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September 6, 2018

Subject: Special Package Authorization Request for One-time Shipment - USA/9297/AF-96 for Model No. Traveller STD, XL, and VVER Packages

References: (1) Certificate of Compliance USA/9297/AF-96, Rev. 10

Dear Director,

Westinghouse hereby requests a special package authorization for transport of two accident tolerant fuel (ATF) fuel assemblies, defined below, within the Traveller package for a shipment authorization from February 1, 2019 through April 1, 2019. The request details the modification of the contents from that described in the current approval [Reference 1], and there is no modification to the packaging.

The two types of ATF designs included for this special authorization are U_3Si_2 pellets and Advanced Doped Pellet Technology (ADOPT) pellets. These ATF pellet types are stacked in separate lead test rods (LTRs) on the periphery of an assembly and arranged in separate lead test assemblies (LTA). For the special authorization, LTA1 includes only U_3Si_2 rods and LTA2 includes only ADOPT rods. Additionally, some periphery rods in both LTAs have a chromium coating on the rod cladding. Both LTAs are the standard 17x17 OFA design. Fuel type 17x17 OFA falls under the Traveller licensed categorized fuel assembly (CFA) 17 Bin 1, per CoC Rev. 10 Section 5.(b)(1)(i) [Reference 1]. Appendix A documents the assessment for the Traveller criticality safety analysis and structural comparison to determine the effect of replacing standard UO_2 rods with ATF test rods.

<u>Certificate Deviation</u>

As there are no changes to the packaging, there are no deviations from the following CoC Rev. 10 sections:

- CoC Section 5.(a): Package description, weights and dimensions
- CoC Section 5.(b)(2), (3), (4), and (5): Contents not applicable
- CoC Section 5.(c): Criticality Safety Indices
- CoC Section 6.: Operations, Acceptance Tests, and Maintenance

Based on the analyses documented in Appendix A, the suggested wording for the special authorization letter is as follows:

Contents under the special authorization include two lead test assembly types of a standard 17x17 OFA design, meeting specifications of the PWR Group 1 Fuel Assembly, specifically 17 Bin 1, as outlined in Section 5.(b)(1) in Revision 10 of the Traveller CoC with the following deviations:

(1) *Fuel assembly cladding on any rod in a periphery location of the fuel assembly may include a Chromium coating up to 30 μm thick.*
(2) *One fuel assembly type may have the UO_2 pellets in any fuel rod on the periphery of the fuel assembly replaced with solid Zircaloy bars and encapsulated U_3Si_2 pellets meeting the following specifications:*
    a. *Maximum density – 12.2 g/cm^3*
    b. *Maximum Enrichment – 5 wt% U-235*
    c. *Minimum Pellet Diameter – [ ]^{a,c}*
(3) *One fuel assembly type may have the UO_2 pellets in any fuel rod on the periphery of the fuel assembly include a Cr_2O_3 concentration up to 700 ppm and an Al_2O_3 concentration up to 200 ppm.*
(4) *Items (2) and (3) may not be combined in a single fuel assembly*

Request

Westinghouse requests a special package authorization for transport of ATF within the Traveller package by February 1, 2019 to allow for shipment planning and notifications from February 1, 2019 through April 1, 2019. Contents are defined above, per evaluations documented in Appendix A.

Westinghouse has a quality assurance program, approved by the Commission, that satisfies the provisions of Subpart H (Quality Assurance) of Part 71. Further, Westinghouse complies with the terms and conditions of the applicable requirements of Subparts A (General Provisions), G (Operating Controls and Procedures), and H (Quality Assurance) of Part 71.

One copy of the special package authorization request is submitted electronically via EIE system and emailed to the prior Project Manager, Pierre Saverot. Additional electronic or hard copy submissions are available upon request. Should you have any questions, or require additional information, please contact one of the additional contacts below.

Best regards,

Wes Stilwell
Global Packaging and Regulatory Compliance Manager
Westinghouse Electric Company LLC

cc:

T. Grange, Westinghouse-UK
P. Saverot, NRC

Appendix A: Traveller (USA/9297/AF-96) Safety Assessment for ATF Special Authorization

1 Overview / Summary

For this special authorization, there are no changes to the Traveller packaging or any operational/ maintenance deviations from what is outlined in the Traveller SAR. The deviation from the Traveller CoC requested in this special authorization is specific to slight changes to rods on the periphery of the LTAs transported in the Traveller. The LTAs for this special authorization are of the standard 17x17 OFA design with the ATF LTRs replacing typical UO_2 rods in the periphery (i.e. outermost row) of the fuel assembly. Thus, for the Traveller Criticality Safety Analysis (CSA), the LTA assemblies fall under the Traveller licensed CFA 17 Bin 1, per SAR Section 6.2.1 (and under CoC Section 5.(b)(1)(i)).

This special authorization covers the transport of two fuel assemblies, labeled LTA1 and LTA2. The rod patterns of these two assemblies are shown in Figure 1 and Figure 2, below. Both LTA1 and LTA2 include rods in the periphery of the assembly that are standard UO_2 fuel rods with a 20-30 μm thick chromium spray-on coating on the fuel cladding. LTA1 has four locations in the periphery of the assembly where the standard UO_2 rods are replaced by U_3Si_2 rods with the following specification:

> Standard cladding filled with Zircaloy bars and encapsulated U_3Si_2 pellets with:
> a. Maximum density – 12.2 g/cm^3
> b. Maximum Enrichment – 5 wt% U-235
> c. Minimum Pellet Diameter – [ ]^{a,c}

LTA2 has four locations in the periphery of the assembly where the standard UO_2 rods are replaced by ADOPT rods with the following specification:

> Standard cladding with a chromium spray-on coating filled with UO_2 pellets with a Cr_2O_3 concentration up to 700 ppm and an Al_2O_3 concentration up to 200 ppm.

The mechanical assessment for the effect of the chromium spray-on coating is provided in Section 2 of this Appendix. In this section, it is determined that the chromium spray-on coating has a negligible effect on the mechanical properties of the fuel cladding and does not compromise the ability of the cladding to retain the fissile material in the configurations analyzed in the criticality analysis.

A criticality assessment for the effect of replacing rods on the periphery of a fuel assembly with LTRs of the specifications provided below is provided in Section 3 of this Appendix. In the criticality assessment, bounding parameters (extended fuel length and additional peripheral rod locations) are analyzed to show the effects on system reactivity of replacing standard UO_2 rods on the periphery of an assembly with these LTRs. Additionally, the bounding analysis allows for the simplification of the wording in, and requirements imposed for, the special authorization. Based on the assessment in Section 3, it is demonstrated that the LTAs covered by this special authorization request are bounded by the CSA in Section 6 of the Traveller SAR. All deviations from the CSA in the SAR for the LTAs result in a reduction in k_{eff} or a result that is effectively statistically identical.

2 Mechanical / Structural Assessment

The current Traveller SAR justifies that "Standard Zirconium Alloy" fuel cladding is the bounding fuel cladding since it possesses the lowest strain energy absorption capability of all the current fuel cladding licensed. Table 2-61 in the SAR provides relative global fuel cladding fuel rod strain energy absorption values based upon specification minimum values (including minimum elongation) of multiple Zirconium alloys. The Zirconium alloy used for the fuel in the LTAs falls under "Alloy 1" in SAR Table 2-61, and thus, is bounded by Standard Zirconium Alloy cladding, which is already covered by the current Traveller license and is used for typical shipments of fuel in the Traveller package.

It is noted that the fuel cladding will be coated with sprayed-on chromium approximately the full length of the rod and 20-30 microns thick. While the coating may superficially lower the tensile properties below the Alloy 1 cladding specification minimum, the energy absorbing capability margin between Alloy 1 and Standard Zirconium Alloy as shown in Table 2-61 will not be significantly degraded. The energy absorbing characteristics are driven by base cladding absorption capability, because the 9-meter impact test is a high strain rate event. This event is global in nature and the surface coatings are considered negligible with respect to energy absorption after a 9-meter free drop. Therefore, the fuel rod cladding of the ATF LTA fuel rods is bounded by the cladding in the current Traveller license application with respect to energy absorption capability up to failure.

From a thermal performance perspective, the zirconium based cladding thermal properties in the current Traveller SAR analysis are also based on standard zirconium alloy (Zircaloy 4), as described in Chapter 3, Section 3.2.1. The chromium coating does not affect the melt temperature or thermal performance of the base alloy and is not considered for any licensed cladding alloys.

3 Criticality Safety Assessment

3.1 Traveller SAR Results – 17 Bin 1

The LTAs for this special authorization are of the standard 17x17 OFA design with the ATF LTRs replacing UO_2 rods in the periphery (i.e. outermost row) of the fuel assembly. Thus, for the Traveller CSA, the LTA assemblies fall under the Traveller licensed CFA 17 Bin 1, per SAR Section 6.2.1. This analysis takes the baseline 17 Bin 1 case from the Traveller package array CSA documented in SAR Section 6.6 and documents an additional sensitivity study, where UO_2 rods in the assembly are replaced by LTRs. From the summary tables of the single package and package array analyses in the Traveller SAR (Table 6-26, Table 6-55, and Table 6-75), the *Maximum* k_{eff} values calculated for all Group 1 (CSI=1.0) single package and package array conditions are listed in Table 1. Table 1 shows that the HAC Package Array margin between the *Maximum* k_{eff} value and the USL is the smallest for all cases. Thus, it is considered that if the HAC Package Array *Maximum* k_{eff} value including any additional penalty from the sensitivity studies provided in this analysis is less than the USL, the effect on k_{eff} for any of the other cases would not be sufficient to result in the *Maximum* k_{eff} exceeding the USL, for the respective case. Therefore, only the HAC package array is analyzed for this additional sensitivity study.

Because this calculation provides an additional sensitivity study for the 17 Bin 1 HAC package array case, any resulting penalty from the study will be added on to the case *Maximum* k_{eff} value of 0.93824.

Table 1: Traveller CSA Results

Case	Transport Condition	SAR Results Table	Baseline $k_{eff} + 2\sigma$	Total Penalty	*Maximum* k_{eff}	USL	Margin
Single Package	NCT	Table 6-26	0.88617	0.03534	0.92151	0.93902	0.01751
	HAC	Table 6-26	0.90307	0.03177	0.93484	0.93902	0.00418
Package Array	NCT	Table 6-55	0.30942	0.00053	0.30995	0.94093	0.63098
	HAC	Table 6-75	0.92750	0.01074	0.93824	0.94093	0.00269

3.2 ATF LTA Designs

There are two types of LTRs: U_3Si_2 and ADOPT rods. These LTRs are placed into standard 17x17 OFA fuel assemblies as two separate LTAs. Figure 1 and Figure 2 show the rod patterns for LTA1 and LTA2, respectively. In the figures it is shown that in LTA1 there are four (4) U_3Si_2 rods on the periphery of the assembly and in LTA2 there are four (4) ADOPT rods on the periphery of the assembly. It can be noted from Figure 1 and Figure 2 that these fuel assemblies also include Integral Fuel Burnable Absorber (IFBA) rods and Cr Coated clad for UO_2 rods. Burnable absorbers are always conservatively neglected from the Traveller CSA because absorbing materials reduce system reactivity. The only change for Cr coated rod cladding is a 20-30 μm thick chromium layer applied for corrosion protection. Considering the slightly elevated absorption cross section and reduced scattering cross section of chromium, when comparted to hydrogen, any effect from the addition of a small chromium layer on the cladding would be a reduction in reactivity. These aspects of the LTAs are neglected as they would either result in a reduction or no significant effect on k_{eff} of the Traveller CSA. The Guide tube/Instrument tube (GT/IT) locations are modeled as empty cells that are flooded in HAC to neglect the additional material in the fuel assembly, consistent with the Traveller licensed CSA method (See SAR Section 6.3.2.5). With these considerations, the only change from a standard 17x17 OFA (17 Bin 1) assembly for the LTAs is the addition of the U_3Si_2 and ADOPT fuel rods, replacing standard UO_2 rods, on the periphery of the assemblies.

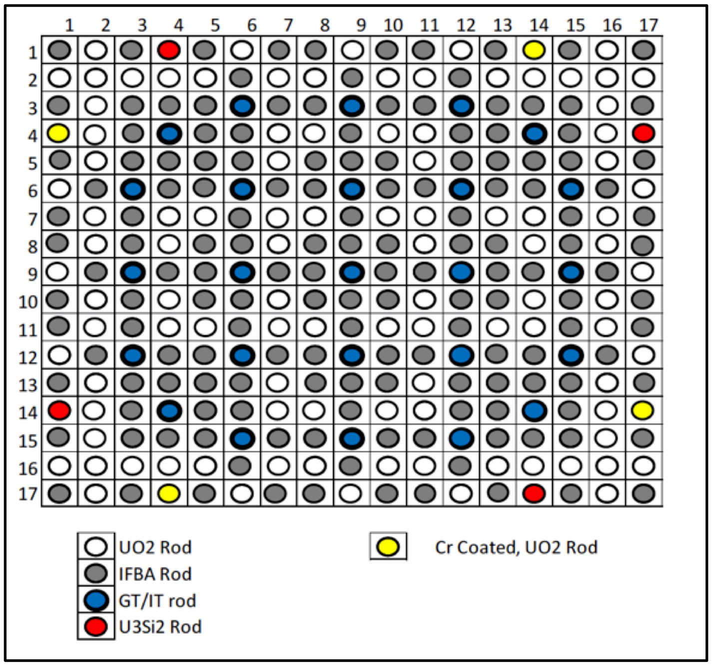
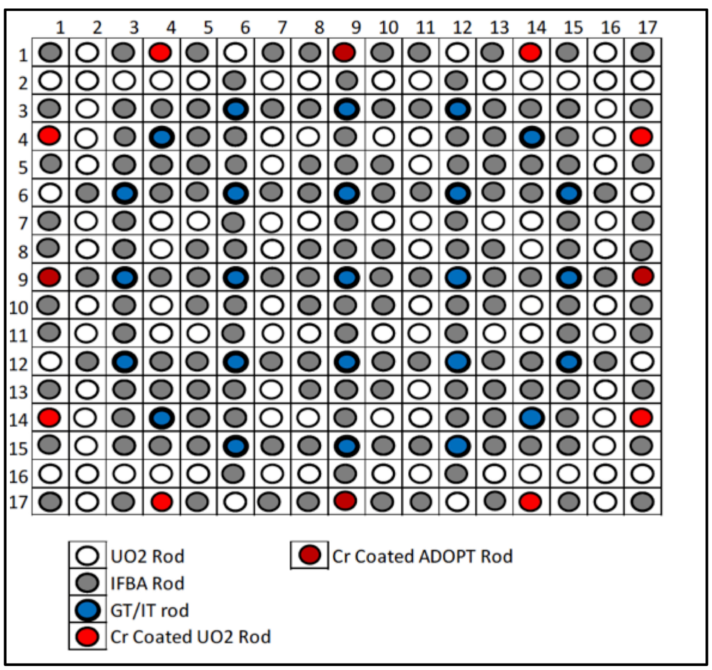


Figure 1: ATF LTA1 Rod Pattern



Note: ADOPT Rods are in positions (row-column): 9-1, 9-17, 1-9, 17-9

Figure 2: ATF LTA2 Rod Pattern

3.3 LTA1 Analysis (U_3Si_2 Rods)

The LTA1 U_3Si_2 rods present a significant deviation from the standard UO_2 rods in a typical 17x17 OFA design fuel assembly. The primary differences between the rods are the pellet composition and geometry, and the active fuel length. These differences are summarized in Table 2, which provides a comparison between these two rod types.

Table 2: Standard vs LTA Rod Comparison

Parameter	LTA1 U_3Si_2 Rod	17 Bin 1 Rod
Uranium Compound	U_3Si_2	UO_2
Pellet Theoretical Density (g/cm^3)	12.2	10.96
Uranium Enrichment (wt%)	3.20 - 4.95	5.0
Minimum Pellet Diameter [1] (inches)	[ ]^{a,c}	0.3076
Active Fuel Length (inches)	[ ]^{a,c}	144.5 [2]

Note: [1] Minimum diameter is nominal diameter minus permissible fabrication tolerance (See Figure 3).
[2] Includes the addition of maximum permissible fabrication tolerance.

From the comparison of the rods in Table 2, it can be noted that the U_3Si_2 pellets have a higher density than the standard UO_2 pellets. While the uranium enrichment of the U_3Si_2 pellets will nominally be some enrichment less than 5 wt%, the enrichment of the fuel in this sensitivity study is 5 wt% to be bounding. The pellet and rod geometry of the LTA1 U_3Si_2 rods are shown in Figure 3 and Figure 4, including the pellet diameter and active fuel length (i.e. pellet stack length) listed in Table 2. The minimum pellet diameter is slightly smaller in the U_3Si_2 rods than is permissible in a fuel assembly that falls under 17 Bin 1. This is due to the pellets being encapsulated in a smaller rod segment that is inserted into the LTR. It is demonstrated in the single package (See SAR Section 6.4.2.2.1) and package array (See SAR Sections 6.5.2.2.1 and 6.6.2.2.1) CSAs that the reactivity effect of fuel pellet diameter within the specified tolerance range is negligible for Group 1. Additionally, in the CFA analysis (SAR Section 6.9.2.6), it is determined that with a large enough change in fuel pellet diameter, reactivity increases as pellet diameter decreases. Consequently, only the minimum diameter (nominal minus tolerance) is analyzed in this report, as the reactivity effect of the pellet diameter tolerance is likely negligible but would only result in an increase in reactivity with a reduction in pellet diameter. Because the pellets are confined to this small rod segment, it is evident that the active fuel length of the LTA1 U_3Si_2 rods is significantly less than that of a standard 17 Bin 1 rod. In the full length LTA1 U_3Si_2 rod, on either end of the rod segment containing the U_3Si_2 pellets, are solid Zircaloy-4 bars to hold the segment in place axially. As in the Traveller CSA (Section 6.2), any dishing or chamfers on the fuel pellets is neglected, resulting in the pellet stack modeled as a single solid cylindrical rod.

The starting point for the LTA1 sensitivity study is the Group 1 (CSI=1.0) HAC Package Array baseline case (See SAR Section 6.6.1.1.1). This model bounds the standard 17x17 OFA assembly. For the sensitivity study, four cases are analyzed. The first pair of cases (True Length) model the baseline case with rods on the periphery of the fuel assembly replaced with LTRs that are similar in geometry to the actual segmented U_3Si_2 rod geometry, with a short pellet stack and Zircaloy-4 bars on either end. The second pair of cases (Full Length) model a U_3Si_2 LTR with a pellet stack equal to the full active fuel length of the rod. The 'True Length' and 'Full Length' rod geometries are shown in Figure 5. The overall height of both rod geometries is based on the 17 Bin 1 length (plus tolerance) of 144.5 inches.

For the HAC Package Array cases, all void space is considered flooded with water, thus the radial gap between the fuel and clad and the plenum above the pellet stack in the 'True Length' geometry are fully flooded. The two rod patterns considered are shown in Figure 6, which shows standard UO_2 rods in gray and U_3Si_2 rod positions in red. One of the patterns models the exact locations of the four U_3Si_2 rods in the LTA1 and the other models the entire periphery of the assembly as U_3Si_2 rods. The U_3Si_2 material pellet stack in each case consists of 12.2 g/cm^3 material at an enrichment of 5 wt% U-235 with a minimum pellet diameter of [ ][a,c] (See Table 2).

a,c

Figure 3: U_3Si_2 Pellet Dimensions

a,c

Figure 4: U_3Si_2 LTR Axial Dimensions

[ ]a,c

Figure 5: LTA1 Rod Geometries (Top – 'Full Length' / Bottom – 'True Length')

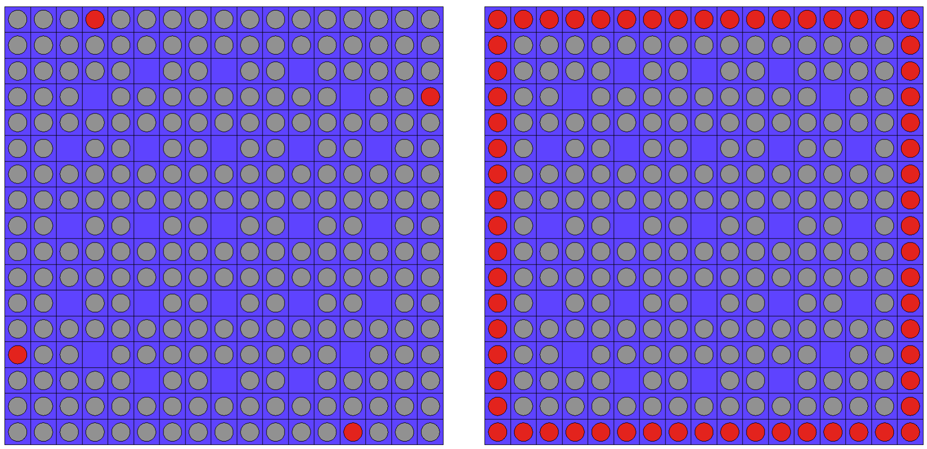


Figure 6: LTA1 Fuel Assembly Rod Patterns

The results of this LTA1 sensitivity analysis are presented in Table 3. The 'Full Length' cases and the cases with all rod positions around the periphery of the assembly replaced with U_3Si_2 rods are included so that the special authorization may allow for any rod on the periphery of the standard 17x17 OFA assembly (17 Bin 1) to be replaced by U_3Si_2 rods, at any pellet stack length. This provides flexibility for the possibility of small changes in the LTA1 design and simplification of the wording in the special authorization. The results of Table 3 demonstrate that the addition of the U_3Si_2 rods at the 'True Length' of the LTRs or at the 'Full Length' of a rod results in a decrease in k_{eff}.

Table 3: LTA1 - U_3Si_2 Rod Case SCALE Results

Case	Fuel Length (in)	Periphery U_3Si_2 Rod Positions	k_{eff}	σ	$k_{eff} + 2\sigma$	Δk_{eff}[1]
SAR Baseline Case	144.5	None	0.92688	0.00031	0.92750	-
4 Peripheral Rods (TL)	[ ]a,c	4	0.92399	0.00024	0.92447	-0.00303
All Peripheral Rods (TL)		All	0.88514	0.00026	0.88566	-0.04184
4 Peripheral Rods (FL)	144.5	4	0.92658	0.00025	0.92708	-0.00042
All Peripheral Rods (FL)		All	0.92282	0.00027	0.92336	-0.00414

Note: [1] Difference between $k_{eff}+2\sigma$ of the sensitivity study case and baseline case.

3.4 LTA2 Analysis (ADOPT Rods)

ADOPT rods are composed of a typical Zirconium Alloy cladding ("Alloy 1" in SAR Table 2-61) with a 20 to 30 µm thick chromium spray-on coating, filled with standard UO_2 pellets that are doped with up to 700 ppm Cr_2O_3 and 200 ppm Al_2O_3 powders. These small quantities of Cr_2O_3 and Al_2O_3 are added to the pellets to reduce the release of fission gases in the event of an accident. The density of ADOPT pellets is slightly higher than typical UO_2 pellets (97.4% vs 95.5% theoretical density). However, the Traveller CSA considers all UO_2 material at 100% theoretical density, bounding this increased density effect. The effect on reactivity from the oxide powder doping of standard UO_2 pellets is expected to be negligible or a slight reduction in reactivity due to the dilution of fissile material.

The starting point for the LTA1 sensitivity study is the Group 1 (CSI=1.0) HAC Package Array baseline case (See SAR Section 6.6.1.1.1). This model bounds the standard 17x17 OFA assembly. For the sensitivity study, two cases are analyzed as a confirmatory analysis to verify the negligible effect on k_{eff} of modeling ADOPT LTRs in the periphery of the assembly. The two rod patterns considered are shown in Figure 7, which shows standard UO_2 rods in gray and ADOPT rod positions in red. The left pattern models the exact locations of the four ADOPT rods in the LTA2 and the right pattern models the entire periphery of the assembly as ADOPT rods.

As the ADOPT pellets are identical to typical UO_2 pellets with the addition of Cr_2O_3 (up to 700 ppm) and Al_2O_3 (up to 200 ppm), the only change for ADOPT LTRs is including these oxide materials into the CSA model. The slight increase in pellet density for ADOPT rods is bounded by the Traveller CSA model, as theoretical density UO_2 is modeled. The densities of the constituents in the ADOPT fuel pellets can be calculated based on the atomic masses of the constituents in each of the oxide additives, the ppm concentration, and the UO_2 fuel density (10.96 g/cm^3). The densities of the oxygen in the Cr_2O_3 and Al_2O_3 are summed and the densities of each of the constituents are set in the SCALE material composition of the ADOPT fuel pellets based on the values in Table 4.

Table 4: ADOPT Fuel Pellet Material Composition

Constituent	Element	Atomic Mass	Density (g/cm^3)
Cr_2O_3 (700 ppm)	Cr	51.996	5.24924E-03
	O	15.999	2.42276E-03
Al_2O_3 (200 ppm)	Al	26.982	1.16014E-03
	O	15.999	1.03186E-03
UO_2	Remainder		1.09501E+01

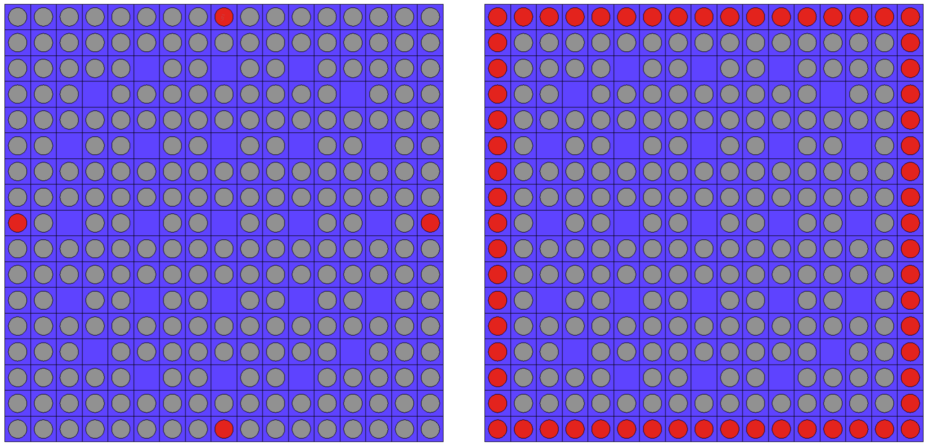


Figure 7: LTA2 Fuel Assembly Rod Patterns

The results of the LTA2 sensitivity analysis are presented in Table 5. The case with all rod positions around the periphery of the assembly replaced with ADOPT rods is included so that the special authorization may allow for any rod on the periphery of the standard 17x17 OFA assembly (17 Bin 1) to be replaced by ADOPT rods. This provides flexibility for the possibility of small changes in the LTA2 design and simplification of the wording in the special authorization. The results of Table 5 indicate that the addition of ADOPT rods results in a statistically insignificant increase in k_{eff}. Thus, there is no significant effect on the criticality safety of the Traveller package from replacing standard UO_2 rods on the periphery of a 17 Bin 1 assembly with ADOPT pellet filled LTRs.

Table 5: LTA2 - ADOPT Rod Case SCALE Results

Case	Fuel Length (in.)	Periphery ADOPT Rod Positions	k_{eff}	σ	$k_{eff}+2\sigma$	Δk_{eff}[1]
SAR Baseline Case	144.5	None	0.92688	0.00031	0.92750	-
4 Peripheral Rods	144.5	4	0.92704	0.00024	0.92752	0.00002
All Peripheral rods		All	0.92724	0.00027	0.92778	0.00028

Note: [1] Difference between $k_{eff}+2\sigma$ of the sensitivity study case and baseline case.