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

February 5, 2019

Mr. Scott P. Murray
Manager, Facility Licensing
Global Nuclear Fuel
3901 Castle Hayne Road
P.O. Box 780
Wilmington, NC 28402

SUBJECT: SPECIAL AUTHORIZATION TO USE THE RAJ-II PACKAGE FOR GNF FeCrAl LEAD TEST ASSEMBLIES

Dear Mr. Murray:

As requested by your application dated October 19, 2018, pursuant to Title 10 of the *Code of Federal Regulations* Part 71, Certificate of Compliance (CoC) No. 9309, Revision No. 12, for the Model No. RAJ-II package is amended to authorize the use of the RAJ-II package for shipment of accident tolerant fuel (ATF) GNF FeCrAl fuel rods installed in a standard GNF2 BWR 10x10 fuel assembly, with the conditions below:

(1) Authorization is for a maximum of 17 shipments of lead test assemblies (LTAs) containing lead test rods (LTRs) with GNF FeCrAl cladding and end plugs.

(2) The GNF FeCrAl LTRs shall contain commercial grade uranium and meet Type A radioactive material contents, while adjacent zirconium alloy fuel rods may contain radioactive material consistent with the radionuclide maximum concentrations of the CoC.

(3) The fuel assemblies shall be shipped unchanneled.

(4) Each shipment shall contain a maximum of 4 LTAs, i.e., two Model No. RAJ-II packages on a single truck, each containing a maximum of two LTAs. The RAJ-II packages containing GNF FeCrAl LTAs shall commingle only with other RAJ-II packages transporting GNF2 fuel, as currently approved in the CoC.

(5) Deviations to the design parameters of the GNF FeCrAl LTAs, from those approved in the CoC, shall be limited to those parameters listed in Table 1-1 of the proprietary application.

(6) If not accepted for loading at the reactor site, this authorization covers the return of the fresh fuel assemblies.

(7) This authorization shall expire on December 31, 2021.

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

Sincerely,

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

Docket No. 71-9309
EPID - L-2018-LLA-0276

Enclosure:
Safety Evaluation Report

cc w/encl: R. Boyle, Department of Transportation
J. Shuler, Department of Energy c/o L. F. Gelder

Safety Evaluation Report
GLOBAL NUCLEAR FUEL
Docket No. 71-9309
Model No. RAJ-II Package

Global Nuclear Fuel - Americas LLC (GNF) submitted a letter authorization request to use the Model No. RAJ-II package for shipment of accident tolerant fuel (ATF) FeCrAl fuel rods, inserted in a standard GNF2 BWR 10x10 fuel assembly [ML18292A603], because the GNF FeCrAl LTAs contain rods which do not meet certain fuel parameters currently specified in the CoC [ML17222A011]. GNF stated that each package would contain two GNF BWR fuel assemblies, where up to eight full-length fuel rods would be fabricated with FeCrAl cladding, and that the Model No. RAJ-II package was not modified by this letter authorization request.

The GNF2 fuel design consists of a 10x10 arrangement of fuel rods with water rods and part-length rods that use a zirconium alloy cladding material. The GNF FeCrAl fuel rods are conservatively restricted to contain only Type A(F) material and the applicant conservatively assumed that all Type A(F) GNF FeCrAl rods completely fail upon impact during the 9-meter Hypothetical Accident Conditions (HAC) drop. Thus, the integrity of the FeCrAl fuel rods is not credited during HAC conditions, and the staff does not rely on structural or cladding materials performance to demonstrate safety.

GNF provided supplemental criticality evaluations to address the consequences of failure of these rods during HAC and demonstrate criticality safety as discussed in the criticality evaluation below.

The applicant did not take credit for the presence of the fuel handling enclosure for structural integrity purposes, and all potential damage to the ATF GNF FeCrAl LTA was accounted for in the criticality evaluation, as verified by the staff. Staff noted also that the mass of the ATF GNF FeCrAl LTA was bounded by that of the previously approved contents, and the general construction arrangement of the fuel handling enclosure is similar in both geometry and materials of construction. Since the design of the Model RAJ-II package is not modified by this letter authorization request, the staff finds that the inclusion of the ATF GNF FeCrAl fuel rods as authorized contents of the package assures that the previously approved structural analyses in the application remain applicable.

The staff reviewed the potential effects of adding GNF FeCrAl as an additional cladding material. Under normal conditions, the applicant concluded that the addition of GNF FeCrAl did not change the RAJ-II package material properties. The applicant also concluded that the addition of GNF FeCrAl fuel rods does not affect the fire test conditions or the heat transfer coefficient during the fire event or during the post-fire period. Because the GNF FeCrAl rods are Type A(F) rods without irradiation, the staff determines that the applicant's conclusions are acceptable.

The staff assessed the potential galvanic effects of zirconium alloy rods with FeCrAl rod. Because zirconium alloy and stainless steel alloy will form a passivated oxide on the surface, the staff determined that there will be no galvanic effects. The staff also considered the potential effects of differential strain between zirconium alloy and FeCrAl during drop tests,

which may affect the integrity of zirconium alloy. From literature data, the elastic modulus values of FeCrAl material tubes are greater than those for zirconium alloy below zero (ASME BPVC Section II) and up to 1000˚C. The creep properties would be similar to those from drop tests. Therefore, the staff determines no differential strains are expected.

With regards to thermal effects, Section 3 of the letter authorization [ML18292A606] stated there is no change in the RAJ-II package decay heat or pressure associated with the RAJ-II due to the presence of the limited FeCrAl fuel rods that contain Type A(F) commercial grade uranium material. According to Section 3 of the letter authorization, because the GNF FeCrAl fuel rods are not credited during hypothetical accident conditions, no new thermal analyses were performed.

With regards to containment, Section 1 and Section 4 of the letter authorization indicate that the aggregate of the GNF FeCrAl fuel rods are restricted to Type A(F) quantity material and that reprocessed material is not permitted within the GNF FeCrAl fuel rods. Although the GNF FeCrAl fuel rods are considered Type A(F), their fabrication and preparation are similar to the Type B(F) zirconium-based fuel rods. For example, both fuel rod types have cladding and a welded end plug that encapsulates the fuel pellets. In addition, both rod types are leak tested to the criteria and approved methods, as described in the most recent application [ML18247A218]. According to Section 4 of the letter authorization, the containment description in the most recent application applies to this current letter authorization, as the limited number of FeCrAl fuel rods does not impact the containment of the RAJ-II package.

CRITICALITY EVALUATION

This Letter Authorization request only applies to the GNF 10x10 fuel assembly contents as described in Table 3 of Certificate of Compliance 71-9309, Revision 12. The applicant has not requested any changes to the other assembly types in Table 3, or the loose fuel rod contents described in Table 4 of the Certificate of Compliance.

The applicant evaluated the Model No. RAJ-II package containing two unchanneled GNF2 fresh UO_2 fuel lead test assemblies, with up to eight (8) iron-chromium-aluminum (FeCrAl) clad segmented fuel rods, in locations indicated in Figure 1-1 of Attachment 2 to the application. The 10x10 GNF-2 fuel assembly consists of 92 rods, 14 of which are partial length. The GNF2 fuel lead test assembly contents are identical to the previously approved GNF2 fuel assembly contents with respect to:

- 10x10 fuel lattice,
- Active fuel lengths and locations for full length, short partial length, and long partial length rods,
- Fuel rod pitch,
- Maximum enrichment,
- Gadolinium oxide (Gd_2O_3) rod required number and location, and
- Maximum allowable polyethylene packing material per assembly.

The FeCrAl clad rods differ from previously approved zirconium clad rods with respect to: 1) pellet diameter, 2) fuel rod outer diameter, and 3) clad thickness. The applicant requested a change to the approved content as described in Table 6-1 of the application. The applicant demonstrated in Section 6.3.4 of Attachment 2 of the application that these parameter changes

increase reactivity, and the applicant conservatively modeled every rod in the GNF2 assembly with these parameters.

The applicant also evaluated the new FeCrAl cladding material, in comparison to the previously approved zirconium alloy cladding material, to determine which is limiting. In Section 6.3.4.8.1 of Attachment 2 of the application, the applicant concludes that the zirconium alloy cladding material is more limiting, and conservatively assumes that all rods in the GNF2 fuel assembly have zirconium alloy cladding. The staff determined that the applicant's conclusion is reasonable because the neutron absorption cross sections for the primary isotopes of iron, chromium, and aluminum are all higher than the primary isotopes of zirconium.

The applicant previously evaluated the GNF2 fuel assembly with a zirconium alloy channel of varying thickness, and without a channel. The applicant stated the results of the analysis, shown in Section 6.3.4.3 of the RAJ-II SAR, demonstrate that the package is more reactive when the GNF2 fuel assembly does not include a zirconium alloy channel.

The FeCrAl clad rods may be segmented, as shown in Figure 1-3 of Attachment 2 of the application.

As shown in Tables 6-13 and 6-14 of Attachment 2 of the application, in all cases, the addition of segmented rods reduces reactivity. The staff determined that this reduced reactivity is expected because the segmented rod model removes fissile material from the system. The staff finds the applicant's use of uniform, full-active length rods for subsequent analyses is conservative.

All other package parameters affecting criticality safety, including packaging materials, material and fabrication tolerances, fuel assembly orientation, polyethylene mass and distribution, and degree of internal and external moderation, remain the same as for the previously approved RAJ-II package with GNF2 fuel assembly contents.

The applicant used the packaging model for the previously approved contents, modified with the FeCrAl clad lead test assembly rod parameters described above, to determine the most reactive combination of fuel enrichment and number of Gd_2O_3 rods from Table 3 of the Certificate of Compliance. The staff determined the results of this analysis, shown in Table 6-16 of Attachment 2 of the application, demonstrate that fuel assembly contents with 3.6 weight percent ^{235}U rods, with four (4) Gd_2O_3 rods, represent the most reactive contents. The applicant used this content configuration for subsequent criticality calculations.

The applicant evaluated an array of 49 packages (7 x 7 x 1) under hypothetical accident conditions, using the fuel and packaging parameters determined to be most reactive as discussed above. This is a smaller array than the applicant previously evaluated (10 x 10 x 1) and will result in a larger package Criticality Safety Index (CSI). The criticality model included reduced package spacing due to the results of the drop tests, variation in inner container and outer container water density, flooding of the pellet-to-clad gap inside the fuel rods, and the moderating effects of melted polyethylene from cluster separators and wrapping material which may be present in the fuel assembly.

The applicant evaluated these parameters for the previously approved contents of the RAJ-II package and determined the most reactive combination. The applicant applied the same limiting parameters to the model for GNF2 lead test assemblies. The staff agrees that these previously determined limiting parameters are appropriate for the GNF2 lead test assembly

evaluation, as the packaging is unchanged, and the fuel assembly contents are similar. The maximum k_{eff} + 2σ under hypothetical accident conditions, 0.91898, is below the calculated Upper Safety Limit (USL) of 0.9340.

The applicant further considered hypothetical fuel reconfiguration from FeCrAl clad rods under hypothetical accident conditions. The applicant considered radial and axial relocation of fuel pellets within the fuel assembly lattice, and complete removal of FeCrAl lead test rod material from the lattice. Figures 6-4 and 6-5 of Attachment 2 of the application show the radial configurations considered by the applicant, and Figure 6-6 of Attachment 2 of the application shows an example of the axial configurations considered by the applicant. Section 6.6.2.2.3 of Attachment 2 of the application states that fuel relocation into the water rods is not possible.

The applicant considered a reduced array size of four packages (2N=4) for this analysis. The staff agrees that the hypothetical fuel relocations considered are conservative with respect to the potential to increase system k_{eff}, and with the applicant's statement that fuel movement into water rod locations is not credible. The results of the applicant's criticality evaluations are shown in Tables 6-8 and 6-9 of Attachment 2 of the application, for primary and secondary bundle locations, respectively. The results demonstrate that arrays of RAJ-II packages under hypothetical accident conditions, with hypothetical fuel relocation from FeCrAl clad rods into various locations in the lattice, will remain subcritical. The maximum k_{eff} + 2σ under hypothetical accident conditions with relocated FeCrAl clad rod material, 0.91589, is below the calculated USL.

The applicant used the SCALE 6.1 code system, with the KENO VI three-dimensional Monte Carlo code and the continuous-energy ENDF/B-VII.0 cross section library, for all criticality analyses. The applicant's previously approved benchmarking analysis for this code and cross-section library determined a USL of 0.9340, which is applicable for the fuel assembly and package evaluated in this criticality safety analysis. The bounding CSI, based on the hypothetical accident conditions array of 4 packages, is 25.

Staff finds that the criticality analyses provided in Attachment 2 of the GNF letter dated October 19, 2018, provides reasonable assurance that a shipment of up to two (2) Model No. RAJ-II packages, containing channeled or un-channeled GNF2 fuel assemblies containing up to eight (8) FeCrAl clad UO_2 fuel rods, meets the criticality safety requirements of 10 CFR Part 71, with a CSI of 25, and is acceptable.

CONDITIONS

The staff finds that the requested ATF shipments in the Model No. RAJ-II package are in compliance with 10 CFR Part 71 provided the following conditions are met:

(1) Authorization is for a maximum of 17 shipments of lead test assemblies (LTAs) containing lead test rods (LTRs) with FeCrAl cladding and end plugs.

(2) The GNF FeCrAl LTRs shall contain commercial grade uranium and meet Type A radioactive material contents, while adjacent zirconium alloy fuel rods may contain radioactive material consistent with the radionuclide maximum concentrations of the CoC.

(3) The fuel assemblies shall be shipped unchanneled.

(4) Each shipment shall contain a maximum of 4 LTAs, i.e., two RAJ-II packages on a single truck, each containing a maximum of two LTAs. The RAJ-II packages containing GNF FeCrAl LTAs shall commingle only with other RAJ-II packages transporting GNF2 fuel currently approved in the CoC.

(5) Deviations to the design parameters of the GNF FeCrAl LTAs, from those approved in the CoC, shall be limited to those listed in Table 1-1 of the proprietary application.

(6) If not accepted for loading at the reactor site, this authorization covers the return of the fresh fuel assemblies.

(7) This authorization shall expire on December 31, 2021.

CONCLUSION

Based on the statements and representations in the application dated October 19, 2018, the staff agrees that the use by Global Nuclear Fuel (GNF) of the Model No. RAJ-II package for the shipments of FeCrAl LTAs meets the requirements of 10 CFR Part 71, subject to the conditions listed above.

Issued on February 5, 2019.