. Section 2.6.6 of the application discusses the water spray test under NCT and there is no in-leakage; therefore, based on the statements in Section 6.5.5.1 of NUREG-1609, the staff found modeling the cavity dry for the NCT array evaluations acceptable.

6.3.3 Hypothetical Accident Conditions

Under HAC, the applicant shows in Section 2 of the application that there is minimal deformation to the Outerpack and therefore the applicant does not model any deformation to the Outerpack within its criticality safety model. The staff found this acceptable.

The results of the drop testing show that the fuel assembly does experience some lattice deformation and pitch expansion. The applicant included pitch expansion within its model, as discussed in Section 6.3.4.2.1.3 of the application. The applicant modeled the pitch as uniformly expanded to the Clamshell boundary.

Based on the results of NUREG/CR-7203, "A Quantitative Impact Assessment of Hypothetical Spent Fuel Reconfiguration in Spent Fuel Storage Casks and Transportation Packages," Section 3.2.1, the most reactive configuration is a non-uniform pitch expansion. However, even with this information, the staff found the applicant's uniform pitch expansion acceptable for the following reasons:

- The results of the drop testing in Section 2.7.1.2 of the application show that there is less pitch expansion overall than what was modeled in the criticality safety evaluation. This is even less for the Type B package in Section 2.7.1.4 of the application.

- The results of the drop testing show that the pitch expansion is random and non-uniform, however the non-uniformity is an expansion at the periphery of the assembly while NUREG/CR-7203 shows that expansion at the center of the assembly is more reactive. The sinusoidal deformation of the assembly, where all rods are pushed to one side, is the expected behavior of an assembly, as a result of the 30 ft drop as discussed in Section 2 of this SER. Thus, the staff has reasonable assurance that the uniform pitch expansion modeled by the applicant is a reasonably bounding representation of the lattice deformation and pitch expansion experienced by the assembly after the HAC 30 ft drop test.

The applicant modeled this pitch expansion for the bottom 20 inches of the fuel assembly. The staff found this acceptable as the drop testing showed that pitch expansion only happened for the bottom 20 inches from the bottom nozzle to Grid 2. Based on the above considerations, the staff found that the applicant modeled a conservative pitch expansion with respect to the drop tests and expected behavior of the fuel. The remainder of the assembly is modeled at nominal pitch.

The HAC fire test showed that there was minimal damage to the UHMW moderator blocks. The applicant performed a sensitivity study in Section 6.3.4.3.3 of the application to investigate the effects the loss of moderator block material has on reactivity. This is included within the sensitivity evaluations performed by the applicant, as discussed in Section 6.3.4 of this SER. The fuel assembly is modeled at the bottom of the inner surface of the Clamshell cavity. The applicant models the package and the fuel-clad gap as fully flooded.

Under HAC, the applicant modeled the package as flooded and determined the most reactive flooding condition. This is discussed in Section 6.3.4, "Demonstration of Maximum Reactivity," of this SER.

The applicant reflects all arrays with 20 cm water reflector. The staff found this acceptable based on its discussion in this SER.

6.4 Material Properties

The staff verified that the appropriate mass fractions and densities are provided for all materials used in the models of the packaging and contents. The applicant provided this information in Tables 6-12 and 6-13 of the application. The staff finds that the values used are standard values for the commonly used materials and are reasonable for use in the criticality analysis. The only non-standard material is the BORAL core. The applicant credited 75% of the B-10 within the criticality safety evaluation. The staff found this acceptable per the recommendations in NUREG-1609.

The staff verified that the amount of B-10 credited in Section 6.3.2.11.1 and Table 6-12 of the application is consistent with this assumption and the B-10 areal density requirement in Drawing 10071E36, Rev. 1. Hydrogenous packaging materials have been replaced with water for flooding situations and replaced with void in dry conditions. The applicant found this to be the most reactive. Water is more hydrogenous than these materials and, therefore, the staff found this assumption conservative and acceptable.

Since these materials are on the exterior of the assembly space, replacing them with void would reduce moderation capability for the absorber blocks and increase neutron communication between packages for array evaluations and there replacing them with void in dry conditions is a reasonable assumption.

The applicant modeled the hydrogenous packing material using a density of 0.922 g/cm^3. This is consistent with the hydrogen density limitations specified in Section 6.2 of the application and was found acceptable by the staff.

The staff finds that the applicant considered material properties that are consistent with the package under the tests in 10 CFR 71.71 and 10 CFR 71.73.

6.5 Computer Codes and Cross Section Libraries

The applicant performs the criticality evaluations using the KENO-VI code within the SCALE 6.1.2 code package with the ENDF/B-VII.0 continuous energy neutron cross section library. The KENO-VI code is widely used in thermal neutron systems to calculate k-eff. The staff found it acceptable to use for this package based on the discussion in Section 4.1 from NUREG/CR-5661.

The staff verified that the applicant provided representative input files. The staff also verified that the information regarding the model configuration, material properties and cross sections is properly represented in the input files.

The staff reviewed the key input data for the criticality calculations specified in the input files and finds them acceptable. The staff reviewed the output files provided and determined that they have proper convergence and that the calculated k_{eff} values from the output files agree with those reported in the text.

6.6 Demonstration of Maximum Reactivity

The applicant determined the most reactive assembly for each bin where the applicant defines each bin as a grouping of fuel assemblies that have the following in common: array size, number and location of non-fueled holes, and as-designed nominal fuel rod pitch. Then, the applicant evaluated the bounding combination of fuel pellet diameter, fuel-clad gap, and cladding thickness. Since these fuel assemblies are designed to be undermoderated, the most reactive condition is reduced fuel pellet diameter, cladding ID and cladding thickness to accommodate more moderator. The applicant documents this analysis in Section 6.9.2 of the application and the results are summarized in Section 6.3.4.1 of the application. The staff reviewed this information and found that the applicant has demonstrated that it has determined reasonably bounding fuel assembly parameters for each bin.

The applicant determined a baseline case. This information is in Section 6.3.4.2 of the application. For each content (fuel assembly and loose pellets in the rod pipe) and condition (NCT and HAC), the applicant uses these evaluations to find the limiting assembly for all of the bins for both Groups (1 and 2) and package variants (STD and XL for Group 1, XL for Group 2) to determine the most reactive axial position and flooding condition (for HAC).

The applicant found that the XL is the limiting package variant. As discussed in Section 6.9.3.5.2 of the application, the applicant found that the most reactive fuel position is with the assembly centered approximately within the Clamshell cavity. The applicant also found that the most reactive flooding configuration consists of a fully flooded Clamshell cavity including fuel envelope and fuel-clad gap with all other floodable regions and interspersed moderation between packages modeled as void.

The staff reviewed this information and found that the applicant's baseline model is the most reactive with respect to the parameters it considered. The staff found this conclusion acceptable based on its expectation that moderation within the assembly envelope would increase the reactivity of the fuel assembly, and void outside of the assembly reduces the absorption (preventing over-moderation) and increases neutron communication between assemblies.

The baseline case for the rod pipe is discussed in Section 6.3.4.2.2 of the application, with the results in 6.9.3.6.1 of the application. The applicant models a wide range of pellet ODs that bound that of the required minimum diameter from Section 6.2.3 of the application to find the most reactive water-to-fuel ratio for both the UO_2 and U_3Si_2. The applicant models both a square and hexagonal pitch. Under NCT the applicant models the pitch equivalent to the fuel diameter.

The staff does not necessarily find this to be a conservative assumption, as there are no restrictions for the loose fuel rods to be shipped in this configuration, and there are no restrictions on the amount of polyethylene packing materials that are allowed; therefore, the pitch could be any amount. However, under HAC, the applicant increases the pitch to find the most reactive water-to-fuel ratio. The HAC analyses give the staff enough assurance to assume that the package is subcritical as the only non-conservative difference is in the size of the arrays (5N for NCT and 2N for HAC). The maximum k_{eff} under HAC for the rod pipe is 0.76836 which is for the U_3Si_2 fuel rods. The staff finds that there is enough margin in k_{eff} to account for this non-conservative assumption and, with the HAC evaluations, the staff still has reasonable assurance that the package will remain subcritical.

After the applicant established the baseline case, the applicant also performs sensitivity studies to determine the most reactive condition. If the result of varying the selected parameters results in an increase of more than 2σ, this amount is added to the baseline k-eff + 2σ value. The applicant performed sensitivity studies to determine the most reactive configuration with respect to:

- lattice expansion
- annular fuel blankets
- shifting the position of the Clamshell, fuel assembly and/or rod pipe within the cavity
- moderator block density
- package outer diameter tolerance
- polyethylene packaging materials
- axial rod displacement
- stainless steel replacement rods
- fuel tolerances
- steel nozzle reflector

For arrays, the applicant also includes sensitivity on the package OD. The assumptions made for each of these effects is discussed in Section 6.3.4.3 of the application.

To demonstrate that this method would produce a maximum reactivity k_{eff}, the applicant created a worst-case HAC array model combining all positive penalty reactivity increases within the same SCALE 6.1 calculation to demonstrate that its method of adding the penalties is comparable to modeling them all at once.

As shown in Section 6.9.4 of the application, the applicant found that the difference in k_{eff} was either less than the maximum k_{eff} values or statistically insignificant. The staff found that the applicant has demonstrated that adding the penalties independently is an appropriate method for calculating the maximum reactivity and found it acceptable.

The staff finds that the applicant's analysis demonstrated that they have found the maximum reactivity per the requirements of 10 CFR 71.55(b).

6.7 Confirmatory Analysis

The staff did not perform confirmatory evaluations on the Traveller, as it had previously performed confirmatory evaluations as part of the certification of Revision 10 of the Traveller AF package with nearly identical contents under Docket No. 71-9297 (Letter from J. McKirgan (NRC), to T. Sloma (Westinghouse), Revision No. 10 of Certificate of Compliance No. 9297 for the Model Nos. Traveller STD, Traveller XL, and Traveller VVER Packages, June 28, 2017, ADAMS Accession No. ML17180A499).

These evaluations provide the staff with additional assurance that the Traveller package was modeled correctly and is subcritical.

6.8 Single Package Evaluation

6.8.1 Configuration

For the single package evaluation, the applicant assumed all inner spaces of the package are flooded with full density water including the fuel-clad gap. The applicant replaced several materials, including fuel structural components and packaging components with full-density water. As discussed in Section 6.3.4 of this SER, this was found to be conservative. The applicant reflected the single package with 20 cm of full-density water. Based on the discussion in Section 6.3.1.1 of this SER, the staff found this to be fully reflected and is therefore conservative.

For a single package with a fuel assembly, in Table 6-26 of the application, the applicant summarized the sensitivity studies that resulted in a reactivity penalty (i.e. the applicant increased k_{eff} to account for the increase in reactivity as a result of varying these parameters). Under NCT, these are annular fuel pellet blanket, centered fuel assembly, polyethylene packing materials, cladding tolerance, and fuel rod pitch tolerance. Under HAC, these are centered fuel assembly, moderator block density, polyethylene packing materials, cladding tolerance, and fuel rod pitch tolerance.

For a single package with the rod pipe, in Table 6-39 of the application, the applicant summarized the sensitivity studies that resulted in a reactivity penalty for both the UO_2 and the U_3Si_2 pellet materials. Under NCT, these are annular fuel pellet blanket length and polyethylene packing materials and fuel pellet tolerance (U_3Si_2 only). Under HAC, the only sensitivity study that resulted in a reactivity penalty is the polyethylene packing materials.

The staff found that the applicant's evaluation demonstrates that a single package is subcritical under both normal conditions of transport and hypothetical accident conditions. The applicant modeled the most reactive credible configuration consistent with the condition of the package and the chemical and physical form of the contents.

The staff found that the applicant's single package analyses include full reflection of 20 cm water on all sides. This meets the requirement in 10 CFR 71.55(b)(3).

6.8.2 Results

6.8.2.1 NCT

The staff confirmed that the results of the applicant's criticality calculations are consistent with the information presented in the summary table from Table 6-2 of the application for the single package analyses.

The maximum k_{eff} for a single package under NCT is 0.92151 for a package with a fuel assembly and 0.60036 for a package with the rod pipe. This is below the USL of 0.93902 and 0.93980 for these configurations, respectively. Since k_{eff} is less than the USL established for the fuel assembly and rod pipe contents under 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 evaluations using reasonably bounding geometry of the fuel assembly and rods within the rod pipe to perform the criticality calculations, the staff verified 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 finds that the applicant meets 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 finds that this meets 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 10cm cube. The staff finds that this meets the requirements in 10 CFR 71.55(d)(4).

6.8.2.2 HAC

The staff confirmed that the results of the applicant's criticality calculations are consistent with the information presented in the summary table from Table 6-2 of the application for the single package analyses.

The maximum k_{eff} for a single package under HAC is 0.91966 for a package with a fuel assembly and 0.74460 for a package with the rod pipe. This is below the USL of 0.93902 and 0.93980 for these configurations, respectively. Since k_{eff} is less than the USL established for the fuel assembly and rod pipe contents 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 under HAC the contents 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).

6.9 Evaluation of Package Arrays

6.9.1 Configuration

The applicant defines the CSI for each package content in Table 6-3 of the application which includes Group 1 fuel assemblies, Group 2 fuel assemblies and the rod pipe. The applicant shows the array size it used in Table 6-2 of the application. Based on the CSI for each content, the staff determined that the array size is appropriate for both NCT and HAC.

The applicant modeled the packages adjacent to each other (i.e., no space between packages) in an hexagonal array. The staff found this acceptable as it minimizes the space between packages and, therefore, increases neutron communication and maximizes reactivity.

For an array of packages with a fuel assembly, in Table 6-54 and 6-73 of the application the applicant summarized the sensitivity studies that resulted in a reactivity penalty (i.e. the applicant increased k_{eff} to account for the increase in reactivity as a result of varying these parameters). Under NCT, these are cladding tolerance and fuel rod pitch tolerance. Under HAC, these are Clamshell/fuel assembly shift, package OD tolerance (Group 2 assemblies only), polyethylene packing materials, cladding tolerance, fuel pellet diameter tolerance (Group 2 assemblies only) and fuel rod pitch tolerance.

For an array of packages with the rod pipe, in Table 6-62 and 6-83 of the application the applicant summarized the sensitivity studies that resulted in a reactivity penalty for both the UO_2 and the U_3Si_2 pellet materials. Under NCT, these are annular fuel pellet blanket length, rod pipe position in Clamshell (UO_2 rods only) and polyethylene packing materials. Under HAC, these are rod pipe position in the Clamshell (UO_2 rods only), moderator block density reduction, package OD tolerance (U_3Si_2 rods only), polyethylene packing materials and moderator variation.

The applicant's array package analyses include full reflection of 20 cm water on all sides of the array. This meets the requirement in 10 CFR 71.59(a).

6.9.2 Results

The maximum k_{eff} for the NCT array analyses is 0.31379 for the assembly content (Group 2) and 0.69571 for the U_3Si_2 rods in the rod pipe. Since k_{eff} for the array is less than the USL of 0.93948 and 0.93873, respectively, under the tests specified in 10 CFR 71.71. This meets the requirements of 10 CFR 71.59(a)(1) which requires that an array size 5N of undamaged packages be subcritical.

The maximum k_{eff} for the HAC array analyses is 0.93945 for the Group 2 fuel assemblies and 0.76836 for the U_3Si_2 fuel rods in the rod pipe. Since k_{eff} for the array is less than the USL of 0.93948 and 0.93873, respectively, under the tests specified in 10 CFR 71.73, this meets the requirements of 10 CFR 71.59(a)(2) which requires that an array size 2N of packages under HAC be subcritical. The k_{eff} for the HAC array analyses for the Group 2 fuel assemblies is very close to the USL so the staff also took into account the conservatisms used within the analysis to find the maximum reactivity (see Section 6.5.1 of this SER). As it is unlikely for all of these parameters to simultaneously exist at their most reactive condition, this gave the staff further confidence that the package meets the regulations in 10 CFR 71.59(a)(2), even though the calculated k_{eff} is very close to the USL.

6.10 Benchmark Evaluations

The applicant performs the criticality evaluations using KENO-VI (CSAS6) of the SCALE 6.1.2 code package. The applicant used ENDF/B-VII.0 continuous energy cross sections. The applicant performed benchmarks with the same computer code and cross section set.

6.10.1 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 finds the use of this guidance acceptable.

The applicant's selected benchmark experiments include water moderated UO_2 fuel rods with materials of construction similar to the Traveller packaging (aluminum, stainless steel, zirconium, and BORAL). The staff verified that the enrichment, fuel rod pitch and diameter were within the design parameters for the Traveller contents.

The applicant did not include experiments with U_3Si_2 in its benchmark calculations. The staff did not find that the UO_2 experiments are adequate to represent the U_3Si_2 fuel rods. However, for this application the staff found the benchmark experiments acceptable because of the margin within k_{eff} for the U_3Si_2 fuel rod evaluations. The maximum calculated k_{eff} for U_3Si_2 within the Traveller packaging is 0.76836.

W. J. Marshall, J. Yang, U. Mertyurek, M. A. Jessee, "Preliminary TSUNAMI Assessment of the Impact of Accident Tolerant Fuel Concepts on Reactor Physics Validation," Transactions of the American Nuclear Society, Vol. 120, Minneapolis, Minnesota, June 9–13, 2019 compare the nuclear data-induced uncertainty from UO_2 fuel to that of U_3Si_2 fuel (along with others) and shows that although it predicts that the uncertainty for the U_3Si_2 would be higher, it is not significantly higher.

The staff does not find this to be a substitution for benchmarking; however, given the margin in k_{eff} for the U_3Si_2 fuel rods, the staff found that the bias and bias uncertainty associated with the U_3Si_2 fuel rods versus that of the UO_2 rods would likely not be large enough that the k_{eff} would increase to the extent that the system would no longer be subcritical.

6.10.2 Bias Determination

The applicant determined the trending parameter for EALF, fuel enrichment, water-to-fuel volume ratio and hydrogen-to-fissile (H/X) ratio and showed these in Table 6-92 of the application. The applicant found that the trending parameter with the largest correlation coefficient is the EALF. Therefore, it used the EALF to generate the USL within the USLSTATS code.

The applicant calculated a separate USL for assembly and rod pipe configurations as a single package and array based on its EALF. These are presented in Table 6-1 of the application. This includes the biases and uncertainties of the model and computer code such that any k_{eff} less than the USL is less than 0.95. The staff finds this acceptable.

6.11 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the nuclear criticality safety design has been adequately described and evaluated and that the package meets the subcriticality requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATING PROCEDURES

The application provides a description of package operations, including package loading and unloading operations, and the preparation of an empty package for shipment. Loading and unloading procedures show a general approach to perform operational activities because site-specific conditions may require the use of different equipment and loading or unloading steps.

The staff reviewed the Operating Procedures in Chapter 7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation.

On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures provide adequate measures and reasonable assurance for safe operation of the package in accordance with 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Section 8.1 of the application, and the RAI responses provided in Appendix A of LTR-LCPT-19-09 (dated July 8, 2019), provide details, including acceptance criteria, for visual, radiographic, and ultrasonic inspections. For example, radiographic inspections ensure there are no unacceptable weld defects, such as lack of penetration.

Likewise, Section 8.1.4 of the application indicates that 100% of the Type B fuel rods undergo a fabrication leak test to a 10^{-7} ref cm^3/sec (air) acceptance criteria, with a sensitivity of 5. 10^{-8} ref cm^3/sec or less, and are in compliance with ANSI N14.5-2014. Since the rods are fabricated and then shipped, Section 4.1 indicates that the fabrication leakage rate test also serves as the pre-shipment leakage rate test.

Strain energy calculations demonstrated that standard ZIRLO cladding has the least total strain energy absorption value of all Zirconium alloys, and is therefore most susceptible to fracture as compared to other Zirconium alloys. In order to ascertain that zirconium alloy claddings meets the minimum requirement to ensure the containment boundary is as tough as the alloy tested in the Traveller package drop test, staff included a condition in the CoC: all Zirconium cladding must have at least a total minimum strain energy of 263 psi–in/in when considering tensile yield strength, ultimate strength and elongation at failure.

According to Section 4.1 and Section 8.1.4 of the application, the rod fabrication acceptance tests are performed under the quality assurance program using qualified processes.

Based on the review of the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71, and that the maintenance program is adequate to assure packaging performance during its service life.

CONDITIONS

The following conditions are included in the Certificate of Compliance:

(a) The package shall be prepared for shipment and operated in accordance with the Operating Procedures of Chapter 7 of the application.

(b) Each packaging must meet the Acceptance Tests and Maintenance Program of Chapter 8 of the application.

(c) The maximum backfill pressure of the fuel rod shall not exceed 460 psig in a Type A configuration or 275 psig in a Type B configuration.

(d) All Zirconium alloy cladding must have at least a total minimum strain energy of 263 psi–in/in when considering tensile yield strength, ultimate strength, and elongation at failure.

(e) Transport by air is not authorized

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. Traveller STD & XL package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9380, Revision No. 0,
on November 7, 2019.