Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

Brian R. Moore, Ph.D.

Global Nuclear Fuel – Americas, LLC
Core & Fuel Engineering Manager
P.O. Box 780, M/C A-75
Wilmington, NC 28401 USA

T 910 819 6684
Brian.Moore@ge.com

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Director, Division of Spent Fuel Management
Office of Nuclear Materials Safety & Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Attention: Document Control Desk

Subject: GNF Responses to the NRC Request for Supplemental Information on the RAJ-II Transportation Package

This letter transmits, in Enclosure 1, the Global Nuclear Fuel (GNF) responses to the Reference 1 Nuclear Regulatory Commission (NRC) Request for Supplemental Information (RSI) for the RAJ-II transportation package submittal provided in Reference 2.

If you have any questions about the information provided here, please contact me at (910) 819-6684 or Lisa Schichlein at (910) 819-4815.

Sincerely,

Brian R. Moore
Core & Fuel Engineering Manager
Global Nuclear Fuel – Americas, LLC

Docket No. 71-9309
TAC No. L25154

References:

1. Huda Akhavannik (NRC) to Scott P. Murray (GNF), "Application for RAJ-II Transportation Package – Supplemental Information Needed," November 10, 2016. (ADAMS Accession No. ML11077A011).
2. Scott P. Murray (GNF) to Director, Division of Spent Fuel Management (NRC), "GNF-A Request for Revision of Certificate of Compliance (CoC) USA/9309/B(U)F-96 for Model No. RAJ-II Package," SPM 16-035, September 30, 2016. (ADAMS Accession No. ML16274A097).

Enclosure:

1. Responses to the NRC RSI for the RAJ-II Transportation Package, Non-Proprietary Information – Class I (Public)

cc: H. Akhavannik, USNRC
JG Head, GEH/Wilmington
PL Campbell, GEH/Washington
SP Murray, GEH/Wilmington
PT Tran, GEH/Vallecitos
PLM Specification 003N9764 R0

ENCLOSURE 1

MFN 16-088

Responses to the NRC RSI for the RAJ-II Transportation Package

Non-Proprietary Information – Class I (Public)

3.0 Thermal

3-1 Describe any changes in the submittal that are consistent (or bounding) with the previously provided thermal analyses and provide an evaluation that justifies the conclusion that those changes are consistent (or bounding).

The information presented in the application's thermal chapter was similar to the previously submitted safety analysis report (SAR), although some details of the text changed and/or are missing. For example, Section 3.3.2 of a previous SAR (ML093020557) described evaluation by test for BWR content; a similar type of evaluation was not included in the present submittal that includes non-BWR (PWR and CANDU) content, and hence, no justification was provided for the statement "... various non-BWR fuel types (PWR and CANDU) have been analyzed to maintain containment up to a temperature of 765 deg C for 30 minutes". Another example is that Section 3.4.3 of a previous SAR (ML093020557) described normal conditions of transportation testing thermal stresses. The description of changes provided with this submittal indicates that this discussion was moved to Section 3.4, "Thermal Evaluation under Hypothetical Accident Conditions," however, this section does not include the normal conditions of transportation discussion. In addition, the current SAR does not clearly state that the change in 10x10 fuel assembly parameters is bounded by the previous thermal analyses for normal conditions of transportation and hypothetical accident conditions. Finally, there is no detailed explanation in Section 3.4.4.1 and Section 3.4.4.2 of the derivation of the thermal effects of the Thermal Performance Criteria listed in Table 3 and Table 4 of the proposed CoC. Since the changes made in this submittal are not clearly marked, staff cannot determine if the changes have safety implications.

This information is needed to determine compliance with 10 CFR 71.35, 71.71, 71.73.

GNF Response

Except for thermal criterion of non-BWR (PWR and CANDU) fuel types, the technical content of Chapter 3.0 in Revision 9 of the RAJ-II Safety Analysis Report (SAR) (Reference 3-1) is consistent with, and thus bounded by, SAR Revision 7.1 (Reference 3-2). The following list summarizes the key changes between SAR Chapter 3.0 Revision 7.1 (Reference 3-2) and Revision 9 (Reference 3-1):

- Contents of SAR Revision 9 Chapter 3.0 (Reference 3-1) were rearranged for consistency with Regulatory Guide 7.9 (Reference 3-3).
- General fuel types (BWR, PWR, and CANDU) defined for shipment in SAR Revision 9 (Reference 3-1) are identical to those in SAR Revision 7.1 (Reference 3-2). BWR fuel types take the form of various loose rod configurations, unchanneled bundles, or channeled bundles. Non-BWR (PWR and CANDU) fuel types only take the form as loose rods contained in a pipe container (Drawing 0028B98 of Reference 3-1). In SAR Revision 9

(Reference 3-1) the general fuel types are divided into two categories (BWR and non-BWR) to clearly signify the distinct transportation conditions.

- With the division of the fuel types into two categories, thermal performance characteristics are distinctly defined for BWR and non-BWR (PWR and CANDU) fuel types in SAR Revision 9 (Reference 3-1). Thermal characteristics of BWR fuel types are identical between SAR Revision 9 (Reference 3-1) and SAR Revision 7.1 (Reference 3-2). Existing empirical data and methodologies outlined in SAR Revision 7.1 (Reference 3-2) for calculating thermal characteristics are also applied in Revision 9 (Reference 3-1) to reflect non-BWR (PWR and CANDU) fuel types.

Details specific to the RAJ-II SAR Revision 9 Chapter 3.0 (Reference 3-1) Request for Supplemental Information (RSI) 3-1 follow.

Non-BWR (PWR and CANDU) Fuel Types

Apart from the revised 10x10 fuel assembly, the fuel types defined for shipment in SAR Revision 9 (Reference 3-1) are identical to those in SAR Revision 7.1 (Reference 3-2). This includes BWR and non-BWR (PWR and CANDU) fuel types. With regards to SAR Chapter 3.0, modifications to the 10x10 fuel assembly have no effect on any thermal evaluations. Thus, all fuel types are considered identical between SAR Chapter 3.0 Revision 7.1 (Reference 3-2) and Revision 9 (Reference 3-1).

BWR fuel types are directly shipped within the RAJ-II package; while non-BWR (PWR and CANDU) fuel types are contained in a secondary piping container (Drawing 0028B98 of Reference 3-1) within the RAJ-II package. Due to the supplemental protection from the piping container, thermal criteria for non-BWR (PWR and CANDU) fuel types were not included in Revision 7.1 of the SAR. Instead, only thermal criteria consistent with BWR fuel types were reported. For clarity and completeness, SAR Revision 9 (Reference 3-1) details thermal criteria for all fuel types shipped in the RAJ-II package.

Thermal stress criteria are placed to ensure the integrity of the fuel rod cladding (the containment). The pressure differential across the thickness of the cladding is a function of temperature and governs the magnitude of the cladding hoop stress. Hoop stress allowables are supported by empirical data.

Thermal testing was performed for a range of fuel rods of different diameters, clad thicknesses, and internal pressures. In these tests, the fuel rods were heated to various temperatures from 700°C to 900°C for periods of over one hour to determine the rupture temperature, and corresponding stress, of the cladding. Because some of the fuel designs for use in the RAJ-II package are outside the range of parameters tested, additional thermal analyses were performed to demonstrate the ability of the fuel rods to maintain containment in a Hypothetical Accident Condition (HAC) environment.

The empirical data was applied to benchmark an analytical thermal creep model of the fuel rod cladding. Both the empirical data and creep model demonstrate BWR fuel types intended for shipment in the RAJ-II package do not rupture at 800°C when held at this temperature for

one hour. This data supports the maximum allowable hoop stress of 31.1 MPa defined in SAR Revision 7.1 (Reference 3-2) and Revision 9 (Reference 3-1). As hoop stress is a function of the pressure differential and cladding geometry, a thermal criterion is defined to check against the allowable hoop stress. The criterion is an abridged equivalent to numerically listing all conceivable variations of acceptable fuel parameters. SAR Revision 7.1 (Reference 3-2) defines this criterion in Table 3-5 based on the maximum hoop stress of 31.1 MPa in Section 3.5.3.2. For clarity, it was proposed that this existing criterion be directly added to the Certificate of Compliance (CoC) and was moved to Section 3.4.4 in SAR Revision 9 (Reference 3-1).

Non-BWR (PWR and CANDU) fuel types were also evaluated with the benchmarked thermal creep model. These fuel types have been analyzed to maintain containment up to a temperature of 765°C for 30 minutes with a corresponding maximum hoop stress of 56.3 MPa. This criterion is reflected in SAR Revision 9 and the proposed CoC (Reference 3-1).

Normal Conditions of Transport (NCT) Thermal Stresses

The information contained in Section 3.4.3 of SAR Revision 7.1 (Reference 3-2) was relocated to Section 3.4.4 of SAR Revision 9 (Reference 3-1) to be consistent with Regulatory Guide 7.9 (Reference 3-3). All content in this section is applicable to both NCT and HAC environments; however, the second paragraph of Section 3.4.4 of SAR Revision 9 (Reference 3-1) is predominantly directed at the HAC evaluation. The rationale for reporting a single thermal stress section (Section 3.4.4 of SAR Revision 9 (Reference 3-1)) is that the conclusions (of negligible thermal stresses of the RAJ-II package itself, negligible interference between components, and thermal criteria) are relevant to all applicable regulatory environments and are bounded by the HAC environment.

Consideration of the Revised 10x10 Fuel Assembly

The SAR Revision 9 (Reference 3-1) Chapter 3.0 thermal evaluation covers all fuel types specified in the CoC. This includes BWR and non-BWR (PWR and CANDU) fuel types. The only difference in fuel type parameters between SAR Revision 7.1 (Reference 3-2) and Revision 9 (Reference 3-1) is for the 10x10 fuel assembly. However, modifications to the 10x10 fuel assembly have no effect on any thermal evaluations. Thus, all fuel types analyzed are considered identical between SAR Chapter 3.0 Revision 7.1 (Reference 3-2) and Revision 9 (Reference 3-1).

Thermal Performance Criteria

Thermal stress criteria are placed to ensure the integrity of the fuel rod cladding (the containment). The pressure differential across the thickness of the cladding and cladding geometry governs the magnitude of the hoop stress. The allowable hoop stress that is consistent with BWR fuel types, of 31.1 MPa, is defined in SAR Revision 7.1 (Reference 3-2) Section 3.5.3.2 and corresponds to the thermal criterion noted in SAR Revision 7.1 Table 3-5. For clarity, it is proposed that this existing criterion be directly added to the CoC, and was moved to Section 3.4.4 in SAR Revision 9 (Reference 3-1).

Thermal criteria consistent with non-BWR (PWR and CANDU) fuel types were not included in SAR Revision 7.1 (Reference 3-2) due to the protective nature of the secondary piping container in which these fuels are contained within the RAJ-II package. For clarity and completeness, SAR Revision 9 (Reference 3-1) details thermal criteria for all fuel types for shipment in the RAJ-II package. Thermal criteria are supported by empirical data and a benchmarked analytical model. The allowable hoop stress consistent with non-BWR fuel types, of 56.3 MPa, is reflected in SAR Revision 9 (Reference 3-1) Section 3.4.4 and the proposed CoC.

References

3-1 Letter, Scott P. Murray (GNF) to Director, Division of Spent Fuel Management (NRC), "GNF-A Request for Revision of Certificate of Compliance (CoC) USA/9309/B(U)F-96 for Model No. RAJ-II Package," SPM 16-035, September 30, 2016.

3-2 Letter, Phillip D. Ollis (GNF) to Division of Spent Fuel Storage and Transportation (NRC), "Request for Renewal of Certificate of Compliance USA/9309/B(U)F-96 for Model No. RAJ-II Package," PDO 14-015, June 13, 2014.

3-3 Regulatory Guide 7.9 Revision 2, "Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material," U.S. Nuclear Regulatory Commission, March, 2005.

Observations

Shielding

5-1 In Section 5.2.1 of the SAR, the applicant stated that the spectrum and source strength of the gammas emitted due to the decay of the actinides were determined using ORIGEN2 Version 2.1 with the default DECAY, BWRUE and GXU02BRM libraries. This includes gammas emitted from all decay modes, such as alpha or spontaneous fission, for all the actinides, in addition to the contribution from Bremsstrahlung due to slowing down of beta particles in the fuel. The gamma source strength from actinides is 3.73E+10 photons/s. However, ORIGEN2.1 libraries were developed for fixed enrichments and can give poor results when applied to other enrichments. The BWRUE library was made assuming 3.4 wt% enrichment and burnups up to 40 GWd/tU. This enrichment is low for many modern fuel designs and could lead to large errors in the calculated neutron source (Cm-244).

The applicant should demonstrate that these libraries have been validated against experimental data, that any potential biases and uncertainties have been quantified, and that the code is appropriate for the fuel design proposed in this amendment.

This information is required to determine compliance with 10 CFR 71.47.

GNF Response

During the RAJ-II Safety Analysis Report (SAR) Revision 9 pre-application meeting with the Nuclear Regulatory Commission (NRC) on March 3, 2016, the NRC specifically requested that GNF add a shielding analysis to Chapter 5 of the SAR. Even though the RAJ-II is approved as a Type B package by the NRC, a formal shielding analysis for the RAJ-II had not been included in the previous RAJ-II SAR revisions because unirradiated fuel is the only approved contents for the RAJ-II package. A shielding analysis was added to Chapter 5 at the NRC's request to make the RAJ-II SAR more consistent with other Type B package SARs.

Revision 9 of the RAJ-II SAR (Reference 5-1) will allow the RAJ-II package to maintain its Type B certification, where the only modification to the approved package contents is the inclusion of a GNF 10x10 fuel assembly with a single axially varying water rod. The RAJ-II package is not approved to ship irradiated fuel. The RAJ-II Type B certification applies only to unirradiated, enriched commercial grade uranium or enriched reprocessed uranium as defined by American Society for Testing and Materials (ASTM) C996-15 (Reference 5-2) (Section 1.2.2.1 of the RAJ-II SAR (Reference 5-1)).

Section 3.1.3 of NUREG-6802 (Reference 5-3) specifically states that ORIGEN2 is acceptable for Light Water Reactor (LWR) fuel source term generation for burn-up values up to 40 GWd/MTU. Section 3.3.3.1 of NUREG-6802 (Reference 5-3) provides acceptance for the use of the given ORIGEN2 LWR nuclear library for the generation of fuel source terms. As stated in Section 5.4.1 of the RAJ-II SAR (Reference 5-1), the ORIGEN2.1 BWRUE nuclear library was used, which is acceptable per the NRC-endorsed NUREG-6802 (Reference 5-3). No

depletion/burn-up steps were performed during the ORIGEN2.1 source term generation. Therefore, the unirradiated fuel source term in Chapter 5 of the RAJ-II SAR (Reference 5-1) is well within the range of applicability for ORIGEN2.1 and the nuclear libraries used.

The ORIGEN2.1 source term was placed into a conservative shielding model using MCNP5 (Reference 5-4). The conservative assumptions within this model include:

1) Modeling the uranium fuel as a diffused volumetric source, which allows more high-energy gammas to escape the source volume.
2) Minimal RAJ-II inner container steel and no outer container steel in the gamma shielding model.
3) No RAJ-II package steel in the neutron shielding model.
4) No other RAJ-II structural material or components included.
5) Air is modeled as void.
6) All fission product gammas allowed per ASTM C1295-15 (Reference 5-5) are assumed to be at the most energetic gamma energy (0.7658 MeV).

In addition to the conservative modeling assumptions 1-6 above, a safety factor of 1.2 was applied to the MCNP5 (Reference 5-4) dose results to generate Table 5-1 of the RAJ-II SAR (Reference 5-1). Note that the 1.2 safety factor is larger than the 10% agreement of the source term validation information presented in Section 3.3.3.4 of NUREG-6802 (Reference 5-3) between the nuclear cross section data files (ENDF/B-V and ENDF/B-VI) and experimental measurements. Even with this high level of intrinsic conservatism, the Table 5-1 results are approximately 93% below the NRC 10 CFR 71 limits.

The RAJ-II package is only approved to ship unirradiated fuel; the shielding analysis presented in Chapter 5 of the RAJ-II SAR (Reference 5-1) was included in response to a request from the NRC. The source term and shielding analysis was performed consistent with the guidance provided in NUREG-6802 (Reference 5-3). The inclusion of a 1.2 safety factor and conservative modeling assumptions more than cover the potential bias and bias-uncertainties from the use of NRC-endorsed ORIGEN2.1 libraries. Inclusion of additional bias and bias-uncertainties will not have a significant effect on the unirradiated fuel dose results for the RAJ-II package.

References

5-1 Letter, Scott P. Murray (GNF) to Director, Division of Spent Fuel Management (NRC), "GNF-A Request for Revision of Certificate of Compliance (CoC) USA/9309/B(U)F-96 for Model No. RAJ-II Package," SPM 16-035, September 30, 2016.

5-2 ASTM C996-15, "Standard Specification for Uranium Hexafluoride Enriched to Less than 5% ^{235}U."

5-3 NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages," May 2003.

5-4 LA-UR-03-1987, "MCNP - A General Monte Carlo N-Particle Transport Code, Version 5," Los Alamos National Laboratory, October 2005.

5-5 ASTM C1295-15, "Standard Test Method for Gamma Energy Emission from Fission and Decay Products in Uranium Hexafluoride and Uranyl Nitrate Solution."

Observations

Operating Procedures

7-1 The description of changes provided with the updated safety analysis report specifies that Section 7.4 is removed because it is redundant and listed in chapter 8. Staff was unable to locate the components originally listed in Section 7.4 in chapter 8.

This information is needed to determine compliance with 10 CFR 71.87(f).

GNF Response

Modifications of Chapter 7.0 were made for the following reasons:

1. To more closely follow the format guidance of Regulatory Guide 7.9 (Reference 7-1).
2. To be consistent with the licensing drawings in Chapter 1.0 which were revised to directly apply importance to safety component classifications based on NUREG/CR-6407 (Reference 7-2).

Reason for Relocation of Content

Section 7.4 of Reference 7-3 included a list of normal routine maintenance items that did not require quality assurance or engineering evaluation for replacement. Per Regulatory Guide 7.9 (Reference 7-1), this section should contain information regarding provisions for special operational controls, such as route, weather, and shipping time restrictions. Therefore, the content of Section 7.4 of Reference 7-3 was moved to Section 8.2.3 of Reference 7-4. Per Regulatory Guide 7.9 (Reference 7-1), this section is the appropriate location for describing periodic tests and replacement schedules for components.

Reason for Change in Content

The RAJ-II component maintenance content was explicitly listed in Section 7.4 of Reference 7-3. The first reason for removal of the explicit content is that the list did not provide a clear linkage to the actual items names on the licensing drawings, nor did it provide a clear definition of the importance to safety classification for each item. The second reason for removal of the content is that there are no RAJ-II package components which require scheduled replacement. The maintenance of the RAJ-II package is instead accomplished by a detailed refurbishment prior to each use. One step of the refurbishment process is a visual inspection of the entire package to ensure that no component is damaged and all components are in place. The refurbishment process is detailed in applicable operating procedures.

In conclusion, content in Section 8.2.3 of Reference 7-4 was changed to more clearly follow the actual refurbishment process of packaging components based on their importance to safety classification, which now appears directly on each licensing drawing in Chapter 1.0. This was done to emphasize the increased quality assurance requirements for Category A or B components versus Category C components.

References

7-1 Regulatory Guide 7.9 Revision 2, "Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material," U.S. Nuclear Regulatory Commission, March, 2005.

7-2 NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," February 1996.

7-3 Letter, Phillip D. Ollis (GNF) to Division of Spent Fuel Storage and Transportation (NRC), "Request for Renewal of Certificate of Compliance USA/9309/B(U)F-96 for Model No. RAJ-II Package," PDO 14-015, June 13, 2014.

7-4 Letter, Scott P. Murray (GNF) to Director, Division of Spent Fuel Management (NRC), "GNF-A Request for Revision of Certificate of Compliance (CoC) USA/9309/B(U)F-96 for Model No. RAJ-II Package," SPM 16-035, September 30, 2016.