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

SAFETY EVALUATION REPORT
Docket No. 71-9380
Model No. Traveller STD and XL Packages
Certificate of Compliance No. 9380
Revision No. 1

SUMMARY

By letter dated August 2, 2021 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML211221A323), Westinghouse Electric Company (Westinghouse or the applicant) submitted an application to revise Certificate of Compliance (CoC) No. 9380 for the Traveller STD and XL packaging's. Westinghouse requested that the changes pertaining to this amendment request be reviewed per NUREG-1886, "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages." By letter dated March 11, 2022, Westinghouse submitted Revision No. 2A of the Safety Analysis Report (SAR) as a supplement of the application, as well as a CoC renewal request (ADAMS No. ML22081A244, ML22081A251), and a request to review the changes in the CoC and the associated SAR Revisions 2 and 2A.

The amendment application includes changes to the design of the Type A and Type B configurations of the Westinghouse Traveller STD and XL packages for transporting a Type A or Type B quantity of fissile radioactive material in the form of new (unirradiated) PWR fuel assemblies (Type A or B quantity), or new PWR or BWR loose fuel rods in a rod pipe (Type A quantity only). This amendment application includes, in particular, the following changes:

- New contents for accident tolerant fuels (ATF).

- Increases in the maximum allowable enrichments for uranium dioxide (UO_2) fuels from five weight percent ^{235}U (5 wt.%) to 6 wt.% ^{235}U for PWR fuel assemblies, and from 5 wt.% ^{235}U to 7 wt.% ^{235}U for loose PWR or BWR fuel rods in a rod pipe.

- Inclusion of a new two-tier bottom support spacer design option in the packaging Clamshell assembly to accommodate an additional type of PWR fuel assembly bottom nozzle design.

- Changes to the structural and criticality evaluations associated with the ATF, higher allowable enrichments, and new bottom support spacer; and

The ATF contents include Advanced Doped Pellet Technology (ADOPT™) UO_2 fuels, which are doped with Cr_2O_3 and Al_2O_3, and new fuel cladding features. The new fuel cladding features include the existing base zirconium alloy cladding options with new options for an external chromium coating and/or an inner zirconium alloy liner, identified as the Optimized ZIRLO™ Liner (OZL). For loose PWR or BWR fuel rods, the new cladding features also include new options for stainless steel or aluminum alloy claddings.

ATF advanced cladding features and UO_2 fuel advancements are evaluated for the new contents. There is no impact to the packaging design, operations, or maintenance due to the new contents and the new bottom support spacer component.

NRC staff reviewed the amendment application using the guidance in NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material,” and NUREG-1886. Staff found that the highlighted areas of emphasis in NUREG-1886 have been appropriately addressed for the changes pertaining to this amendment request but did not review the entire package using NUREG-1886.

Based on the statements and representations in the application, and the conditions listed in the CoC, the U.S. Nuclear Regulatory Commission staff (the staff) concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

EVALUATION

1.0 GENERAL INFORMATION

All changes made to the application support the addition of the new contents and the insertion of a new component to support the fuel assembly; however, the packaging design has been not been modified.

Sections 1.1, 1.2.2.1, and 1.2.2.2 were revised to clarify the permissible enrichments of 5 wt.% for PWR Group 1 and 2 fuel assemblies and U_3Si_2 loose rods, 6 wt.% for PWR Group 4 fuel assemblies, and 7 wt.% for UO_2 loose rods. Table 1-1 was revised to include PWR Group 4 contents and clarify maximum wt.% for each content.

Section 1.2.1.2 now clarifies the Type B containment of the packaging and includes alloy cladding and welded or bonded end plugs to form the fuel rod containment system. Section 1.2.1.5.3, Type B Configuration Shoring Components, was revised to include details of new bottom support spacer design for four-legged, side-skirted nozzles, as shown also in Figure 1-11B.

Section 1.2.2.1.1 includes now zirconium alloys with allowance for chromium coating and/or Optimized ZIRLO Liner (OZL). The applicant specifies that loose fuel rod shipments in the Rod Pipe are restricted to Type A contents and may have aluminum cladding with bonded end plugs or stainless-steel cladding with welded end plugs.

Section 1.2.2.1.2, Fuel Assembly, clarifies that only zirconium alloy tubes with welded end plugs are permitted for fuel assembly content.

The maximum quantity of radioisotopes in the contents of the package is limited to the quantity contained in a single fuel assembly or in the maximum number of fuel rods that can be transported in the Rod Pipe. The only fissile material is low-enriched uranium that is:

- ≤ 5.0 wt.% ^{235}U for PWR Group 1 and 2 fuel assemblies and U_3Si_2 loose rods,
- ≤ 6.0 wt.% ^{235}U for PWR Group 4 fuel assemblies,
- ≤ 7.0 wt.% ^{235}U for UO_2 loose fuel rods.
- ≤ 5.0 wt.% ^{235}U for U_3Si_2 loose fuel rods

The packaging is constructed and assembled in accordance with the following Drawing Nos.:

10071E36, Rev. 4 (sheets 1-9) and
10006E58, Rev. 7. Traveller Type A Design (RTP and FTP)
10004E58, Rev. 9 (Sheets 1-9) Traveller Type B Design (RTP)
Rod Pipe – Licensing Drawing 10006E58, Rev. 7

Figure 1-15 of the application represents the Traveller package as prepared for transport in compliance with NUREG-1886.

Based on review of the statements and representations in the application, the staff concludes that the package design has been adequately described and evaluated, meeting the requirements of 10 CFR Part 71. The staff found that the highlighted areas of emphasis in NUREG-1886 have been appropriately addressed for the changes pertaining to this amendment request but did not review the entire package using NUREG-1886.

2.0 STRUCTURAL AND MATERIALS EVALUATION

2.1 Structural Evaluation

The staff reviewed the proposed changes to the Westinghouse Traveller PWR Fuel Shipping Package provided in Revision 2 to the Safety Analysis Report (SAR) to verify that the applicant has adequately evaluated the impact of the changes to the structural performance of the package and to confirm that the package continues to comply with the regulations of 10 CFR Part 71. The staff's review followed the guidance in NUREG-1886, "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages," and accordingly, evaluated the changes to the structural performance of the package to confirm that these changes comply with the requirements of IAEA SSR-6. The NRC staff has not previously reviewed the Westinghouse Traveller package for compliance with IAEA SSR-6. As this review only evaluated the addition of the new bottom support spacer, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

The staff's structural review focused on the addition of a new two-tiered design of the bottom support spacer that would support fuel assemblies with side skirts around the bottom nozzles. The previously approved Type B Traveller package is provided with axial restraints to provide structural support to the fuel assemblies during the 9 m free drop test of the 10 CFR 71.73 Hypothetical Accident Conditions (HAC). These axial restraints include a bottom support spacer and a top clamping mechanism. In this amendment, the applicant proposed a variant of the bottom support spacer to accommodate fuel assemblies with four-legged bottom nozzles with side skirts.

The applicant depicted the proposed support spacer for bottom nozzle with skirted sides and four corner legs in Figure 2.1-4B of the SAR and Revision 3 of Licensing Drawing No. 10071E36, and the applicant described the details of the support spacer in Section 2.12.4 of the SAR. The side skirted bottom nozzle support spacer is a two-tiered, setback aluminum structure. The spacer is positioned inside the package's Clamshell and rests on the Clamshell's bottom end plate. The solid upper tier supports the bottom nozzle flow plate of the fuel assembly and has a reduced area to provide clearance for the side skirts. The lower tier has a void center and supports the four corner legs of the fuel assembly. Both tiers of the spacer are topped with compressible rubber pads that fill the space between the bottom of the fuel assembly and the top of the spacer. The bottom support spacer geometry may vary to ensure the fuel assembly is supported with the maximum heights of the support spacer listed on sheet 7 of Licensing Drawing No. 10071E36.

The applicant described the structural design criteria in Section 2.1.2.1 of the SAR. For this amendment, the applicant did not change these design criteria, which the NRC staff had previously approved. For the previously approved Type B four-legged support spacer, shown in SAR Figure 2.1-4A, the applicant demonstrated that the design criteria and regulations were met through physical testing. The physical testing of the Type B package, particularly in the bottom-end HAC free drop test, showed that a rigid bottom spacer was needed to ensure that the fuel rods remained leak tight and weren't damaged by inertial forces.

The applicant used a Finite Element Analysis (FEA) to demonstrate that the structural design criteria and regulations were met for the Type B package with the proposed side-skirted bottom nozzle support spacer. The applicant first validated FEA models by simulating the results of prior testing. These included results from the HAC bottom-end drop of a Type B package without a support spacer and a Type B package with a four-legged bottom nozzle support spacer. The applicant demonstrated that the FEA model results closely matched the results of the physical drop testing, in both cases.

Following this validation, the applicant updated the Type B FEA model to include the side-skirted bottom nozzle support spacer. The applicant demonstrated the safety of the package by showing that displacements in the FEA model with the proposed side-skirted bottom nozzle support spacer closely matched the results of the other FEA models and the results of the physical drop tests. The NRC staff review of this FEA model and results are further discussed in this SER.

The applicant concluded that the proposed change to the bottom support spacer only affects the results of the HAC free drop test and the results of the previous analyses of the Normal Conditions of Transport (NCT), other HAC, or any other structural performance requirements remain unchanged. Based on the information in the SAR, the NRC staff reviewer agrees that the previously approved analyses of the NCT, HAC other than the free drop, and other structural performance requirements remain unaffected by the proposed side-skirted bottom nozzle support spacer and continue to adequately maintain the safety and regulatory compliance of the Traveller PWR Fuel Shipping Package.

The applicant described the FEA and results for the HAC free drop of the Type B Traveller Package with the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer in Section 2.12.4 of the SAR. The applicant validated the use of FEA modeling for the Type B package by creating FEA models of the Type B package and benchmarking the model results to the previously performed physical testing for the Type B package.

The benchmark models included HAC bottom-end drops of a Type B package without a support spacer and a Type B package with a four-legged bottom nozzle support spacer. The results of the benchmark models showed close agreement with the Type B drop tests. Particularly, the applicant noted the Outerpack impact limiter crush depth (i.e., the distance the bottom plate of the clamshell embedded into the center of the impact limiter) was approximately the same in the model and the drop testing. Following this validation, the applicant updated the Type B FEA model to include the side-skirted bottom nozzle support spacer.

The applicant created an FEA model in the program LS-DYNA to analyze the bottom-end HAC free drop for the Type B package with the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer. The applicant only analyzed the bottom-end drop orientation because this was the only orientation that resulted in damage to fuel rods in the Type B physical testing and the only orientation affected by the addition of the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer. The FEA model included only the bottom regions of the Clamshell (since the Clamshell walls do not absorb a significant amount of energy in the drop); the fuel rods (since the fuel rod bottom region was the only area to deform in the physical drop testing); and the Outerpack (since the bottom impact limiter is the only component of the Outerpack that absorbs a significant amount of energy in the drop).

The results from the FEA of the Type B package with the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer demonstrated that no buckling nor significant deformation occurred in the bottom nozzle, bottom support spacer, or fuel rods from the HAC free drop. The applicant noted that the Outerpack impact limiter crush depth in the model matched the crush depth of the physical drop test of the Type B package with a four-legged bottom nozzle support spacer and the corresponding benchmark FEA model almost exactly.

The staff notes that the results of the physical drop tests showed that the bottom nozzle did not experience significant buckling, the fuel assembly did not fail or buckle, and the fuel rods were tested to be leak-free. The results of the model with the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer also showed similar decelerations to the benchmark model and no significant deformation in the fuel assemblies. In the FEA, the bottom support spacer acted as an essentially rigid member supporting the fuel assembly bottom nozzle and transferring kinetic energy into the Clamshell structure and then to the Outerpack impact limiter. The applicant concluded that the strength of the Side-Skirted, Four-Legged Bottom Nozzle Support Spacer was adequate to stabilize and support the side skirted, four-legged bottom nozzle during a bottom-down impact.

The NRC staff reviewed the FEA for the HAC free drop and finds that the applicant's FEA modeling is consistent with the guidance in NUREG-2216 and the applicant's evaluation of the HAC free drop is consistent with NUREG-1886. Thus, the staff finds the package meets the requirements of 10 CFR 71.73(c)(1).

The staff's review evaluated the changes to the structural performance of the package to confirm that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff has not previously reviewed the Westinghouse Traveller package for compliance with IAEA SSR-6. As this review only evaluated the addition of the new bottom support spacer, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment. This is described further in the structural evaluation findings below:

1. The staff has reviewed the package structural design description and concludes that the contents of the application satisfy the requirements of 10 CFR 71.31(a)(1) and (a)(2), 10 CFR 71.33(a) and (b). In addition, the changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraphs 607.

2. The staff reviewed the application and finds that the package was evaluated by subjecting a specimen or scale model to the specific tests, or by another method of demonstration acceptable to the Commission, and therefore satisfies the requirements

of 10 CFR 71.41(a). In addition, the changes to the package in this amendment satisfy the requirements of IAEA SSR-6 paragraph 673.

3. The staff reviewed the structural performance of the packaging under the normal conditions of transport required by 10 CFR 71.71 and IAEA SSR-6 and concludes that there will be no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(1) for a Type B package, 10 CFR 71.55(d)(2) for a fissile material package. In addition, the changes to the package in this amendment satisfy the IAEA SSR-6 requirements for Type B(U) packages and requirements for packages containing fissile materials.

4. The staff reviewed the structural performance of the packaging under the hypothetical accident conditions required by 10 CFR 71.73 and the accident conditions of transport required by IAEA SSR-6 and concludes that the packaging has adequate structural integrity to satisfy the subcriticality, containment, and shielding requirements of 10 CFR 71.51(a)(2) for a Type B package, 10 CFR 71.55(e) for a fissile material package. In addition, the changes to the package in this amendment satisfy the IAEA SSR-6 requirements for Type B(U) packages and requirements for packages containing fissile materials.

2.2 Materials Evaluation

The NRC staff performed its materials evaluation for the Westinghouse Traveller STD and XL amendment application (ADAMS Accession Nos. ML21216A324), as supplemented on March 11, 2022), by following the guidance in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material," August 2020 (ADAMS Accession No. ML20234A651).

The objective of the NRC staff's materials evaluation is to verify that the applicant has adequately evaluated the changes affecting the materials performance of the Traveller STD/XL transportation package under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) to meet the requirements of 10 CFR Part 71.

2.2.1 Technical Evaluation

Based on the guidance in NUREG-2216, the NRC staff identified the proposed changes in the application that are relevant to the staff's materials evaluation. All of the proposed changes for this amendment, including changes to the licensing drawings, are included in Revision Nos. 2 and 2A of the application (ADAMS No. ML 22081A244, and A251), whereas Revision 1 of the application (ADAMS Accession No. ML19308C710) is the version that was previously reviewed and approved by the NRC. A summary of amendment changes that are relevant to the staff's materials evaluation follows below:

- Changes to the licensing drawings for the Westinghouse Traveller STD/XL Type B packaging (Outerpack and Clamshell assembly) components to include a new two-tier bottom support spacer design option for structural support of PWR fuel assembly bottom nozzles;

- New fuel cladding features associated with the new ATF contents. The new fuel cladding features include:

- For PWR fuel assemblies (Type A and Type B contents) and loose PWR or BWR fuel rods (restricted to Type A contents only), there are new options for an external chromium coating and/or an inner zirconium alloy liner (identified as the Optimized ZIRLO™ Liner (OZL)) for the existing optimized base zirconium alloy claddings;

- For loose PWR or BWR fuel rods that are carried in a rod pipe (located inside the Traveller packaging), there are also additional options for stainless steel or aluminum alloy claddings and the addition of a non-weld bonding option (in addition to welding) for joining the fuel rod end plugs to aluminum alloy cladding tubes. It should be noted that loose fuel rods carried in a rod pipe are still restricted to Type A contents only.

- Changes to the structural and criticality evaluations of the package associated with the new claddings for ATF contents, higher allowable UO_2 fuel enrichments, and the new two-tier bottom support spacer option that is incorporated in the packaging.

- Changes to the acceptance tests and maintenance program including:

  - A change to the allowable editions of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) that are used for post-fabrication weld acceptance inspections; and

  - Enhancements to the package maintenance program, including new inspection criteria for periodic visual examinations of packaging structural welds and the acetate plugs.

Drawings

The amendment application includes proposed changes to the licensing drawings for the Traveller STD/XL Type B packaging components in Drawing No. 10071E36, "Safety Related Items Traveller Type B XL & STD".

The NRC staff reviewed the proposed changes to the licensing drawings by comparing the proposed revisions to the most recent approved version of the drawings included in Revision 1 of the application. The proposed revision includes a new line entry in the bill of materials (BOM) to specify the materials for the new two-tier bottom support spacer design, which is installed inside the packaging Clamshell assembly to provide structural support to PWR fuel assemblies.

The new two-tier bottom support spacer design is included as an additional option to provide structural support to PWR fuel assembly bottom nozzles with four legs and skirted sides. Whereas the prior approved version of the application (Revision 1) included just one single-tier design option for the aluminum bottom support spacer, the current application also includes the two-tier bottom support spacer as a new design option along with the existing single-tier design.

The staff noted that the BOM in the drawings lists the same materials for both the original single-tier and the new two-tier bottom support spacer designs, specifically ASTM B209/B221 6061-T6 Aluminum with a 1/8 inch-thick rubber pad. The original single-tier bottom support spacer design and the new two-tier bottom support spacer option both have the same function of protecting PWR fuel assemblies from structural damage and fuel rod failure during a package drop accident. The difference between the single-tier and two-tier design is associated with the difference in the geometry of the interfacing PWR fuel assembly bottom nozzles, such that the two different geometric configurations of bottom support spacer are needed to interface with and support the different geometric configurations of fuel assembly bottom nozzles.

The staff confirmed that there is no difference between the two bottom support spacer designs that would affect the suitability of the aforementioned materials for performing the needed structural support functions. The staff determined that the specified materials for both the original single-tier and the new two-tier bottom support spacer design are appropriate for their intended application. Therefore, the staff finds that this addition to the BOM in the licensing drawings for the Traveller Type B packaging components is acceptable.

2.2.2 Component Inspections and Associated Codes and Standards

The application includes several changes to the inspection criteria for Traveller package components. These changes are included in the application's description of the acceptance tests and maintenance program for the Traveller package. The NRC staff's evaluation of the specific changes follows below.

Changes to the Acceptance Tests Program. For the post-fabrication acceptance tests of Traveller packaging welds, there is a change to the cited Editions and Addenda of the ASME BPVC, Section III, upon which the weld nondestructive examination (NDE) procedures and associated NDE acceptance criteria are based. Whereas previously, the application cited and referenced just the 2001 Edition with 2003 Addenda of the ASME BPVC, Section III, Division 1 for the packaging weld inspections per Code Article NF-5000, the proposed change would allow for later ASME BPVC Editions and Addenda to be used for these inspections, subject to approval by the engineering department.

The staff reviewed this proposed change and noted that NUREG-2216, Section 2.4.1.2, "Identification of codes and standards for package design," states (in part) that the NRC may accept (as part of its review and approval for the package application) the use of the most recent code year for the design of shipping packages for new applications. This section of NUREG-2216 also cites the provisions of the ASME BPVC, Section III, Division 1, Paragraph NCA-1140 governing the use of Division 1 Code Editions and Addenda that may be applied to both new applications and amendments.

The staff noted that NCA-1140(b) provides that Code Editions and Addenda later than those previously established by the Owner or his designee for inclusion in the Design Specifications in accordance with NCA-1140(a), including any referenced Code Edition and Addenda, may be used by mutual consent of the Owner or his designee and Certificate Holder. The NRC staff determined that this provision provides an adequate basis for the use of later Editions and Addenda of the ASME BPVC Section III, Division 1 for post-fabrication inspections of the Traveller packaging welds per Code Article NF-5000, provided that such a change is made in accordance with the NRC-approved QA program.

The NRC staff also compared the 2001 Edition of Code Article NF-5000 to the later Editions up through Calendar Year 2021 and noted these examination requirements are generally unchanged and have remained adequate for ensuring the integrity of Subsection NF support welds, as previously approved for the Traveller packaging welds. On this basis, the staff determined that the applicant's proposal to allow for the use of later Code Editions and Addenda for the packaging weld inspections, subject to approval by the engineering department, is acceptable.

Changes to the Maintenance Program. For the Traveller package maintenance program, the application includes new criteria for periodic visual examinations of the structural welds in the packaging Outerpack and Clamshell assemblies and periodic visual examinations of packaging Outerpack acetate plugs.

The staff noted that criteria for periodic examination of these items were not included in the prior approved version of the application (Revision 1); hence they represent an enhancement to the maintenance program for the Traveller package relative to what the NRC previously approved. Both new sets of periodic examinations are specified to occur on an inspection interval that is not to exceed every two years. For the periodic visual inspections of the Outerpack and Clamshell structural welds, the application specifies the ASME BPVC, Section III, Article NF-5000 requirements applicable to the performance of these visual examinations. The NRC staff reviewed these inspection criteria and found them acceptable because these ASME BPVC requirements provide the appropriate level of rigor and detail for the visual examination methods and techniques and for the associated flaw evaluation criteria and acceptance standards.

For the periodic visual inspections of the Outerpack acetate plugs, the application does not cite any ASME BPVC provision or other published consensus standard, but it specifies sufficiently detailed visual examination acceptance criteria for determining the continued functionality of the acetate plugs during package maintenance activities.

The NRC reviewed the acetate plug visual acceptance criteria and found them acceptable for providing reasonable assurance that the acetate plugs will continue to perform their design functions during the service life of the package. Based on the foregoing review of these inspection criteria, the staff finds these enhancements to the Traveller package maintenance program to be acceptable.

2.2.3 Fresh (Unirradiated) Fuel Cladding

The Traveller package amendment application includes new fuel cladding features associated with the new ATF contents. The new fuel cladding features include:

- For PWR fuel assemblies (Type A and Type B contents) and loose fuel rods in a rod pipe (Type A contents only), new options for an external chromium coating and/or an inner OZL liner for the existing base zirconium alloy claddings.

- For loose PWR or BWR fuel rods carried in a rod pipe (Type A contents only), the new cladding features also include additional options for stainless steel or aluminum alloy claddings and an option to use a non-weld “bonding” method (in addition to welding) for joining the fuel rod end plugs to aluminum alloy cladding tubes.

The existing base zirconium alloy claddings (i.e., the claddings previously evaluated and approved in Revision 1 of the application) include the Standard Zirconium Alloy (Standard ZIRLO™) and five proprietary variations of zirconium alloy, identified in the application as “Alloy 1”, “Alloy 2”, “Alloy 3”, “Alloy 4”, and “Alloy 5”. These base zirconium alloy cladding options are not changed in subject amendment application. The subject amendment application proposes that these base zirconium alloy claddings may incorporate the external chromium coating, which is applied to the outer surface of the base zirconium alloy; the inner OZL liner, which is bonded to interior surface of the base zirconium alloy; or both the external chromium coating and the inner OZL liner.

In addition to the optional chromium coating and/or OZL liner on the base zirconium alloys, the optional base alloy fuel claddings for the loose fuel rods may also include Annealed Type 304 Stainless Steel or Type 5052 Aluminum Alloy cladding. The staff confirmed that the type of stainless steel and aluminum alloy that may be used for loose fuel rod cladding are adequately specified in the application. The chromium coating and OZL liner are not included as options for use with stainless steel and aluminum alloy claddings for loose fuel rods.

The effects of these new cladding materials on package performance for NCT and HAC is primarily addressed as part of application's structural and thermal evaluations. The NRC staff's review of the applicant's evaluation of the structural and thermal properties and performance for the new cladding features is documented in the SER subsections below.

Structural Properties of Fresh Fuel Cladding

The NRC staff reviewed the applicant's evaluation of the structural properties and performance of the cladding materials, documented in Section 2.2.1.8 of the application, considering the new cladding features summarized above. The fuel cladding constitutes the containment boundary for the nuclear fuel and is also relied upon for ensuring that the geometric form of the package contents meets the assumptions and inputs used in the criticality evaluation.

As such, the staff considered whether the application included sufficient information for demonstrating that the cladding materials are capable of meeting their structural performance requirements under NCT and HAC for ensuring that the analyzed geometric form of the fresh nuclear fuel contents will not be substantially altered and there will be no loss or dispersal of the nuclear fuel.

The fuel rod containment boundary for the Traveller package is constituted by (1) the fuel rod cladding tube, (2) the fuel rod end plugs and (3) the cladding-to-end-plug joint itself. The approved version of the application (Revision 1) specified just "welding" as the method for joining the end plugs to the zirconium alloy cladding tube for fuel rods in a fuel assembly (Type A and Type B contents) and for loose fuel rods carried in a rod pipe (Type A contents only).

For the new aluminum alloy cladding option that may be used for loose fuel rods, the amendment application includes a new non-weld bonding method, in addition to welding, as an option for joining the end plugs to the aluminum alloy cladding tube. The staff verified that the details on this new non-weld bonding method, including bonding material product specification, thermal, and mechanical properties, are adequately specified in the application.

Current Package Certification Basis

With respect to the structural properties and performance of the cladding materials, the bounding service condition for NCT and HAC is the 30-foot package drop test; thus, the impact energy absorption capabilities of the cladding materials are of primary importance from a structural performance standpoint. The performance of the fuel assemblies and fuel rods during the 30-foot package drop test forms the basis upon which the relative energy absorption characteristics of the various cladding material options are evaluated.

As addressed in the approved version of the application (Revision 1), the Standard Zirconium Alloy was selected for use as the fuel rod cladding during the actual 30-foot drop test of the package due to its bounding strain energy absorption characteristics from uniaxial tensile tests. The selection of the Standard Zirconium Alloy cladding for the 30-foot drop test was based on destructive uniaxial tensile tests of the six zirconium alloy cladding materials, which include the Standard Zirconium Alloy and the five zirconium alloy variants (Alloys 1 thru 5).

The tensile tests of the six zirconium alloys demonstrated that the Standard Zirconium Alloy has the lowest total strain energy absorption capability of all six zirconium alloy cladding options. By demonstrating acceptable Standard Zirconium Alloy cladding performance during the 30-foot package drop test, cladding Alloys 1 thru 5 were determined by the applicant to be at least as capable of exhibiting acceptable 30-foot drop test performance based on their higher strain energy absorption capabilities from tensile tests in comparison to the Standard Zirconium Alloy.

Tensile Testing of New Fuel Cladding Materials

For the subject amendment application, Section 2.2.1.8 expands the scope of cladding materials that received tensile testing to derive measured values for total strain energy absorption capacity. The new tensile test data and associated calculations of measured strain energy absorption include Alloy 1 with the chromium coating, Alloy 1 with the OZL liner, Alloy 2 with the chromium coating, annealed Type 304 stainless steel, and Type 5052 aluminum alloy. For these cases, the application reports measured stress-strain data and associated strain energy absorption calculations. The reported data show that Alloys 1 and 2 with the chromium coating, Alloy 1 with OZL liner, annealed Type 304 stainless steel, and Type 5052 aluminum alloy have greater strain energy absorption capacity based on tensile tests when compared to the Standard Zirconium Alloy that was used for the HAC 30-foot package drop test.

For new cladding materials, the NRC staff reviewed the applicant's reported values for the total strain energy absorption by verifying the applicant's calculation of the area under the measured stress-strain curve up the point of tensile failure. The staff noted that the area under the stress-strain curve up to failure is a valid and well-established method for assessing the total elastic and plastic strain energy absorption capability of a material under uniaxial tensile loading. The staff confirmed that the reported strain energy absorption values are valid based on the measured stress-strain curves that were reported from the tensile tests of the new materials. On this basis, the staff determined that the new cladding materials show better strain energy absorption capability in comparison to the Standard Zirconium Alloy cladding that was used for the 30-foot package drop test.

For the new non-weld bonding method that may be used to join the end plugs to aluminum alloy cladding tubes for loose fuel rods, the applicant provided an analysis to demonstrate that the bonded end plug joints are capable of maintaining their integrity during the HAC 30-foot package drop test. The NRC staff reviewed this information and confirmed that the strength of the new non-weld bonded joint is sufficient to ensure that the fuel rod end plug joint will maintain its structural integrity during the 30-foot drop test.

Based on the foregoing evaluation, the NRC staff finds that the applicant's reported test data and analyses addressing the structural properties and performance of the new fuel cladding materials are acceptable for demonstrating adequate package performance for NCT and HAC.

Thermal Properties of Fresh Fuel Cladding

Section 3.2.1 of the application addresses the thermal properties of the Traveller package materials, which are used for the evaluation of package thermal performance for NCT and HAC. For the subject amendment application, Section 3.2.1 includes a new subsection (Section 3.2.1.1) addressing the thermal properties of new cladding materials and an evaluation of their impact on the package thermal performance.

Since the Standard Zirconium Alloy was used for the HAC fire test of package, the application evaluates the potential for the chromium coating to affect the thermal performance of chromium-coated zirconium alloy claddings at elevated temperatures. As demonstrated in the prior approved application (Revision 1), the maximum measured cladding temperature of 104 °C from the HAC fire test is well below the melting temperature of zirconium alloy claddings.

For the new chromium-coated zirconium alloy cladding, the application demonstrates that any potential localized intermixing of chromium and zirconium at the interface would not have an adverse effect on potential for melting since any localized lowering of the melting temperature caused by localized intermixing (i.e., formation of a eutectic) at the interface would be insignificant. The NRC staff reviewed the minimum eutectic melting temperature from the binary zirconium-chromium phase equilibrium diagram and confirmed that any potential lowering of the melting temperature caused by localized intermixing at the chromium/zirconium interface is of no concern for package fire test performance given the large margin between the lowest eutectic melting temperature for a zirconium-chromium mixture and the highest measured fire test temperature for the cladding.

The amendment application also reports and evaluates new cladding burst test data for the Standard Zirconium Alloy, the Alloy 1, and the chromium-coated Alloy 1. The application noted that the data shows that the chromium coating does not have an adverse impact on cladding burst test performance at elevated temperatures. The NRC staff reviewed the new burst test data and determined that it provides an acceptable demonstration that the chromium coating would not adversely affect the thermal performance of the base zirconium alloy claddings in the package under HAC fire test conditions.

The amendment application also evaluates the potential impact of the OZL liner on thermal performance and explains how the OZL-lined zirconium alloy cladding tube is expected to perform thermally the same as the fire-tested Standard Zirconium Alloy cladding tube. The staff reviewed this information and noted that that the OZL liner and base zirconium alloy claddings have the same thermal properties. Further, since the minimum allowable base cladding thickness without the liner was used for the package fire test and the associated thermal evaluations for NCT and HAC, the OZL liner would not be expected to adversely affect the thermal performance of the zirconium alloy claddings in the package for NCT and HAC.

The amendment application evaluates the expected HAC fire test performance of the new stainless steel and aluminum alloy cladding tube options for Traveller STD/XL packages containing loose fuel rods in a rod pipe. The application also evaluates the expected fire test performance of the new non-weld bonding method for joining the end plugs to the aluminum alloy cladding tubes.

The staff reviewed this information and noted that the maximum measured cladding temperature of 104 °C from the HAC fire test is well below the melting temperature of stainless steel and aluminum alloy, and it is also lower than the specified maximum service temperature for the bonded end plug joints. Therefore, the staff determined that the new stainless steel and aluminum alloy cladding tubes and the new non-weld bonded end plug joints are suitable for ensuring that the thermal performance of the package would be acceptable during the HAC fire test.

Based on its foregoing review of the applicant's evaluation of the thermal properties and expected HAC fire test performance of the new cladding materials, the NRC staff determined that the new cladding materials would not be expected to have any adverse impact on the thermal performance of the Traveller STD/XL package for NCT and HAC. Accordingly, the staff finds that applicant's thermal evaluation of the new cladding materials is acceptable.

Fresh Fuel Cladding Corrosion Resistance and Content Reactions

Section 2.2.1.8.3 of the amendment application addresses changes to fuel cladding materials and associated evaluations of their potential impact on corrosion resistance (including galvanic effects) and content reactions. For the OZL liner, which is bonded to the interior surface of the zirconium alloy cladding tube, the application notes that the chemically similar bonded materials do not form a galvanic couple. The staff confirmed that the bonding of the OZL liner onto the interior surface of the zirconium alloy cladding tube would have no adverse effect on corrosion resistance or susceptibility to undesirable chemical reactions with the fuel inside the cladding tube because these materials are electrochemically similar.

The application notes that the chromium coating, which is applied to the exterior surface of the zirconium alloy cladding, is also expected to be unreactive when in contact with zirconium alloy base cladding and other package components. The application documented corrosion testing for demonstrating that chromium coating would not adversely affect the susceptibility of zirconium alloy base cladding to undesirable chemical or galvanic reactions during transport conditions.

The staff reviewed this information and confirmed that the passivity of chromium (formation of a durable protective oxide surface layer) in ambient air environments would preclude any likelihood of the chromium coating causing any undesirable corrosive, galvanic, or chemical reactions with zirconium alloy base cladding or other package components when exposed to the package transport environment.

The application also identified that the manufacturing process for the chromium-coated zirconium alloy cladding follows the Westinghouse quality control program, and as part of the product specification, process chemistry is controlled for select elements including hydrogen. The application notes that the chemical content is controlled and testing is performed to ensure that cladding mechanical properties are not adversely altered by the chromium coating process.

The staff reviewed this information and determined that the applicant's identification of chemistry controls and product testing is sufficient to conclude that the manufacturing process for the chromium-coated cladding will not result in the uptake of undesirable chemical species that could adversely affect the mechanical properties of the zirconium alloy cladding.

The staff noted that the application did not address chemical reactivity, galvanic, or corrosion performance of the new stainless steel and aluminum alloy cladding options for loose fuel rods carried in a rod pipe. Based on the guidance in NUREG-2216 Section 7.4.10.2, staff determined that 304 stainless steel and 5052 aluminum alloy claddings may reasonably be expected to not undergo adverse corrosive, galvanic, or chemical reactions with the fuel or with other package components in the transport environment. The staff's determination is based on the fact that stainless steel and aluminum alloys form an oxide film that will impede any such reactions. Further, all loose fuel rods may be individually wrapped in a protective polyethylene sleeve, which provides additional protection against such reactions. Also, the packaging Outerpack and Clamshell are designed to provide adequate protection against the in-leakage of water and dissolved compounds due to weather and debris, thereby protecting loose fuel rods from the formation of a chemically reactive or corrosive environment inside the rod pipe.

Based on its foregoing review of the corrosion resistance, galvanic, and chemical properties of the new ATF cladding features, the NRC staff finds that the application provided an acceptable demonstration that the new cladding features are not expected to reduce corrosion resistance or cause undesirable chemical reactions for package components in the transport environment.

2.2.4 Radiation Shielding and Radiation Effects on Materials

Chapter 5 of the application addresses the radiation shielding evaluation for the Traveller Type B package. The subject amendment application addresses the impact of the increase in U-235 enrichment on radiation shielding performance. The NRC staff reviewed this information and confirmed that the package materials that are evaluated and credited for radiation shielding will continue to be acceptable for performing this function to meet external dose rate requirements. Given the relatively low dose rates for the fresh fuel contents, the staff also determined that the radiation effects of the increase in U-235 enrichment will not have any adverse effect on any other properties for package materials that are relied upon for demonstrating acceptable structural, thermal, and criticality safety performance.

2.2.5 Criticality Control

Section 6.3.2 of the amendment application addresses the changes to the material properties that are used as inputs into the criticality evaluation. The NRC staff's review of the material property changes associated with the new ATF contents follows below.

The application's description of the material properties for the criticality evaluation addressed the new ATF features for the UO_2 fuel contents to include increases in the maximum allowable enrichments from 5 wt.% ^{235}U to 6 wt.% ^{235}U for PWR fuel assemblies, and from 5 wt.% ^{235}U to 7 wt.% ^{235}U for loose PWR or BWR fuel rods in a rod pipe. The application also addressed the properties of the new ADOPT™ UO_2 fuels, which are doped with Cr_2O_3 and Al_2O_3. The staff's material properties review of the new UO_2 fuel features confirmed that the new UO_2 fuel contents is adequately described and, considering the NRC staff's detailed criticality safety review in Chapter 6 of this SER, the changes to the UO_2 fuel will not have an unacceptable impact on the criticality safety performance of existing neutron absorber materials. The new UO_2 fuel material properties are incorporated into the application's modeling and simulation of criticality safety for the package. The NRC's detailed review of the application's modeling and simulation of criticality safety for the new ADOPT™ UO_2 fuel and the higher U-235 enrichments for NCT and HAC is documented in Chapter 6 of this SER.

The NRC staff's materials review for the criticality evaluation addressed the changes to the fuel rod cladding features, including the new options for the zirconium alloy claddings to incorporate the external chromium coating and/or the OZL inner liner, as well as the new options for the use of stainless steel or aluminum alloy claddings for loose fuel rods. The previously approved application (Revision 1) identifies that the criticality modeling of the PWR fuel assembly packages used the minimum required zirconium alloy cladding thickness.

The subject amendment application states that the addition of the chromium coating and/or OZL liner to the base zirconium alloy claddings for PWR fuel assemblies will have a negligible effect on system reactivity through the removal of moderation and the presence of neutron absorbing materials (i.e., a very small but slightly favorable impact on criticality safety). The application also stated that these advanced cladding features are in addition to the base zirconium alloy cladding and may not be credited in the minimum cladding thickness requirement, which is used in the criticality modeling. The NRC staff reviewed this information and found the applicant's evaluation of the impact of new chromium coating and OZL liner on the criticality safety analyses to be acceptable since the addition of these materials to the existing base zirconium alloy cladding would have a very small (albeit slightly favorable) impact on the overall criticality safety analyses of the package.

In considering the new stainless steel and aluminum alloy cladding options for loose fuel rods carried in a rod pipe, the staff noted that, per the previously approved application (Revision 1), the cladding material for loose fuel rods is not included in the criticality safety model for the loose fuel rod package. The loose fuel rods are modeled as continuous cylinders of UO_2 fuel without cladding material for all normal operating and accident conditions.

The staff noted that this is conservative from a criticality safety modeling perspective since it includes more water (in place of cladding) for neutron moderation under flooded conditions, and it removes any potential neutron absorption in the cladding material. Therefore, the staff determined that the change to use a stainless steel or aluminum alloy cladding option for loose fuel rods will not have any adverse impact on the criticality safety modeling for the loose fuel rod package.

Based on the foregoing review, the staff finds the applicant's evaluation of the impact of the new cladding materials on the criticality safety modeling of the package to be acceptable. As requested by the applicant, only the changes associated with Revision 1 of the certificate, and the associated SAR Revisions 2 and 2A, were reviewed for the Joint United States – Canada process for package approval and validation, in accordance with NUREG-1886. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

Evaluation Findings

- The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.33. The applicant described the materials used in the transportation package in sufficient detail to support the staff's evaluation. In addition, the changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraphs 501 and 502.

- The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.31(c). 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. In addition, the changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraph 640.

- 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). The applicant demonstrated effective materials performance of packaging components under normal conditions of transport and hypothetical accident conditions. In addition, the changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraphs 507, 614, 639, and 679.

- The staff has reviewed the package and concludes that the applicant has met the requirements of 10 CFR 71.43(d). 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 changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraphs 507 and 614.

- 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) for Type B packages and 10 CFR 71.55(d)(2) for fissile packages. 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 normal conditions of transport. In addition, the changes made for this amendment request satisfy the requirements of IAEA SSR-6 paragraphs 507, 614, 639, and 679.

3.0 THERMAL EVALUATION

Section 3.2.1, Material Properties, and Table 3.2-2 were updated to include Uranium Silicide (U_3Si_2) and Aluminum alloy thermal properties. A section on cladding materials was added to address thermal comparison of advanced cladding variations including cladding treated with a chromium coating, Optimized ZIRLO Liner, and stainless steel and aluminum cladding.

The staff confirms that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

4.0 CONTAINMENT EVALUATION

The containment evaluation was not changed in this amendment request. The package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71, and that the package meets the containment criteria of ANSI N14.5-2014.

The staff confirms that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

5.0 SHIELDING EVALUATION

Westinghouse (the applicant) submitted an application for an amendment to the Traveller STD and Traveller XL PWR fuel shipping package (Traveller), Docket No. 71-9380 Type B(U)F certificate of compliance (CoC). The current CoC, Rev. 0, was issued on November 7, 2019.

The application for the revised CoC requests new contents for accident tolerant fuels (ATF) with increased enrichment. The proposed contents consist only of unirradiated uranium, however 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 are authorized to be shipped as long as they are within the limits shown in Table 1-2 of the application. This is a condition of Section 5(c)(1)(i) of the CoC.

Unirradiated fuel does not have a significant source term that would challenge any of the dose rate limits in 10 CFR 71.47(b) or 10 CFR 71.51(a)(2). The applicant has not proposed to change the contaminant levels as previously authorized, and there are no changes to the design that would significantly decrease the shielding performance of the package. Therefore, the staff found that the previous evaluation, documented in the staff's safety evaluation report supporting Rev. 0 of this CoC, is still applicable with the proposed revisions in Rev. 1.

The staff confirms that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

6.0 CRITICALITY EVALUATION

The applicant requested to modify the Certificate of Compliance (CoC) for the Model No. Traveller package to authorize fuel with accident tolerant fuel (ATF) features, including coated cladding and doped pellets, loose rods enriched up to 7.0 weight percent in ^{235}U (wt%), and pressurized water reactor (PWR) fuel assemblies enriched up to 6.0 wt% as allowable package contents. The applicant also 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 changes pertaining to this amendment request 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."

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 uranium oxide (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 and/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 Groups 1, 2, and 4 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 Groups 1, 2, and 4 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 uranium silicide (U_3Si_2) loose rods.

The results of the single package sensitivity studies for ADOPT rods are included in Table 6-31A of the SAR for a fuel assembly under normal conditions of transport (NCT), Table 6-38A of the SAR for a fuel assembly under hypothetical accident conditions (HAC), Table 6-43A of the SAR for a rod pipe under NCT, and Table 6-48A of the SAR for a rod pipe under HAC. The results of the array sensitivity studies for ADOPT rods are included in Table 6-61A of the SAR for fuel assemblies under NCT, Table 6-67A of the SAR for the rod pipe under NCT, Table 6-82A of the SAR for fuel assemblies under HAC, and Table 6-90A 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 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 ^{235}U. 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}, reported in Table 6-72 of the SAR for the HAC array of 150 packages containing loose UO_2 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 array size demonstrated by the applicant to be subcritical corresponds to the requested criticality safety index (CSI) of 0.7.

The applicant revised the criticality analysis to consider the addition of Group 4 fuel assemblies as allowable contents for the Traveller package. Group 4 fuel assemblies are limited to the physical characteristics described in Tables 6-8A and 6-8B of the SAR, with the fuel rod patterns shown in Figures 6-5A and 6-5B of the SAR. Group 4 fuel assemblies consist of zirconium clad rods with UO_2 pellets enriched up to a maximum of 6.0 weight percent U-235. The cladding may include a chromium coating or an OZL, and the UO_2 pellets may consist of ADOPT fuel material.

The applicant modeled the Traveller packaging and the Group 4 PWR fuel contents similar to previously approved analyses for Groups 1 and 2 fuel assemblies, with two exceptions: 1) the applicant did not model fuel rod lattice expansion under HAC; and 2) the applicant did not perform uniform polyethylene melt and collected polyethylene melt studies under HAC. These deviations from previous analyses are acceptable to the staff because: 1) package testing in

Section 2.7.1.4 demonstrated no significant assembly deformation or fuel rod lattice expansion; and 2) the applicant's thermal analysis demonstrated that package internal temperatures remain below polyethylene melt temperatures.

The applicant performed baseline analyses and all sensitivity analyses relevant to the Group 4 fuel assemblies 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}, reported in Table 6-72 of the SAR for the HAC array of 40 packages containing Group 4 fuel assemblies, was 0.93943, including the calculation Monte Carlo uncertainty and the sum of penalties assessed for each sensitivity study. The maximum system k_{eff} is less than the applicant's calculated USL of 0.94082. The array size demonstrated by the applicant to be subcritical corresponds to the requested criticality safety index (CSI) of 2.5.

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 and 6.0 weight percent Group 4 fuel assembly 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 UO_2 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 6-91 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. For the 6.0 weight percent Group 4 fuel assembly contents, the USL function gives a USL of 0.94082. 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 performed confirmatory calculations using the SCALE 6.2.3 Monte Carlo radiation transport code, with the CSAS6 criticality sequence and the continuous-energy ENDF/B-VII.1 neutron cross section library. The staff's confirmatory analyses consisted of models of the arrays of packages under HAC, as this was the most reactive configuration identified by the applicant. 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 ^{235}U in the rod pipe and 6.0 weight percent ^{235}U Group 4 fuel assemblies. The staff used the TSUNAMI sequence of the SCALE 6.2.4 code package, with the ENDF/B-VII.1 252-group cross section library, to independently select experiments with high integral index (c_k) 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 c_k values, and benchmark experiments with high similarity were then used to determine a USL. The SDFs used are from Oak Ridge National Laboratory's VALID library of benchmark cases.

The staff then used the Validation and Data Evaluation Resource (VADER) tool within SCALE 6.3b16 to determine a set of independent USLs using varying statistical methods. These methods included those available in NUREG/CR-6698 (Guide for Validation of Nuclear Criticality Safety Calculational Methodology), NUREG/CR-6361 (Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages), and the parametric and non-parametric estimates available in the SCALE USLSTATS tool. Using these four different methods, and trending on c_k, EALF, and enrichment, the staff determined 12 independent USLs for the Traveller package. All of these USLs were greater than the applicant's USLs for loose UO_2 rods enriched to 7.0 weight percent ^{235}U in the rod pipe and 6.0 weight percent ^{235}U Group 4 fuel assemblies, indicating that the USL determined by the applicant is conservative.

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 of IAEA SSR-6 for the changes pertaining to this amendment request. The staff confirms that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

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

The operating procedures were not modified by this amendment request. A unit conversion error was corrected in Sections 7.1.2.1 and 7.1.2.2.

8.0 ACCEPTANCE TESTS AND MAINTENANCE

The application includes several changes to the inspection criteria for Traveller package components.

For the post-fabrication acceptance tests of Traveller packaging welds, there is a change to the cited Editions and Addenda of the ASME BPVC, Section III, upon which the weld nondestructive examination (NDE) procedures and associated NDE acceptance criteria are based. Whereas previously, the application cited and referenced just the 2001 Edition with 2003 Addenda of the ASME BPVC, Section III, Division 1 for the packaging weld inspections per Code Article NF-5000, the proposed change would allow for later ASME BPVC Editions and Addenda to be used for these inspections, subject to approval by the engineering department. The staff reviewed this proposed change and noted that NUREG-2216, Section 2.4.1.2, “Identification of codes and standards for package design,” states (in part) that the NRC may accept (as part of its review and approval for the package application) the use of the most recent code year for the design of shipping packages for new applications. This section of NUREG-2216 also cites the provisions of the ASME BPVC, Section III, Division 1, Paragraph NCA-1140 governing the use of Division 1 Code Editions and Addenda that may be applied to both new applications and amendments.

The staff noted that NCA-1140(b) provides that Code Editions and Addenda later than those previously established by the Owner or his designee for inclusion in the Design Specifications in accordance with NCA-1140(a), including any referenced Code Edition and Addenda, may be used by mutual consent of the Owner or his designee and Certificate Holder. The NRC staff determined that this provision provides an adequate basis for the use of later Editions and Addenda of the ASME BPVC Section III, Division 1 for post-fabrication inspections of the Traveller packaging welds per Code Article NF-5000, provided that such a change is made in accordance with the NRC-approved QA program.

The NRC staff also compared the 2001 Edition of Code Article NF-5000 to the later Editions up through Calendar Year 2021 and noted these examination requirements are generally unchanged and have remained adequate for ensuring the integrity of Subsection NF support welds, as previously approved for the Traveller packaging welds. On this basis, the staff determined that the applicant’s proposal to allow for the use of later Code Editions and Addenda for the packaging weld inspections, subject to approval by the engineering department, is acceptable.

As part of the package maintenance program, the application includes new criteria for periodic visual examinations of the structural welds in the packaging Outerpack and Clamshell assemblies and periodic visual examinations of packaging Outerpack acetate plugs. The staff noted that criteria for periodic examination of these items were not included in the prior approved version of the application (Revision 1); hence they represent an enhancement to the maintenance program for the Traveller package relative to what the NRC previously approved. Both new sets of periodic examinations are specified to occur on an inspection interval that is not to exceed every two years. For the periodic visual inspections of the Outerpack and

Clamshell structural welds, the application specifies the ASME BPVC, Section III, Article NF-5000 requirements applicable to the performance of these visual examinations.

The NRC staff reviewed these inspection criteria and found them acceptable because these ASME BPVC requirements provide the appropriate level of rigor and detail for the visual examination methods and techniques and for the associated flaw evaluation criteria and acceptance standards. For the periodic visual inspections of the Outerpack acetate plugs, the application does not cite any ASME BPVC provision or other published consensus standard, but it specifies sufficiently detailed visual examination acceptance criteria for determining the continued functionality of the acetate plugs during package maintenance activities.

The NRC reviewed the acetate plug visual acceptance criteria and found them acceptable for providing reasonable assurance that the acetate plugs will continue to perform their design functions during the service life of the package. Based on the foregoing review of these inspection criteria, the staff finds these enhancements to the Traveller package maintenance program to be acceptable.

Section 8.2.3.2 was also revised to properly characterize the weather “seal” as weather “gasket”.

CONDITIONS

The following Conditions are included in the certificate:

Item No. 3(b) was updated to reference the Revision No. 2 of the application, as supplemented by Revision No. 2A

Condition No. 5(a)(2) was revised to allow for slightly contaminated uranium fuel assemblies with enrichment up to 6.0 weight percent or rods with enrichment up to 7.0 weight percent as authorized contents of the package.

Condition No. 5(a)(3) was revised to include the latest revisions of the licensing drawings10071E36, Rev. 4 (sheets 1-9) and 10006E58, Rev. 7.

Condition No. 5(b)(1)(iii) was revised to include cladding with a chromium coating of 25 μm thick and/or an Optimized ZIRLO Liner (OZL).

Condition No. 5(b)(1)(ix) was revised to allow fuel rods with ADOPT uranium dioxide pellets that are doped with up to 700 ppm Cr_2O_3 and up to 200 ppm Al_2O_3 in any location of the fuel assembly.

Condition No. 5(b)(2)(iii) was revised to include cladding with a chromium coating of 25 μm thick and/or an Optimized ZIRLO Liner (OZL).

Condition No. 5(b)(2)(ix) was revised to allow fuel rods with ADOPT uranium dioxide pellets that are doped with up to 700 ppm Cr_2O_3 and up to 200 ppm Al_2O_3 in any location of the fuel assembly.

Condition No. 5(b)(3) for the PWR group 4 Fuel Assembly is entirely new. All subsequent conditions (b)(3) and b(4) were renumbered (b)(4) and (b)(5) respectively/

Condition No. 5(b)(4) for fuel rods with a maximum ^{235}U enrichment of 7.0 weight percent, and an isotopic composition not exceeding a Type A quantity, was revised to include rods with ADOPT uranium dioxide pellets that are doped with up to 700 ppm Cr_2O_3 and up to 200 ppm Al_2O_3. The definition of the cladding material and the integral absorber was also modified.

Condition No. 5(b)(5) was modified to include Zirconium, aluminum, or stainless steel alloy for the cladding. Also, zirconium alloy cladding may include a chromium coating of 25 μm thick, and/or an Optimized ZIRLO Liner (OZL).

Condition No. 5(c)(1) was revised to include PWR fuel assemblies as described in 5(b)(1), 5(b)(2) and 5(b)(3) that can be transported as Type B quantities.

Condition No. 5(c)(2) was revised to PWR fuel assemblies as described in 5(b)(1), 5(b)(2) and 5(b)(3) and Loose rods in the rod pipe as described in 5(b)(4) and 5(b)(5) that can be transported as Type A quantities.

Condition No. 5(d) was revised to add the new CSI of 2.5 when transporting Group 4 PWR fuel assemblies, and of 0.7 when transporting loose rods in the rod pipe as described in 5.(b)(4) and 5.(b)(5).

A new Condition No. 9 was added to authorize the use of the previous certificate for approximately one more year.

Condition No. 10 (previously numbered 9) shows the new expiration date of the certificate in line with the renewal request received by letter dated March 11, 2022.

The references section of the certificate was updated to include (1) the Safety Analysis Report, Revision No. 2A - Application for Certificate of Compliance for the Traveller PWR Fuel Shipping Package, NRC Certificate of Compliance USA/9380/B(U)F-96, (2) the Revision Request Letter dated August 2, 2021, and the CoC renewal request letter dated March 11, 2022.

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 and Traveller XL packages meet the requirements of 10 CFR Part 71. The changes requested in this amendment also meet the guidance on format and content in NUREG-1886 for joint approval in Canada. The staff confirms that these changes comply with the requirements of IAEA SSR-6. However, the NRC staff cannot conclude whether the Westinghouse Traveller package, as a whole, meets the requirements of IAEA SSR-6, and the staff's evaluation findings regarding IAEA SSR-6 apply only to the changes in this amendment.

Issued with CoC No. 9380, Revision No. 1.