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

SAFETY EVALUATION REPORT

Docket No. 71-9294
Model No. New Powder Container
Certificate of Compliance No. 9294
Revision No. 9

SUMMARY

By letter dated December 12, 2019 (Agencywide Documents Access and Management System Accession No. ML19346H890), Global Nuclear Fuel-Americas, LLC submitted an application for renewal of Certificate of Compliance (CoC) No. 9294 for the Model No. New Powder Container (NPC) package. In addition, the applicant requested a revision to CoC No. 9294 and submitted a safety analysis report (SAR) documenting the results of a revised criticality evaluation in support of authorizing the introduction of additional uranium compounds as approved content and reestablishing heterogeneous uranium payload limits previously authorized in CoC No. 9294, Revision 5.

The Nuclear Regulatory Commission staff (staff) reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material" and Interim Staff Guidance-15, "Materials Evaluation." Based on the statements and representations in the application, as supplemented, the staff agrees that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71. The staff concludes that the certificate can be renewed for a five-year term.

1.0 GENERAL INFORMATION

The applicant requested that additional uranium compounds be approved as authorized content and that the heterogeneous uranium payload limits previously authorized in CoC No. 9294, Revision 5 be reestablished. The applicant updated the maximum loading limits specified in SAR Table 1.1, and revised the format of notes containing information about the contents specified in SAR Table 1.1 versus the previous safety analysis report revision. The applicant also provided additional examples of chemical compounds that would be presented for shipment and added additional constraints on the material to be presented for transport. In addition, the applicant also made various editorial and administrative changes. Based on a review of the statements and representations in the application, the staff concludes that the package contents have been adequately described to meet the requirements of 10 CFR Part 71.

2.0 STRUCTURAL

The applicant did not propose any changes to the construction for the NPC package. The staff reviewed the proposed changes and determined that they did not impact the staff's previous SER findings. Therefore, the staff finds that a new evaluation is not needed.

2.1 Materials

The applicant proposed to expand the authorized contents of the NPC to include additional solid form uranium compounds. In SAR Sections 1.2.3 and 6.1, the applicant expanded the definition of "Homogenous Uranium Oxide Compounds" to include uranyl nitrate (UN), uranyl nitrate hexahydrate (UNH), uranium tetrafluoride (UF_4), sodium urinate, sodium diuranate, dried sodium containing sludges, ammonium diuranate (ADU), and ammonium uranyl carbonate (AUC). The materials review evaluated the potential for the additional contents to undergo chemical or galvanic reactions and the potential for the contents to expose the packaging materials to detrimental levels of heat and radiation.

2.1.1 Chemical, Galvanic, or Other Reactions

The staff evaluated the proposed additional uranium compound contents to ensure that there would be no significant chemical reactions, galvanic reactions, or other reactions. SAR Table 1.1 provided specifications for the requested contents and their chemical and physical forms. In addition, note 2 of Table 1.1 listed dried calcium-containing sludges, dried sodium containing sludges, uranium oxide bearing ash, and other solid uranium compounds as proposed contents. The applicant removed the uranium compound descriptions from the Table 1.1 notes and moved details of uranium compounds to SAR Table 6.21. In addition, the applicant modified the Table 1.1 notes to state that homogeneous compound material forms are limited to solid uranium compounds as well as to clarify the criteria for both heterogeneous compounds and homogeneous material forms.

The staff noted that UF_4 may react with water, including moisture in the atmosphere, to produce hydrofluoric acid (HF) which has the potential to degrade both the stainless steel used to fabricate the inner containment canister assembly (ICCA) and the silicon rubber used in the ICCA gasket. In addition, the corrosion of stainless steel by HF releases hydrogen gas, which could potentially cause over-pressurization of the ICCA or create an explosive atmosphere within the ICCA. Therefore, staff independently reviewed various technical literature on UF_4. Staff found that UF_4 has a low vapor pressure, and a low solubility in water (approximately $1x10^7$ mole/cm^3). From the literature, the staff noted that, although UF_4 produces HF in reaction with water, UF_4 reacts slowly with moisture at ambient temperature, and that very small amounts of HF repress further reactions to form additional HF. Because the applicant limited the amount of air within the package by placing the UF_4 into either plastic bags or high density polyethylene (HDPE) polymer bottles and because the moisture in air is approximately $1x10^{-4}$ g/cm^3, staff finds that there is insufficient moisture within the package to generate significant amounts of HF. The staff also noted that the package's seal prevented water ingress from the exterior of the package as discussed in SAR Section 2.7.6. In addition, the applicant's use of plastic bags or HDPE polymer bottles as inner packaging provided an additional barrier from moisture that may enter the package. Finally, the staff determined that, should corrosion occur, the pre-shipment and annual inspections required by SAR Sections 7 and 8, respectively, can identify it before the integrity of package components is compromised. Therefore, the staff finds that there is no credible corrosion or other adverse reactions.

2.1.2 Effects of Radiation and Temperature on Packaging Materials

The staff evaluated the potential for the added uranium compounds to degrade the packaging materials through thermal or irradiation effects. The staff reviewed SAR Sections 3, "Thermal," and 5, "Shielding Evaluation," and noted that the proposed contents did not result in any additional heat loads or additional radiation exposure compared to those associated with the previously approved contents. Therefore, the staff finds that the proposed uranium concentrates will not result in thermal or irradiation degradation of the package.

2.2 Evaluation Findings

The staff has reviewed the material aspects of the package structural design description and finds that the package meets the regulatory requirements for mitigating galvanic or chemical reactions and is constructed with materials and processes in accordance with acceptable industry codes and standards.

3.0 THERMAL EVALUATION

The staff reviewed the proposed changes and determined that they did not impact the staff's previous SER findings regarding the package thermal design. Therefore, the staff finds that a new evaluation is not needed.

4.0 CONTAINMENT EVALUATION

The staff reviewed the proposed changes and determined that they did not impact the staff's previous SER findings regarding the package containment design. Therefore, the staff finds that a new evaluation is not needed.

5.0 SHIELDING EVALUATION

The staff reviewed the proposed changes and determined that they did not impact the staff's previous SER findings regarding the package shielding design. Therefore, the staff finds that a new evaluation is not needed.

6.0 CRITICALITY

The applicant submitted a revised criticality evaluation for the Model No. NPC package to add additional uranium contents and to reestablish previously authorized heterogeneous uranium payload limits. In addition, the criticality evaluation supported revised polyethylene packaging material requirements. The staff had reviewed and accepted the previous homogeneous and heterogenous uranium compounds, enriched up to 5.0 wt% ^{235}U, as meeting the requirements of 10 CFR Part 71 for a Type A fissile material shipping container. The staff reviewed the new contents using the same methodology. The applicant listed the new content limits for the NPC package in the amended SAR Section 1.2.3. The contents consisted of:

- uranium oxides (UO_2, U_3O_8, or UO_x, x>2)
- uranyl nitrate (UN, $UO_2(NO_3)_2$)
- uranyl nitrate hexahydrate (UNH, $UO_2(NO_3)_2$*$6H_2O$)
- uranium tetrafluoride (UF_4)
- sodium uranate (Na_2UO_4)
- sodium diuranate ($Na_2U_2O_7$)
- sodium diuranate hexahydrate ($Na_2U_2O_7$*$6H_2O$)
- ammonium diuranate (ADU, $3UO_3$*$2NH_3$*$4H_2O$)
- ammonium uranyl carbonate (AUC, $(NH_4)_4$*UO_2*$(CO_3)_3$)
- dried calcium (Ca) containing uranium compound/mixture/sludge/ash, such as $CaUO_3$. $CaUO_4$, Ca_2UO_5, Ca_2UO_4, Ca_3UO_6, CaU_3O_{10}*$4H_2O$, CaU_6O_{19}*$11H_2O$ and CaU_6O_{19}*$10H_2O$
- dried sodium (Na) containing uranium compound/mixture/sludge/ash, such as $Na_2U_2O_7$*$3H_2O$ and $Na_2U_2O_7$*H_2O

- dried iron (Fe) containing uranium compound/mixture/sludge/ash

The applicant also added additional information to the SAR to evaluate: (1) the k-infinite (k_{inf}) comparison of uranium compounds; (2) a sensitivity study regarding the use of polyethylene packaging materials; (3) an evaluation of the homogeneous to heterogeneous particle size transition; and (4) a description of the convergence plots for the GEMER Monte Carlo code.

6.1 Description of Criticality Design

The applicant designed the NPC transportation package with an internal 3x3 array of stainless-steel ICCAs enclosed within a stainless steel reinforced Outer Confinement Assembly (OCA) as described in SAR Section 1.2. The applicant used the stainless-steel ICCAs, which have a maximum inner diameter of 8.515 inches (21.63 cm), to transport the various uranium contents. The applicant spaced the ICCAs 12.0" (30.48-cm) center-to-center within the OCA. This package design did not require water exclusion from the ICCAs because all criticality models generated by the applicant assumed the package was completely flooded. The applicant analyzed each ICCA within the package in both undamaged and damaged container arrays under optimal moderation conditions with a uranium enrichment of 5.0 wt% ^{235}U. The applicant's analysis demonstrated a favorable geometry at this enrichment.

6.2 Nuclear Contents

As listed above, the NPC contents included a variety of homogenous and heterogenous uranium bearing compounds. In addition, the contents included UO_2 pellets for both boiling water reactor and pressurized water reactor fuel assemblies. SAR Table 6.1 (replicated below) listed the uranium mass limits per ICCA and per package for the NPC container. The applicant stated that uranium compounds complying with the maximum stated loading requirements may be shipped provided the equivalent uranium payloads are not exceeded.

Material Form (≤ 5.00 wt.% U-235)	**Particle Size Restriction: Minimum OD (Inches)**	**Maximum Loading per ICCA (kg)**		**Maximum Loading per NPC (kg)**	
		Net	Uranium	Net	Uranium
Homogeneous Uranium Compounds	N/A	60.0	52.89	540.0	476.0
Heterogeneous UO_2 Pellets (BWR)	0.342	60.0	48.48	540.0	436.3
Heterogeneous UO_2 Pellets (PWR)	0.300	60.0	46.71	540.0	420.4
Heterogeneous Uranium Compounds	Unrestricted particle size	60.0	40.54	540.0	364.8

The applicant performed a series of k_{inf} reactivity calculations to compare the relative reactivities of all proposed contents. The applicant found that, at the maximum 5.0 wt% ^{235}U enrichment, the theoretical optimal mixture of UO_2 and water was conservatively bounding for all uranium compound and water mixtures. Staff reviewed the reactivity comparison and finds the assessment reasonable.

The applicant also evaluated the effects of particle sizes on k_{inf} for heterogeneous uranium compounds. The applicant determined that these compounds are subcritical for the maximum loading parameters per ICCA and per NPC package specified in SAR Table 6.1.

The applicant stated that the mass of plastic bags or HDPE bottles used for inner packaging is unrestricted provided the mean hydrogen atom density inside the inner volume of each ICCA is not greater than water. The applicant restricted solutions and liquids as authorized contents as well as required that the solid form material within any individual NPC must be the same (e.g., BWR pellets cannot be intermixed with PWR pellets within an individual NPC). The applicant allowed uranium compounds to be mixed with non-fissionable diluent materials other than deuterium, tritium, and beryllium. In addition, the applicant restricted the contents for transport in the NPC to those specified in the SAR, and prohibited materials such as uranium metal and uranium metal alloys.

Since the NPC design uses foam and polyethylene as part of the packaging, the applicant limited the hydrogen content in the foam to 6.4 wt.% and in the polyethylene regions surrounding the cadmium to 14.3%.

6.3 General Considerations for Criticality Safety

The applicant evaluated a single package, arrays of packages under normal conditions of transport, and arrays under hypothetical accident conditions for the loaded NPC package for the allowable contents.

The applicant used the SCALE6.1 code package with the ENDF/B-VII continuous energy group cross section library for evaluating the respective k_{inf} of the various uranium bearing materials. The applicant modeled the NPC package using GEMER, which is a proprietary GNF Monte Carlo criticality analysis computer code that solves the neutron transport equation and allows for advanced geometry inputs. GEMER is very similar in capability to the SCALE code package. Staff finds this acceptable since the staff's confirmatory analysis with the SCALE code yielded k_{eff} results in close agreement to the GEMER k_{eff} results.

The applicant provided a discussion of the convergence plots in SAR Figures 6.10a through 6.10d. Although these plots were for explicit model cases with homogeneous UO_2 and H_2O mixtures, they also provided representative results for the heterogeneous lattices. These figures provided a composite illustration of the batches run and the batches skipped. After reviewing these plots, staff finds the applicant adequately addressed the convergence of the GEMER code.

The applicant constructed models that were consistent with the as-designed package using tolerances and material specifications of package components that maximize reactivity. The applicant considered deviations from nominal design configurations as well as package flooding effects. Staff finds these models acceptable because the applicant used conservative assumptions where appropriate to maximize the calculated reactivity of the NPC transportation package.

6.4 Demonstration of Maximum Reactivity

As described in SAR Section 6.12, the applicant performed a series of calculations to evaluate the unrestricted use of HDPE polyethylene packaging materials within the NPC. Building upon the previous analyses performed for the prior revision, the applicant considered all three particle sizes referenced in Condition 5(b) of the certificate. To account for the effect of inner packaging materials inside the ICCA, the applicant conservatively assumed that the material was distributed inside standard Model No. NPC polyethylene bottles which were located inside the ICCA. Staff finds this acceptable because this assumption maximizes the amount of HDPE present in any given ICCA. In the analysis, GNF demonstrated that the additional hydrogenous material decreases overall reactivity for the damaged package array. The staff performed an independent confirmatory analysis for a 5 x 5 x 6 array of packages under HAC using SCALE6.1 and the continuous energy ENDF/B-VII cross section set. The staff's results confirmed that the inclusion of the HDPE polyethylene decreases the overall system reactivity. Therefore, staff finds the use of HDPE in the NPC transportation package acceptable provided the mean hydrogen atom density of the packaging materials to be shipped inside the inner volume of each ICCA is not greater than water.

Building upon the bounding theoretical UO_2 and water mixture determined in SAR Section 6.11, the applicant also evaluated the maximum particle size for transitioning between homogeneous and heterogeneous forms of uranium bearing materials. The applicant evaluated an infinite array of UO_2 particles using SCALE6.1. To emulate the heterogeneity of particles the applicant determined the water-to-fuel ratio, and varied particle sizes to cover the applicable range. Based on the results of this analysis, the applicant determined the reactivity effects for heterogeneous uranium systems relative to homogenous uranium systems. For the purposes of the homogeneous to heterogeneous transition, the applicant therefore concluded that the unrestricted particle size payload in Condition 5(b) of the certificate applies if most of the particles are 1730 μm or greater; and the homogeneous payload in Condition 5(b) of the certificate remains valid If most of particles are less than 1730 μm. Staff reviewed the applicant's analysis of the particle size transition and finds that the limits imposed by Condition 5(b) of the certificate are adequate to maintain criticality safety of the NPC transportation package.

Staff reviewed the applicant's updated criticality analysis of the bounding payloads with the HDPE and various particle configurations. Staff finds that the applicant used conservative assumptions, and in all instances, that the maximum k_{eff} determined by the applicant for each scenario was less than acceptance standard of 0.95.

6.5 Evaluation Findings

The staff found that the proposed contents cited in the Model No. NPC transportation package Certificate of Compliance with a maximum enrichment of 5.0 wt% ^{235}U will remain subcritical for all routine, normal, and accident conditions of transport for the contents specified in the certificate. The staff based its finding on a determination of adequate system modeling performed by the applicant and its own independent confirmatory analysis. The applicant adequately related the relative k_{inf} of the various uranium compounds allowed in the NPC transportation package, and the applicant maintained a maximum k_{eff} acceptance standard for all analyzed transportation scenarios. In addition, the applicant met the requirement that the package maintain subcriticality under all conditions of routine, normal and accident conditions as required by 10 CFR Part 71.

7.0 PACKAGE OPERATIONS

The applicant modified the SAR Section 7.1.2 instructions to identify the location of authorized contents within the SAR for the package user and to provide detailed instructions for shipping powders. Based on a review of the statements and representations in the application, the staff concludes that the operating procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

The staff reviewed the maintenance procedures for the package using the guidance in NUREG-1609 and found them to be adequate. Based on a review of the statements and representations in the application, the staff concludes that the maintenance procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be maintained in a manner consistent with its evaluation for approval.

CONDITIONS

The CoC includes the following condition(s) of approval:

Condition 5(b) was revised to increase the maximum allowable mass of BWR and PWR UO_2 pellets and to provide more clarity on content restrictions.

Condition 6(a) was revised to remove redundant information.

The references section has been updated to include this request.

Minor editorial corrections were made.

CONCLUSIONS

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 No. New Powder Container package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9294, Revision No. 9
on June 19, 2020.