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

September 15, 2020

Ms. Tanya Sloma
Licensing, Compliance and Package Technology
Nuclear Fuel Transport
Westinghouse Electric Company, LLC
5801 Bluff Road
Hopkins, SC 29061

SUBJECT: REVISION NO. 12 OF CERTIFICATE OF COMPLIANCE NO. 9297 FOR THE MODEL NOS. TRAVELLER STD, TRAVELLER XL, AND TRAVELLER VVER PACKAGES

Dear Ms. Sloma:

As requested by your application dated April 6, 2020, as supplemented June 22 and August 14, 2020, enclosed is Certificate of Compliance No. 9297, Revision No. 12, for the Model Nos. Traveller STD, Traveller XL, and Traveller VVER packages. Changes made to the certificate are indicated by vertical lines in the margin. The staff's safety evaluation report is enclosed.

The approval constitutes authority to use the package for shipment of unirradiated fissile 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 me or Pierre Saverot of my staff at 301-415-7505.

Sincerely,

John B. McKirgan Digitally signed by John B. McKirgan
Date: 2020.09.15 10:55:58 -04'00'

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

Docket No. 71-9297
EPID No. L-2020-LLA-0073

Enclosures:
1. Certificate of Compliance No. 9297, Rev. No. 12
2. Safety Evaluation Report

cc w/encls 1 & 2: R. Boyle, Department of Transportation
J. Shuler, Department of Energy, c/o L. F. Gelder
K. Owen-Whitred, Canadian Nuclear Safety Commission

SUBJECT: REVISION NO. 12 OF CERTIFICATE OF COMPLIANCE NO. 9297 FOR THE MODEL NOS. TRAVELLER STD, TRAVELLER XL, AND TRAVELLER VVER PACKAGES. DOCUMENT DATED: September 15, 2020

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(THIS CLOSES EPID No. L-2020-LLA-0073)

AMDAS Accession Package Number: ML20255A295 *** via-e-mail**

OFC:	DFM	DFM	DFM	DFM	DFM	SFM
NAME:	PSaverot	JWise	RTorres	YKim	ABarto	JBorowski
DATE:	07/07/2020	09/08/2020	09/08/2020	07/29/2020	08/13/2020	07/07/2020
OFC:	DFM	DFM	DFM	DFM	DFM	
NAME:	RChang	TBoyce	YDiaz-Sanabria	SFigueroa	JMcKirgan	
DATE:	08/13/2020	07/30/2020	07/07/2020	09/10/2020	09/15/2020	/ /

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

SAFETY EVALUATION REPORT
Docket No. 71-9297
Model Nos. Traveller STD, Traveller XL and Traveller VVER
Certificate of Compliance No. 9297
Revision No. 12

SUMMARY

By application dated April 6, 2020, as supplemented June 22 and August 14, 2020, Westinghouse Electric Company, LLC (Westinghouse or the applicant) requested an amendment to Certificate of Compliance (CoC) No. 9297 for the Model Nos. Traveller STD, XL, and VVER packages.

This amendment request was submitted to include new contents for accident tolerant fuels (ATF), and 7wt.% U^{235} fuel rods, as well as provide a new criticality analysis and additional specifications for maintenance examinations. The ATF advanced cladding features and UO_2 fuel advancements are evaluated for the new contents. Also, upgrades to the Rod Pipe drawing (10006E58, Revision 7) have been included in this amendment request.

The ATF advancements of UO_2 fuels and cladding features include: (i) Advanced Doped Pellet Technology (ADOPT™) UO_2 fuel, doped with Cr_2O_3 and Al_2O_3, (ii) 7wt.% U^{235} fuel rods, and (iii) cladding with chromium-coating or an Optimized ZIRLO™ liner (OZL). These ATF features and contents, designed to enhance reactor in-core performance, do not impact to the package design, operations or maintenance.

As requested by the applicant, this application was reviewed using NUREG-1886, "Joint Canada - United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages." The current Canadian endorsement for the Traveller STD, XL and VVER Package is CDN/E216/-96.

Based on the statements and representation in the application, as supplemented, and the conditions listed below, the staff concludes that the changes proposed for this amendment request do not affect the ability of the package to meet the requirements of 10 CFR Part 71. Staff also found that the highlighted areas of emphasis of NUREG-1886 have been appropriately addressed.

1.0 GENERAL INFORMATION

The packaging design has not been modified by this amendment request. All changes made in the application either address previous staff's concerns or support the addition of the new criticality methodology for the new contents and their allowable enrichments.

Section 1.2.2.1 includes the ADOPT specification allowance for UO_2 contents and updates the restriction on loose rod content quantity in the Rod Pipe. Cladding may be treated with a chromium coating or include an Optimized ZIRLO Liner (OZL). The applicant removed the option for steel alloy cladding.

Section 1.3.2, updated Rod Pipe Licensing drawing 10006E58 Rev. 7: changes include additional detail of assembly and detailed views, an updated of bill of materials, the addition of notes to the drawing, and a new sheet 2 is added to show the Rod Pipe and Clamshell assembly. Another change to this licensing drawing removes the set point for the accelerometers on the Rod Pipe. This will give flexibility for the applicant to monitor the forces to the fuel. The accelerometers are not a safety feature of the package, are not discussed in the safety analysis report, but are required to be present per the licensing drawings and Chapter 7 operations.

2.0 STRUCTURAL AND MATERIALS EVALUATIONS

The applicant submitted an amendment request for the Traveller PWR Fuel Shipping Package to include new contents of ATF fuel and 7 weight percent (wt.%) U^{235} fuel rods. The structural chapter was revised to include total strain energy absorption evaluation and materials comparison of existing alloys with advanced variations of chromium coating and Optimized ZIRLO Liner.

The staff reviewed the application to verify the structural performance of the package for normal conditions of transport (NCT) and hypothetical accident conditions (HAC). The staff concludes that no changes were made with respect to the structural design of the package that affects the structural performance or the licensing basis of the package.

2.1 Description of Structural Design

The Traveller package, designed to ship enriched commercial grade uranium fuel assemblies or rods, has three packaging variants: Traveller Standard (STD), Traveller XL (XL), and Traveller VVER (VVER). The Traveller package consists of two main structural components: the Outerpack and the Clamshell. The Outerpack provides impact and thermal protections to the Clamshell and the contents, while the Clamshell, which resides inside the Outerpack cavity, protects the contents of the fuel assembly or the rod during handling and limits rearrangement of the contents in the event of a transportation accident.

The applicant stated in the submittal letter LTR-LCPT-20-06, dated April 6, 2020, that there were no structural design changes to the Traveller packages (STD, XL, and VVER). The structural design of the Traveller packages in this amendment request (Revision 15 of the SAR) is identical to that of the previously reviewed and approved Revision 14 of the SAR. The staff reviewed Revision 14 of the SAR and confirmed that there are no structural design changes in Revision 15.

2.2 Structural Evaluation under Normal Conditions of Transport

The applicant performed structural evaluations for the Traveller package under NCT. Section 2.5 of the SAR presents the parameters (i.e., hot/cold temperatures, internal/external pressures, vibration, water spray, compression and penetration) considered for the evaluations of the Traveller package to demonstrate compliance with the requirements of 10 CFR Part 71.71(c).

The results of the structural evaluations under NCT are presented and discussed in Section 2.6 of the SAR. These results with the methodology used for the structural evaluations under NCT were previously reviewed and accepted by the staff during the review of previous SAR revisions (i.e., Revisions 0, 1, 2, 9, 10, 12 and 13). The applicant indicated that there were no additional structural evaluations required with the proposed new contents (ATF and 7 wt.% U^{235} fuel rods), because the total weight of the Traveller package with new contents is still bounded by the total weight of the package used in the previous evaluations.

The staff finds that no further structural evaluations are required because: (i) there are no design changes in the Traveller package, (ii) there are no changes of the structural design criteria, and (iii) the total weight of the package with its new contents is bounded by the total weight of the package specified in Section 2.12 of the SAR. As stated previously, the structural evaluations for the Traveller package under NCT were previously reviewed and accepted by the staff.

Therefore, the staff confirms that the structural evaluations for the Traveller package under NCT, in Revision 15 of the application, continue to be valid and the design of the Traveller package meets the requirements of 10 CFR 71.71(c). It is noted that evaluations for the performance of the cladding (i.e., fuel rods with the chromium coating and the Optimized ZIRLO liner) under NCT are provided in the Materials Evaluation of this SER (See Section 2.4).

2.3 Structural Evaluation under Hypothetical Accident Conditions

The applicant also performed structural evaluations for the Traveller package under HAC to demonstrate compliance with the requirements of 10 CFR 71.73(c). The results of the structural evaluations under HAC are presented and discussed in Section 2.7 of the SAR. These results, with the methodology used for the structural evaluations under HAC, were previously reviewed and accepted by the staff during the review of previous SAR revisions (i.e., Revisions 0, 1, 2, 9 and 10). The applicant indicated that there was no additional structural evaluation required with the new contents (ATF and fuel rod) under HAC, because the total weight of Traveller package with new contents is still bounded by the total weight of the package used in the previous evaluations.

The staff finds that this statement is acceptable, because: (i) there are no design changes in the Traveller package, (ii) there are no changes of the structural design criteria, and (iii) the total weight of the package with new contents is bounded by the total weight of package specified in Section 2.12 of the SAR. As stated previously, the structural evaluations for the Traveller package under HAC were previously reviewed and accepted by the staff. Therefore, the staff confirms that the structural evaluations for the Traveller package under HAC, in Revision 15 of the application, continue to be valid and the design of the Traveller package meets the requirements of 10 CFR 71.73(c). It is noted that evaluations for the performance of the cladding (i.e., fuel rods with the chromium coating and the Optimized ZIRLO liner) under HAC are provided in the Materials Evaluation of this SER (See Section 2.4).

2.4 Materials

The staff reviewed the application to identify revisions to the materials of construction of the package and the associated technical discussions in justification of compliance with the regulations in 10 CFR Part 71 and IAEA, SSR-6, Revision 1 (2018), requirements.

2.4.1 Material Properties and Specification

The Traveller package is designed to carry loose fuel rods using a rod pipe fabricated of stainless-steel tube and plates. A single fuel assembly or a single rod pipe is transported in a package. The rod pipe may be loaded with either loose uranium dioxide (UO_2) fuel rods or loose uranium silicide (U3Si2) fuel rods.

The staff reviewed Drawing No. 10006E58, Revision 6, which included revisions to identify (1) the allowable stainless-steel grades and elastomeric materials, (2) codes for weld fabrication and inspections, (3) bolt torque specification, and (4) tolerances for all parts. The drawing was also revised to identify a fit up of the rod pipe in the clamshell, which is used to enclose the rod pipe inside the overpack. The clamshell protects and restrains the fuel assembly or Rod Pipe contents during all transport conditions. During accident transport conditions, the clamshell remains closed and its structure does limit rearrangement of the fuel assembly. The staff confirmed that the applicant identified the pertinent material properties for the specified materials in the drawing, as are discussed in Section 2.2.1 of the application. The staff finds that the material properties and specifications for the rod pipe and associated clamshell assembly provided in the application are adequate for the evaluation of the package.

2.4.2. Chemical, Galvanic or Other Reactions

The applicant did not propose any revisions to the materials used for packaging construction. The staff has previously approved these materials for their stability against chemical, galvanic or other reactions.

The applicant clarified that exterior chromium coating, the Optimized ZIRLO™ inner liner and the zirconium-based substrate alloy are chemically inert individually and when in contact with other fuel rods and grid components during transport conditions. The applicant clarified that these three components are chemically and galvanically unreactive under the temperature range and transport environment for normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

The application also includes UO_2 contents in the form of loose fuel rods or fuel assemblies, which may include Advanced Doped Pellet Technology (ADOPT™) pellets. The fuel rod is assembled by loading the UO_2 or U_3Si_2 pellets into the cladding tube. The rods are pressurized with helium and the end plugs are welded to the tube which effectively seals and contains the radioactive material. Welds of the fuel rods are verified for integrity by non-destructive methods such as radiographic or ultrasonic testing.

The staff finds that no significant chemical, galvanic, or other reaction is credible due to the incorporation of the chromium coating, the Optimized ZIRLO™ inner liner and ADOPT™ fuel pellets.

2.4.3 Effects of Radiation on Materials

The Traveller packaging does not contain neutron or gamma shielding features because neutron and gamma radiation emitted from the allowable contents is negligible in quantity. The staff finds that the use of material properties in the unirradiated state is appropriate for use in the safety analyses.

The staff has reviewed the package and concludes that the applicant has met the requirement of 10 CFR 71.33, as well as IAEA, SSR-6, Revision 1 (2018), requirements 501 and 502. The applicant described the materials used in the transportation package in sufficient detail to support the staff's evaluation.

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a), as well as IAEA, SSR-6, Revision 1 (2018), requirements 507, 614, 639 and 679. The applicant demonstrated effective materials performance of packaging components under NCT and HAC.

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(d), 10 CFR 71.85(a), and 10 CFR 71.87(b) and (g), as well as IAEA, SSR-6, Revision 1 (2018), requirements 507 and 614. The applicant has demonstrated that there will be no significant corrosion, chemical reactions, or radiation effects that could impair the effectiveness of the packaging. In addition, the package will be inspected before each shipment to verify its condition.

2.5 Fabrication and Examination

2.5.1 Fabrication

The applicant did not identify any revisions to the package design, except a revision to Drawing No. 10006E58, Revision 6, which adequately identifies materials of construction, dimensions and tolerances for the rod pipe design. The staff finds that the drawing clearly identifies the Code for weld fabrication of the rod pipe assembly.

2.5.2 Examination

The applicant did not identify any revisions to the package design, except a revision to Drawing No. 10006E58, Revision 6, which adequately identifies materials of construction, dimensions and tolerances for the rod pipe design. The staff finds that the drawing clearly identifies the code for examination of welds of the rod pipe assembly.

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.31(c), as well as IAEA, SSR-6, Revision 1 (2018), requirement 640. The applicant identified the applicable codes and standards for the design, fabrication, testing, and maintenance of the package and, in the absence of codes and standards, has adequately described controls for material qualification and fabrication.

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.85(a). The applicant has adequately described examinations requirements to ensure that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the packaging.

2.6 Fuel Rods

2.6.1 Mechanical properties

The cladding of the PWR fuel assembly and loose rod contents was revised to include either an exterior chromium coating or an Optimized ZIRLO™ inner liner (i.e., new cladding alloy contents). The applicant provided material properties for the new cladding alloy contents based on the strain energy absorbing capacity (SEAC) to failure as determined by uniaxial tensile testing, which were then compared to the analysis for the 9-m (30-ft) drop accident.

More specifically, the applicant compared the SEAC of the new cladding alloy contents to the base material without the coating/liner and to the calculated strain energy absorption during an actual 9-m (30-ft) drop accident. The applicant evaluated the individual fuel rod's minimum-specification SEAC to failure for each of the cladding alloys in Table 2-61 of the application and compared those to the calculated strain energy absorbed by each rod during actual results from the Certified Test Unit (CTU) used to assess the 9-m (30-ft drop accident).

The applicant defined minimum-specification yield and ultimate strength used for the fabrication of the prototype fuel bundle used in the HAC test sequence, which bound the cladding material properties at temperatures pertinent to NCT and HAC. The applicant clarified that this minimum yield strength and ultimate strength, which are specified per the previously approved Standard Zirconium Alloy, provide a bounding SEAC to the new cladding alloy contents. The bounding

SEAC considers the total elongation at failure for the limiting previously approved Standard Zirconium Alloy. The applicant also clarified that the base zirconium alloys, used as a substrate, have a hexagonal closed-pack crystalline structure, which do not exhibit an apparent nil ductile-brittle transition at temperatures at or above -40°F (-40°C).

The applicant concluded that the SEAC of the new cladding alloy contents is adequate since the failure of the previously approved Standard Zirconium Alloy occurs at a much lower SEAC than that of the new cladding alloy contents. More specifically, the SEAC for the new cladding alloy contents is at least an order of magnitude larger than that of the previously approved Standard Zirconium Alloy. Therefore, the staff finds that there is reasonable assurance that the new cladding alloy contents relative to the previously approved Standard Zirconium Alloy will not fracture during the 9-m (30-ft) drop accident.

The staff notes that the basis for the approval is not based on a yield-stress acceptance criterion, but the ability of the fuel rod to withstand both elastic and plastic deformation during the 9-m (30-ft drop accident). This is consistent with the method of evaluation previously approved for other contents of the application (including the Standard Zirconium Alloy), which the staff determines is still reasonable upon considering that the fuel design change involves either a coating or an inner chemically-bound liner on the same previously-approved substrate alloys.

The staff notes that the applicant identified higher bending moments observed at the end-plug locations during a 9-m (30-ft) drop test, since the peripheral fuel rods slipped outwards due to the chamfered edge geometry of the bottom nozzle. Bending and buckling of the cladding occurred at the lower span due to the instantaneous axial load without any cladding fracture at the base material.

The applicant justified that these results are not impacted by the chromium coating or an inner liner on the previously-approved base alloy materials since the chromium coating stops prior to the ends of the tube; therefore, the heat affected zone region is unaffected, and the base cladding material has higher ductility than the heat affected zone of the end plugs.

The applicant concluded that there will be no greater fuel assembly damage experienced by the new cladding alloy contents (i.e., failure or assembly lattice expansion) than what has already been considered in the criticality safety analysis for the Standard Zirconium Alloy. Based on the previously discussed justification, the staff finds the conclusion to be acceptable.

The staff's conclusion is consistent with those of an NRC-sponsored technical assessment on chromium-coated cladding performance (see Section 4.2 of Geelhood, K., "Fresh Fuel Transportation of Accident Tolerant Fuel Concepts – Chromium Coated Zirconium Alloy Cladding", PNNL-29773, March 2020). The assessment concluded that, for in-reactor performance, recent data on unirradiated Cr-coated zirconium alloys indicate the yield stress and elastic modulus of a coated part will be the same (within existing data variability, <10%) as that of an uncoated part. This conclusion is also valid for fresh fuel transport as most of the data was taken at room temperature and on unirradiated material. PNNL-29773 also notes that more recent data has further corroborated this conclusion.

2.6.2 Fatigue Endurance

The staff evaluated the cladding endurance limits of the new cladding alloy contents as a function of maximum stress and number of cycles. The staff finds the technical basis to be acceptable for demonstrating compliance with 10 CFR 71.71(c)(5) and Paragraph 613 of IAEA SSR-6, Revision 1 (2018).

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.55(d)(2), as well as IAEA, SSR-6, Revision 1 (2018), requirements 613, 639 and 679. The applicant has demonstrated that the package will be designed and constructed such that the analyzed geometric form of its contents will not be substantially altered and there will be no loss or dispersal of the contents under the tests for NCT and HAC.

2.7 Material Properties and Component Specifications

2.7.1 Material Properties

The applicant justified the applicability of the thermal properties in the application to the new cladding contents, i.e., the chromium-coated cladding and cladding with an inner Optimized ZIRLO liner. The applicant provided a technical basis that both the Cr-coating and the inner-diameter Optimized ZIRLO liner are not expected to impact the thermal performance of the cladding, and therefore the previous thermal properties for the un-coating cladding (i.e., Standard Zirconium Alloy in Table 3-3A and 3-3B of the application) remain valid for the package thermal evaluations with the new cladding contents.

Further, the applicant provided data in support of the burst performance of both new cladding contents under the fire scenario of the HAC. The staff reviewed the applicant's justification and finds it to be acceptable.

2.7.3 Component Specifications

The applicant did not identify additional technical specifications of components that are important to the thermal performance of the package. The revision to include the cladding's chromium coating and Optimized ZIRLO™ inner liner, as well as the ADOPT fuel pellets, do not impact the specifications for the fuel contents. The minimum allowable service temperature of all components, including the stainless-steel rod pipe, is less than or equal to -40 °C (-40 °F).

The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a), as well as IAEA SSR-6, Revision 1 (2018), requirements 507, 614, 639 and 679. The applicant demonstrated effective materials performance of packaging components under NCT and HAC.

2.8 Findings

Based on a review of the statements and representations in the application (Revision 15 of the SAR), the staff concludes that the structural design has been adequately described and evaluated in the SAR and that the Traveller transportation packages (STD, XL and VVER) have acceptable structural integrity to meet the structural requirements of 10 CFR Part 71.

Staff concludes that the guidance on format and content in NUREG-1886 has been met, and finds that the highlighted areas of emphasis have been appropriately addressed.

3.0 THERMAL EVALUATION

The Traveller package is a Type AF-96 package for transport of Type A fissile content. Specifically, the package is for ground transport of fissile content consisting of a single fresh fuel (UO_2) fuel assembly or a single Rod Pipe that holds loose fuel rods. According to SAR Section 6.2, the single fuel assembly can be a PWR assembly with UO_2 enrichment up to 5 weight percent of U^{235}. Loose PWR or BWR fuel rods with UO_2 enrichment up to 7 weight percent of

U_{235} and uranium silicide (U_3Si_2) with enrichment up to 5 weight percent can also be transported in the Rod Pipe.

The focus of this amendment request is the inclusion of loose UO_2 fuel rods with enrichment up to 7 weight percent of U^{235} , UO_2 content as loose fuel rods or fuel assemblies in PWR Group 1 or Group 2 manufactured with Advanced Doped Pellet Technology (ADOPT^{TM}) fuel pellets having up to 700 ppm of Chromium Oxide (Cr_2O_3) and up to 200 ppm of Aluminum Oxide (Al_2O_3), and new cladding types that include a chromium-coating or an Optimized ZIRLO^{TM} liner (OZL). In addition, the applicant provided clarifications in various SAR chapters to address questions and issues from recent revalidations and requests for additional information. It was stated there were no changes to the Traveller package for this amendment request.

The staff reviewed the application (LTR-LCPT-20-06-P and Safety Analysis Report, Revision 15 as attachment), using NUREG-1886 "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages" to verify the package thermal design was described and evaluated for normal conditions of transport and hypothetical accident conditions, per 10 CFR Part 71.

3.1 Description of Thermal Design

As stated in the application submittal letter, there were no changes to the Traveller package, which includes the Traveller Standard, Traveller XL, and Traveller VVER. According to SAR Sections 1.2.1.5., 3.2.1, and 3.3.3, the package's Clamshell provides structural rigidity to keep the fuel rods in a secure arrangement, the Outerpack, constructed from double walled stainless steel and filled with polyurethane foam insulation, provides thermal (and impact) protection to maintain low temperatures during a hypothetical accident fire condition, and the Ultra-High Molecular Weight (UHMW) polyethylene, which is positioned on the Outerpack inside walls between the Outerpack and Clamshell, is used as a neutron absorber.

SAR Section 3.2.1 stated the polyurethane foam is a flame-retardant thermoset plastic that decomposes to an intumescent char at temperatures above 204.4°C. The intumescent material seals voids during the decomposition process and continues to act as an insulation. The decomposition process produces gases, which exit the package via vent plugs located along the package length; it was noted Outerpack components that contain polyurethane foam have at least one vent plug. In addition, SAR Section 3.3.2 and Section 3.3.3 indicated that the continuous hinge lengths along the Outerpack seam and a large lip over the bottom seam were shown to prevent ingress of hot gases into the Outerpack during a fire test. The result of the package design, according to SAR Table 3.1, were component temperatures below their allowable values during the hypothetical accident condition fire test.

SAR Section 3.3.1.1 and Section 3.5 indicated that the thermal analysis was based on the Traveller XL package. According to SAR Section 3.2.1, the presence of the fuel assembly affects the package's thermal response during the hypothetical accident fire condition; this is due to the nearly 40% contribution of the fuel assembly to the package weight, which impacts the package's thermal capacity. SAR Table 3-3C and Section 3.3.1.1 showed that the fuel assembly mass, "heat sink mass", Clamshell length, and mass per unit length were reasonably similar (less than 8.9% difference) between the VVER and 17x17XL fuel assembly; these differences were relatively slight considering the large temperature margins (e.g., greater than 172°C) that were reported in SAR Table 3.1 between package component temperatures and their allowable values. Therefore, the results from the Traveller XL thermal analyses also were considered representative for the Traveller VVER and Traveller Standard packages.

Nonetheless, SAR Section 3.3.1.1 included a hypothetical accident fire condition thermal analysis that modeled the Traveller VVER properties (provided in SAR Table 3-3B); the result showed an Outerpack moderator cover temperature of 108°C, compared to the 106°C temperature with the Traveller XL model. Because of the similar temperature response, the SAR indicated that the Traveller XL and Traveller VVER have design similarities such that the Traveller XL thermal analyses and tests are applicable to the Traveller VVER package.

3.2 Material Properties and Component Specifications

SAR Table 3-2, Table 3-3A, and Table 3-3B listed thermal conductivity, specific heat, and melting temperature of materials of Traveller packaging and a fuel assembly (e.g., 304 stainless steel, Inconel, Zircalloy 4, uranium dioxide, and uranium silicide); updates to the uranium dioxide and uranium silicide properties were included. SAR Section 3.2.1.1 stated that a fuel rod with the external chromium coating or the internal zirconium-tin alloy lining (i.e., Optimized ZIRLO liner) has a Zircalloy 4 fuel rod base cladding.

According to SAR Section 3.2.1.1, the chromium coating has a nominal 25 micron thickness and the manufacturing process produces an “interaction volume” between the chromium and zirconium interface that is a fraction of the chromium coating thickness; SAR Section 3.2.1.1 stated that the small thickness is negligible such that it would not change modeled properties and, therefore, the fuel rod’s thermal performance would be similar for a fuel rod without chromium-coating.

It was reported that the eutectic that forms from the zirconium and chromium has a melting point that is less than the melting point of either chromium or zirconium. The eutectic temperature is much greater than the 104 deg C cladding temperature measured during the hypothetical accident condition fire test (per SAR Table 3-1); the measured cladding temperature is low considering that SAR Section 3.1.1 stated the fuel rods can withstand temperatures up to 1,204°C.

With regards to fuel rod pressure, SAR Figure 3-1A provided test data that showed a fuel rod with chromium-coated cladding had greater capacity to withstand pressure compared to ZIRLO cladding without the chromium coating.

SAR Section 3.2.1.1 stated that the Optimized ZIRLO liner is a zirconium-tin-iron alloy that thermo-mechanically interacts with the Optimized ZIRLO cladding. The liner thickness is a few mils and is essentially zirconium by weight. SAR Section 3.2.1.1 stated that fuel rods with the standard fuel cladding, OZL liner cladding, and the chromium-coated cladding have identical minimum wall thicknesses per their respective engineering drawings.

Thus, the SAR stated that the thermal performance of a fuel rod with the Optimized ZIRLO liner would be similar for a fuel rod without the liner. Additional discussion about the chromium coating and Optimized ZIRLO liner is provided in the Materials Evaluation of this SER (See Section 2.4).

3.3 Thermal Evaluation under Normal Conditions of Transport

According to SAR Section 3.4, contents include non-irradiated nuclear fuel with negligible decay heat. As a result, package surface temperatures would not rise above ambient temperatures in the shade and, therefore, would satisfy the exclusive use and non-exclusive use surface temperature per 10 CFR 71.43(g). SAR Table 2-3 and SAR Section 2.6.1.1 stated that the NCT tests (e.g., differential thermal expansion, vibration, free drop, water spray, compression, puncture) were evaluated between the design temperature range of -40 °F minimum temperature and 158 °F maximum temperature. In addition, SAR Section 2.6.2, Section 2.12.9, and Section 2.12.9.4.1 stated that Traveller materials, as well as the fuel rod cladding's zirconium alloy and chromium coating, are not degraded at -40 °C.

As previously mentioned, there were no changes to the Traveller package and no new thermal analyses for normal conditions of transport. SAR Section 3.1.4 stated that the package's Clamshell and Outerpack are not pressurized, such that operating pressure would be in equilibrium with ambient conditions. SAR Section 1.2.2.1.1 stated that the fuel rods, which use the ASME Boiler and Pressure Vessel Code, Section III in their mechanical design and stress analysis, are pressurized to a nominal 380 psig at room temperature.

The rod pressure at normal conditions is relatively low and does not stress the rod compared to hypothetical accident conditions. It is noted that SAR Section 3.2.1.1 and Figure 3-1A showed that the chromium-coated cladding fuel rod had greater capacity to withstand pressure compared to fuel rods without the chromium coating.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

As previously stated, there were no changes to the Traveller package and no new hypothetical accident fire condition tests were conducted. Previous results from the Certification Test Unit thermal tests showed that the package would withstand the fire condition and that the UHMW neutron absorber material would maintain its effectiveness.

Regarding the new cladding associated with this amendment, SAR Section 2.12.9.2 discussed that fuel rods with chromium-coated cladding and the OZL have higher total strain energy absorption capability than the tested Standard Zirconium Alloy; therefore, their response would be less susceptible to mechanical failure from the 9 m drop test.

Likewise, as noted above, SAR Section 3.2.1.1 and SAR Figure 3-1A provided test data that showed a fuel rod with chromium-coated cladding had greater capacity to withstand pressure when compared to ZIRLO cladding without the chromium coating. It is noted that the burst pressures shown in SAR Figure 3-1A are associated with temperatures greater than 1,000 °F , which is well above the 104 °C cladding temperature measured during the Certification Test Unit (CTU) hypothetical accident condition fire test discussed in SAR Section 3.6.5.

3.5 Evaluation Findings

Based on a review of the statements and representations in the application, the staff concludes that the Traveller Type AF-96 package thermal design has been adequately described and evaluated, and that the package meets the thermal requirements of 10 CFR Part 71 and the guidance on format and content in NUREG-1886 for joint approval in the U.S. and Canada.

4.0 CONTAINMENT EVALUATION

The application submittal letter stated there were no changes to the Traveller package for this amendment request, although new cladding types include a chromium coating and an Optimized ZIRLO liner (OZL). The content is inside a Clamshell structure that is placed within an Outerpack with a bolted torqued closure. SAR Section 3.1.3 stated the radioactivity of the fresh fuel contents is negligible.

SAR Section 1.2.1.2 stated that the Traveller containment boundary consisted of the fuel rod's zirconium alloy clad and end plugs welded to the fuel tube; the integrity of the welds is tested using radiographic or ultrasonic non-destructive test methods. The fuel rod with welded end plugs satisfies 10 CFR 71.43(c). SAR Section 1.2.2.1.1 stated that the fuel rods, which use the ASME Boiler and Pressure Vessel Code, Section III in their mechanical design and stress analysis, are pressurized to a nominal 380 psig at room temperature.

SAR Section 3.2.1.1 and Figure 3-1A showed that the chromium-coated cladding fuel rod had greater capacity to withstand pressure compared to a fuel rod without the chromium coating. Likewise, SAR Section 2.12.9.2 provided calculations demonstrating that the chromium-coated cladding and the OZL have higher total strain energy absorption capability than the previously tested Standard Zirconium Alloy; therefore, their response would be less susceptible to mechanical failure from the 9 m drop test. These performance aspects of the chromium coating and OZL indicated that the amendment's new cladding types would continue to retain fuel content at normal conditions of transport, thus satisfying 10 CFR 71.43(f).

Based on a review of the statements and representations in the application, the staff concludes that the Traveller Type AF-96 package containment design has been adequately described and evaluated, and that the package meets the containment requirements of 10 CFR Part 71. Staff concludes that the guidance on format and content in NUREG-1886 has been met.

6.0 CRITICALITY EVALUATION

The applicant submitted an amendment request for the Model No. Traveller package to authorize fuel with accident tolerant fuel (ATF) features, including coated cladding and doped pellets, and loose rods enriched up to 7.0 weight percent in U^{235} as allowable package contents, as well as liners. The applicant also revised the definition of statistical significance for when a k_{eff} penalty is applied as a result of a sensitivity analysis, and included a discussion about integral neutron absorbers which may be part of the fuel material contents in any rod. Additionally, the applicant requested that the package be reviewed for the Joint United States – Canada process for package approval and validation, in accordance with NUREG-1886, "Joint Canada - United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages."

In Section 6.1.2 of the SAR, the applicant discusses the criteria for determining when a sensitivity study case is determined to have a more reactive result than the baseline case. More reactive k_{eff} results determine a penalty to be added to the baseline case k_{eff} for determining the final system k_{eff}. In the previous revision of the SAR, the applicant stated that sensitivity case results were included as a k_{eff} penalty if the result is greater than the baseline case, regardless of the magnitude of the difference. The applicant states in the revised SAR that sensitivity case results are included as a k_{eff} penalty if the result differs from the baseline case k_{eff} by two times the Monte Carlo uncertainty (2σ) or more. Sensitivity case k_{eff} results that are lower than the baseline case, or are greater by less than 2σ, are not included in the final k_{eff} results.

No changes in this revision resulted in changes to the criticality safety indexes (CSIs) or approved transport configurations for the various contents. The staff agrees that this criteria for including sensitivity study result penalties is appropriate, as changes in k_{eff} that are less than 2σ are not statistically significant, and because the applicant's analysis in Section 6.9.4 of the SAR demonstrates that the method of applying penalties from independent sensitivity studies is conservative.

The applicant added Section 6.3.2.15 of the SAR, which discusses integral neutron absorbers which may be part of the fuel contents in any rod. These are materials added to the UO_2 in fuel pellets to absorb neutrons, thereby reducing reactivity. As these materials reduce reactivity, the applicant conservatively ignores them in the criticality safety analysis of the package. The staff agrees that it is conservative to ignore integral absorbers in the criticality analysis, since these materials only serve to reduce reactivity.

The applicant stated that any rod may include a chromium coating or an Optimized ZIRLO Liner (OZL), as described in Section 1.2.2.1.1 of the SAR. The applicant stated in Section 6.3.2.4 of the SAR that clad coatings and the OZL are conservatively neglected in the criticality analysis. Coatings and the OZL are additional to the base zirconium alloy cladding and will displace moderator and increase neutron absorption. Additionally, the applicant states that any thickness associated with coatings and the OZL shall not be included in determining the minimum clad thickness for comparison with the CoC limit.

The staff agrees that the applicant's treatment of clad coatings and the OZL is appropriate, and that it is conservative to ignore these features in the criticality analysis. The most reactive configurations are at minimum clad thickness, and the clad coating and OZL features would only result in increased clad thickness which correspond with lower system reactivity.

The applicant revised the safety analysis report to include PWR Group 1 and Group 2 uranium oxide (UO_2) fuel rods, as assemblies or as loose rods in the rod pipe component, with pellets which may be doped with chromium oxide (Cr_2O_3) and aluminum oxide (Al_2O_3) (ADOPT fuel), as described in Section 1.2.2.1 of the SAR. Any number of rods within the fuel assembly or the rod pipe may consist of ADOPT fuel, at the same maximum enrichment of standard UO_2 rods. The applicant evaluated ADOPT fuel as described in Section 6.3.4.3.14 of the SAR. The applicant modeled ADOPT rods in any location in Group 1 or Group 2 fuel assemblies, and as loose rods in the rod pipe, to determine the difference in k_{eff} from standard UO_2 fuel assemblies and rods. ADOPT rods are not authorized for Group 3 fuel assemblies, or for uranium silicide (U_3Si_2) loose rods.

The results of the single package sensitivity studies for ADOPT rods are included in Table 6-33A of the SAR for a fuel assembly under normal conditions of transport (NCT), Table 6-40A of the SAR for a fuel assembly under hypothetical accident conditions (HAC), Table 6-45A of the SAR for a rod pipe under NCT, and Table 6-50A of the SAR for a rod pipe under HAC. The results of the array sensitivity studies for ADOPT rods are included in Table 6-64A of the SAR for fuel assemblies under NCT, Table 6-70A of the SAR for the rod pipe under NCT, Table 6-86A of the SAR for fuel assemblies under HAC, and Table 6-94A of the SAR for the rod pipe under HAC.

The results showed decreases in k_{eff} for all configurations except the single package under HAC with a fuel assembly, the single package under NCT with a rod pipe, and the array under NCT with the rod pipe. These configurations showed minor increases in k_{eff}, which the applicant included in the assessed penalties for determination of maximum system k_{eff}, consistent with the other sensitivity analyses previously performed for the package and approved by the staff. All calculated k_{eff} values for configurations with ADOPT fuel rods remain below the applicant's calculated Upper Subcritical Limit (USL).

The staff finds this analysis, along with the assessed penalties in k_{eff}, acceptable for demonstrating that the package continues to meet the criticality safety requirements of 10 CFR Part 71 when transporting Group 1 and Group 2 fuel assemblies and loose rods in the rod pipe which contain ADOPT fuel rods.

The applicant revised the criticality analysis of loose UO_2 fuel rods in the rod pipe to consider a maximum enrichment of 7.0 weight percent U^{235}. All other parameters, except the addition of ADOPT fuel contents, were maintained consistent with the previously approved analysis for this content type, including the package array size for the NCT and HAC array evaluation. ADOPT fuel contents with higher enrichment in the rod pipe is included in the SAR analysis as a new sensitivity study, for which a k_{eff} penalty is applied if it increases system k_{eff} by 2σ or more.

The applicant performed baseline analyses and all sensitivity analyses relevant to the rod pipe for UO_2 fuel rods with the higher enrichment, for the single package and arrays of packages under NCT and HAC. The k_{eff} results are discussed in Section 6.4.2 for the single package under NCT and HAC, Section 6.5.2 for the NCT array, and Section 6.6.2 for the HAC array. The maximum calculated system k_{eff}, for the HAC array of 150 packages containing loose UO2 rods in the rod pipe, was 0.81588, including the calculation Monte Carlo uncertainty and the sum of penalties assessed for each sensitivity study. The maximum system k_{eff} is significantly less than the applicant's calculated USL of 0.94044.

The staff reviewed the configurations modeled by the applicant for the single package and array analyses. The staff agrees that the applicant has identified the most reactive credible condition of the single package and arrays of packages, consistent with the condition of the package under NCT and HAC, and the chemical and physical form of the fissile and moderating contents.

For all calculations, the applicant used the CSAS6 sequence of the SCALE 6.1.2 computer code, with KENO VI and the continuous energy ENDF/B-VII.0 cross section library. This is the same code and cross section library used for calculations of the previously approved packaging and contents configuration, which is benchmarked as discussed in Section 6.8 of the SAR.

In the applicant's benchmarking analysis, two new benchmark series were added to supplement the addition of 7.0 weight percent UO_2 loose rod contents, in addition to previously included series at enrichments of 7.0 and 10.0 weight percent. The two new series have uranium enrichments of 7.41 and 6.903 weight percent. No experiments were added to address the addition of ADOPT fuel material.

The applicant's analysis of fuel and rods with ADOPT fuel material demonstrate that the doping material, chromium and aluminum oxides, have little effect on system reactivity. This is expected, as chromium and aluminum have low neutron cross sections, and are expected to have little effect on system neutron energy spectrum. Therefore, the staff finds the applicant's use of the same USL for both standard UO2 fuel and ADOPT UO_2 fuel to be acceptable for both assemblies and loose rod contents.

With the additional experimental series added, the applicant's benchmark suite included 83 critical experiments ranging from 2.6 to 10.0 weight percent enrichment, as shown in Table 6-95 of the SAR. As with the previous benchmarking analysis, the applicant performed a trending analysis of k_{eff} versus energy of average lethargy causing fission (EALF), fuel enrichment, water-to-fuel volume ratio, and hydrogen-to-fissile isotope (H/X) ratio. The highest correlations were k_{eff} versus EALF and H/X, which were similar in magnitude.

The applicant determined the USL as a function of EALF using the USLSTATS code. The resulting USL function, shown in Section 6.8.2 of the SAR, gives a USL of 0.94044 for the loose rod contents containing uranium enriched to 7.0 weight percent when the EALF for the limiting case is entered into the function.

The staff agrees that the code and cross section library used by the applicant are appropriate for the analysis, and that the USL determined by the applicant is calculated appropriately. The staff also notes that there is significant margin between the USL and the maximum calculated system k_{eff} (greater than 10% in k_{eff}).

The staff performed confirmatory calculations using the SCALE 6.2.3 Monte Carlo radiation transport code, with the CSAS6 criticality sequence and the 252-group ENDF/B-VII.1 neutron cross section library. The staff's confirmatory analyses consisted of models of the single package under NCT, and arrays of packages under HAC. Using modeling assumptions similar to the applicant's, the staff's independent evaluation resulted in k_{eff} values that were similar to, or bounded by, the applicant's results.

The staff also performed confirmatory benchmarking calculations. The staff verified that the critical experiments selected by the applicant were applicable to the package with loose UO_2 rods enriched to 7.0 weight percent U^{235} in the rod pipe. The staff used the TSUNAMI sequence of the SCALE 6.2.3 code package, with the ENDF/B-VII.1 252-group cross section library, to independently select experiments with high integral index (ck) values compared to the package with the requested contents.

The staff created sensitivity data files (SDFs) for the confirmatory models and the TSUNAMI tool was used to compare the SDFs with benchmark SDFs to determine ck values that were then used to determine a USL. The SDFs used are from Oak Ridge National Laboratory's VALID library of benchmark cases.

Using the USLSTATS code within the SCALE 6.2.3 package with an administrative margin of 5%, and a ck of 0.95 (indicating a high degree of experiment similarity to the confirmatory model), the staff determined a USL of 0.94 based on a ck trending analysis of 76 critical experiments which met the minimum ck criteria. This USL is very close to the applicant's calculated USL of 0.94044. Although this analysis was performed using a different version of the SCALE code and different set of critical experiments, this indicates that the USL calculated by the applicant is appropriate.

The staff reviewed the application according to the guidance for approval in both the U.S. and Canada in NUREG-1886. This NUREG addresses differences between 10 CFR Part 71 and IAEA SSR-6, and how they are to be addressed for approval in both the U.S. and Canada. Chapter 6 of NUREG-1886 identifies two differences between 10 CFR Part 71 and IAEA SSR-6 in the area of fissile materials: fissile material exemptions and exceptions to water in-leakage requirements. All other fissile materials regulations are identical between 10 CFR Part 71 and IAEA SSR-6.

Since the Model No. Traveller package is for fresh fuel, which is not fissile exempt under either regulation, and since the applicant considers optimum internal moderation by water in its criticality analysis, neither of these two regulatory differences are relevant to this review. Therefore, staff concludes that the applicant has met the criticality analysis guidance in NUREG-1886 for fissile materials package approval per 10 CFR Part 71 and IAEA SSR-6.

The staff reviewed the applicant's requested changes to the Certificate of Compliance, initial assumptions, model configurations, analyses, and results. The staff finds that the applicant has identified the most reactive configuration of the Model No. Traveller package with the requested contents, and that the criticality results are conservative.

Therefore, the staff finds with reasonable assurance that the package, with the requested contents, will meet the criticality safety requirements of 10 CFR Part 71 and IAEA SSR 6.

7.0 OPERATING PROCEDURES

No specific changes were made to the operating procedures or the activities that are applicable to all sites that use the packages. Some minor clarifications were made on the package loading and unloading operations, details were added in the previous revision of the application for the inspection of Clamshell and BORAL neutron absorber plates, as well as restrictions for lifting stacked packages.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Minor changes were made to Section 8.1.2 to allow for a later edition of the ASME Code at time of manufacturing the package, Section 8.2.3.2 to replace “Weather Seal” by “Weather Gasket”, and to Section 8.2.6 to address “Periodic Weld Examinations”. A new Section 8.2.7 was added to address “Periodic Acetate Plug Examinations”.

CONDITIONS

The following changes have been made to the certificate:

Condition No. 3(b), “Title and Identification of Report or Application,” has been updated to reference the latest application, Rev. No. 15.

Condition No. 5(a)(2) was modified to change “seal” to “barrier”.

Condition No. 5(a)(3) was modified to include the latest revision, Revision No. 7 of Drawing No.10006E58.

Condition No. 5(b)(1)(i) was updated for two of the parameters for square lattice group 1 fuel assemblies.

Condition No. 5(b)(1)(iii) was updated to include the condition that the cladding may include a chromium coating of 25 µm thick nominally, or include an Optimized ZIRLO Liner.

Condition No. 5(b)(1)(v) was modified to allow the use of lead-filled replacement rods.

Condition No. 5(b)(1)(ix) was added to state that fuel rods in any location of the assembly may include ADOPT uranium dioxide pellets doped with up to 700 ppm Cr2O3 and up to 200 ppm Al2O3.

Condition No. 5(b)(2) (iii) was modified to add that all rod cladding must be composed of a Zirconium Alloy. Cladding may include a chromium coating of 25 µm thick nominally, or include an Optimized ZIRLO Liner.

Condition No. 5(b)(2)(ix) was added to allow fuel rods in any location of the assembly to include ADOPT uranium dioxide pellets doped with up to 700 ppm Cr2O3 and up to 200 ppm Al2O3

Condition No. 5(b)(3)(iii) was updated to allow cladding with a chromium coating of 25 µm thick, nominally or an Optimized ZIRLO Liner.

Condition No. 5(b)(3)(v) was modified to allow lead-filled replacement rods in the assembly.

Condition No. 5(b)(4) was modified to allow any fuel rod to include ADOPT uranium dioxide pellets that are doped with up to 700 ppm Cr_2O_3 and up to 200 ppm Al_2O_3. Limits for the cladding material and the integral absorber were updated accordingly.

Condition No. 5(b)(5) was updated for the limits for the cladding material and the integral absorber.

Condition No. 9 has been updated to authorize use of the previous certificate for approximately one year.

The references section has been updated to include the application Revision No. 15, and its supplement dated August 14, 2020.

CONCLUSION

Based on the statements and representations contained in the application and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Model Nos. Traveller STD, Traveller XL, and Traveller VVER packages meet the requirements of 10 CFR Part 71 and the guidance on format and content in NUREG-1886 for joint approval in the U.S. and Canada.

Issued with Certificate of Compliance No. 9297, Revision No. 12.