Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

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Subject: Draft Safety Evaluation (SE) For Amendment 32 To Global Nuclear Fuel (GNF) Topical Report (TR) NEDE-24011-P General Electric Standard Application For Reload (GESTAR II) (TAC No. MD9939)

In Reference 1, the NRC provided the draft Safety Evaluation (SE) of the subject topical report and requested that Global Nuclear Fuel (GNF) identify any information that it considers proprietary and provide comments on factual errors or clarity concerns. Enclosure 1 contains the GNF comment summary and a non-proprietary markup of the draft SE.

If you have any questions about the information provided here, please contact me at (910) 819-5954 or Jim Harrison at (910) 819-6604.

Sincerely,

Andrew A. Lingenfelter
Vice President, Fuel Engineering
Global Nuclear Fuel–Americas, LLC

Project No. 712

Reference

1. Letter from SL Rosenberg (NRC) to AA Lingenfelter (GNF), Subject: Draft Safety Evaluation (SE) For Amendment 32 To Global Nuclear Fuel (GNF) Topical Report (TR) NEDE-24011-P General Electric Standard Application For Reload (GESTAR II) (TAC No. MD9939), January 15, 2009.

Enclosure

1. Comment Summary and Safety Evaluation Markup – Non- Proprietary Information

cc: MC Honcharik, NRC
SS Philpott, NRC
AA Lingenfelter, GNF Wilmington
JG Head, GEH Wilmington
eDRF Section 0000-0103-3095

ENCLOSURE 1

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Comment Summary and Safety Evaluation Markup

Non-Proprietary Information

IMPORTANT NOTICE

Enclosure 1 is a non-proprietary version of the Comment Summary and the Safety Evaluation Markup, which has the proprietary information removed. Portions that have been removed are indicated by open and closed double brackets as shown here [[ ]].

Comment Summary for Draft Safety Evaluation By The Office Of Nuclear Reactor Regulation Topical Report NEDE-24011-P-A/NEDO-24011-A Amendment 32

Location	Comment
Page 1 Line 17	Correct GE Hitachi brand name as noted.
Page 3 Line 15	Add space ……to NEDE-…… as noted.
Page 4 Line 16 and 32	The term NCLO used in these 2 locations should be Clad Lift-Off (CLO) or else change the sentence to reflect the negative context.
Page 5 Line 11	The second sentence implies it should follow from the first, but it does not.

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT NEDE-24011-P-A/NEDO-24011-A

"GENERAL ELECTRIC STANDARD APPLICATION FOR RELOAD (GESTAR II)"

GLOBAL NUCLEAR FUEL

PROJECT NO. 712

1.0 INTRODUCTION AND BACKGROUND

By letter dated October 15, 2008, Global Nuclear Fuel (GNF) submitted Amendment 32 to NEDE-24011-P, entitled "General Electric Standard Application for Reload Fuel (GESTAR II)" (Reference 1). GESTAR II provides a fuel design and core reload process used extensively by licensees with GNF or ~~General Electric~~**GE** ~~–~~ Hitachi **Nuclear Energy Americas, LLC** (GEH) fuel designs. This U.S. Nuclear Regulatory Commission (NRC)-approved process allows GNF to modify fuel assembly designs without undergoing a formal NRC submittal and review. As part of this process, GNF provides written notification outlining the new design and acknowledging compliance with the requirements of the NRC-approved GESTAR process. Upon notification, the NRC staff may conduct an audit of the engineering calculations supporting the new fuel design. Amendment 32 to GESTAR II was necessitated by an NRC staff audit of the GNF2 fuel design compliance report.

By letter dated March 14, 2007, GNF submitted a GESTAR II Compliance Report for the advanced fuel assembly design referred to as GNF2 (Reference 2). A subsequent NRC staff audit of the GESTAR II Compliance Reports (Reference 3) yielded several NRC staff findings which need to be addressed prior to batch implementation of GNF2 fuel. One of the findings involved the use of General Electric Stress and Thermal Analysis of Reactor Rods - Mechanical (GESTR-M) fuel thermal-mechanical methodology for GNF2 fuel above a rod power of 13.4 KW/ft. Issues associated with GSTR-M had been the focus of recent ~~General Electric-Hitachi Nuclear Energy Americas, LLC (~~GEH~~)~~ notifications pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 21 (References 4 and 5). In response to the audit finding, GEH supplemented the Part 21 Notification (Reference 6) to expand its assessment of the adequacy of GSTR-M to GNF2 fuel design at rod powers in excess of 13.4 KW/ft. As part of its finding that the application of GSTR-M does not constitute a reportable condition under 10 CFR Part 21, GEH included a qualification (i.e., condition) which imposed a limit of applicability for [[ ]] A subsequent revision to the GNF2 GESTAR II Compliance Report (Reference 7) captured this qualification.

ENCLOSURE

In response to NRC staff concerns regarding the application of a fuel rod nodal exposure limit, which is more restrictive than the NRC staff's current approval of GESTAR II (including GSTR-M methods), GNF submitted Amendment 32 to GESTAR II in order to capture this interim GNF2 exposure limit.

2.0 REGULATORY EVALUATION

TR NEDE-24011-P-A/NEDO-24011-A, provides an NRC-approved fuel design and core reload process. The approved methodology and acceptance criteria detailed within TR NEDE-24011 are cited within many boiling water reactor (BWR) technical specifications as references in the core operating limits report (COLR).

Regulatory guidance for the review of fuel rod cladding materials and fuel system designs and adherence to 10 CFR Part 50 Appendix A, General Design Criteria (GDC) 10, 27, and 35 is provided in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 4.2, "Fuel System Design". In accordance with SRP Section 4.2, the objectives of the fuel system safety review are to provide assurance that:

- The fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs),
- Fuel system damage is never so severe as to prevent control rod insertion when it is required,
- The number of fuel rod failures is not underestimated for postulated accidents, and
- Coolability is always maintained.

GESTAR II provides a licensed reload methodology, including an NRC-approved fuel thermal-mechanical design methodology utilized to demonstrate compliance with the fuel design criteria in SRP Section 4.2. The fuel thermal-mechanical design methodology and design criteria in GESTAR II are based upon the NRC-approved GSTR-M methodology. The GSTR-M methodology is approved up to a peak pellet exposure of [[ ]] In response to NRC staff concerns regarding the conservatism of GSTR-M calculations, GEH performed several Part 21 Notification evaluations (References 4, 5, and 6). The GEH basis for concluding that the application of GSTR-M for GNF2 fuel does not constitute a reportable condition under 10 CFR Part 21 is based upon limiting this application to [[ ]] Specifically, the Part 21 Notification (Reference 6) states:

> More specifically, this evaluation demonstrates that the GESTR-M code and associated application methodology is adequate for GNF2 fuel [[ ]]

A subsequent revision to the GNF2 GESTAR II Compliance Report (Reference 7) captured this qualification, stating:

> The GNF2 peak pellet exposure based on the GESTR-Mechanical model is limited [[ ]] consistent with Reference 58 [Part 21, Supplement 2].

The GEH justification (as to why the GSTR-M application to GNF2 does not constitute a reportable condition under 10 CFR Part 21) does not address operation [[ ]] GEH has not demonstrated (1) an adequate level of conservatism within the GSTR-M methodology nor (2) an acceptable GNF2 fuel performance over the entire range of the NRC staff's original review and approval [[ ]] Furthermore, as will be discussed in Section 3.0 of this SE, independent calculations performed by the NRC staff reveal that the GNF2 fuel rod design violates design requirements prior to the approved end-of-life (EOL).

In response to NRC staff concerns regarding the application of a fuel rod nodal exposure limit, which is more restrictive than the NRC staff's current approval of GESTAR II (including GSTR-M methods), GNF submitted Amendment 32 to GESTAR II.

3.0 TECHNICAL EVALUATION

The latest approved version of GESTAR II is Amendment 30 to NEDE-24011-P (Reference 8). Amendment 31 updates the Stability Analysis and is currently undergoing staff review. Amendment 32 addresses staff audit findings and proposes a more restrictive fuel exposure limit for application of GESTAR II to GNF2 fuel.

Up to a peak pellet exposure [[GEH has addressed (1) the adequacy of GSTR-M for application to GNF2 (Reference 6) and (2) GNF2 fuel design's compliance with GESTAR II approved design methodology and design criteria (Reference 7). Amendment 32 (Reference 1) builds upon these previous evaluations and specifically addresses each audit finding.

The staff's assessment of GEH's response to each audit finding (located in Table 1, Enclosure 1, Reference 1) is provided below.

Audit Finding #1:
Based on limited lead use assembly (LUA) operating history and the lack of a post-irradiation examination (PIE) to validate in-reactor performance up to EOL exposure, GEH has neither met the intent of the GESTAR II LUA requirement, nor satisfied established regulatory practice.

In its response, GEH states that the LUA program for GNF2 "…is completely consistent with GESTAR II and with the long history of LUAs applied under GESTAR II." Further, GEH states that the "…evolutionary changes from an experience base of over 26,000 GE14 and GE12 bundles, not warranting more extensive LUA exposure or examinations." The NRC staff does not accept this position and expects further in-reactor experience and inspection prior to batch application.

GEH acknowledges that continued inspections at interim exposures are planned and will reveal any unanticipated behavior well before GNF2 reload bundles reach similar exposures. In addition, the exposure of GNF2 LUAs will always lead the reloads by a substantial margin.

Approval of the application of GESTAR II and use of GNF2 fuel for the [[ ]] is supported by the limited LUA operating experience documented in the compliance report and in Amendment 32. Extension [[ ]] requires further LUA operating experience and inspection along with NRC review and approval.

Audit Findings #2, #6, #7, #8, and #9:
All findings are related to adequacy of GSTR-M methods [[ ]]and GNF2 No Clad Liftoff (NCLO) rod internal pressure design calculations.

In addition to the detailed information provided by GEH, the NRC staff has performed independent calculations using the FRAPCON-3 fuel thermal-mechanical model. The NRC staff's calculations are documented in Table 3 of the audit report (Reference 3). The FRAPCON-3 calculations confirm that the GNF2 fuel rod design satisfies all thermal-mechanical design criteria except NCLO rod internal pressure criteria. Independent calculations reveal that the NCLO criteria (cladding creep outward, fuel pellet/cladding gap opening) are violated prior to the approved EOL [[ ]]

The FRAPCON-3 calculations confirm earlier concerns regarding the adequacy of GSTR-M at higher burnup. Specifically, GSTR-M calculations under predict UO_2 fuel temperature, which results in an under prediction of fission gas release and rod internal pressure. Hence, GSTR-M calculations do not predict ~~N~~CLO for the GNF2 fuel rod design.

In Item 2 of Table 1 (Reference 1), GNF states that GE11 fuel rods were licensed at [[ ]] Based upon the concerns discussed above, this would bring into question the adequacy of the GSTR-M calculations for these higher power fuel rods. During a past audit, the NRC staff discussed the impact of the GSTR-M 10 CFR Part 21 concerns on the GE11/13 rod designs. Crediting the larger fuel rod plenum region of the GE11/13 (relative to the GE14 design), GEH provided sample rod internal pressure calculations, which demonstrate significant pressure margin to the NCLO criteria. GEH stated that millions of GE11/13 rods have operated to design exposures with no indications of problems due to high internal rod pressure. This design is now being phased out in BWR/3-6 reactors, but is still being supplied to BWR/2 reactors. However, its application to BWR/2 reactors is limited to a peak linear heat generation rate [[ ]] due to the loss-of-coolant accident (LOCA) response characteristics for these reactors. The NRC staff accepts the disposition of this issue for GE11/13 fuel rods designs.

The NRC staff's independent calculations predict ~~N~~CLO of the GNF2 fuel rod design, but at an exposure [[ ]] Based upon the GEH thermal-mechanical analyses and the NRC staff's independent calculations, the NRC staff finds the application of GSTR-M to GNF2 fuel acceptable up to a peak pellet exposure of [[ ]] Extension [[ ]] requires further justification. This may involve using an approved PRIME methodology and/or a modified GNF2 fuel rod design. NRC review and approval is required to [[ ]]

Audit Finding #3:
The GNF2 design continues to use the [[ ]] strain design criteria. While this approach is consistent with GESTAR II, it does not address issues identified by the NRC staff during the economic simplified BWR (ESBWR) review of GE14E fuel design. Note that GEH plans to revise the fuel rod cladding strain design criteria for the ESBWR fuel design (GE14E). GEH needs to demonstrate, via empirical data, that the GNF2 fuel rod cladding is capable of achieving the [[ ]] at EOL conditions or revisit the criterion.

This item is discussed in Supplement 2 of the Part 21 Notification (Reference 6). GEH states that the exposure-dependent strain limits proposed for ESBWR are consistent with the analyzed strain criteria [[ ]] The NRC staff agrees with this statement. However, the GNF2 Alloy X-750 grid spaces provide an additional source of hydrogen pickup for the fuel rod cladding which must be considered when setting the exposure-dependent breakpoint. Extension [[ ]] requires further justification for the exposure-dependent strain limits for GNF2 and NRC review and approval.

Audit Finding #4:
The GNF2 fuel rod design needs to include limits for cladding corrosion. **(2nd Sentence doesn't follow from the 1st)** While this approach is consistent with GESTAR II, corrosion limits are required to ensure that key assumptions related to fuel performance analyses remain applicable. Specifically, an upper limit on local cladding oxidation (corresponding to oxide spallation) and an upper limit on local cladding hydrogen content (corresponding to the strain limit) need to be provided.

This item is being addressed for the GE14E fuel assembly design in the ESBWR design review. It is anticipated that a similar approach will be pursued for GNF2. Since cladding corrosion is expected to be low [[

]] Extension [[ ]] requires further justification, established corrosion limits, and NRC review and approval.

Audit Finding #5:
The GNF2 design maintains an allowance for fuel centerline melting during local anticipated operational occurrences (AOOs). While this approach is consistent with GESTAR II, little data is available to validate fuel swelling models at melting conditions, especially for higher burnup fuel. In addition, little data is available to validate fuel performance models for future operation with fuel rods which have previously undergone melting. If GNF desires to maintain this approach, then validation of these models against measured data should be included in the ongoing PRIME review.

In its response, GEH states that the GSTR-M application methodology is such that melting during local AOOs is precluded for any fuel design and that current reloads do not utilize the GESTAR II allowance for limited fuel melting. The NRC staff considers this issue resolved for GNF2 fuel.

Audit Finding #10: Open Items.

Amendment 32 provides a response to the open items identified in the NRC staff's GNF2 audit (Reference 3). The first open item requested information related to GNF2 channel design's susceptibility to shadow corrosion induced channel bow. In its response, GEH stated that the minor differences between GNF2 channels and GE14 channels will not exacerbate channel bow. Further, GNF continues to manage channel distortion via the cell friction methodology, which minimizes the likelihood of control blade interference. Based upon ongoing efforts to control channel bow and no significant differences in channel design (which would exacerbate the issue), the NRC staff finds the GNF2 channel design acceptable.

In a second open item, the NRC staff requested information related to the effect of GNF2 design features on flow induced vibration. In its response, GEH stated that there were no known occurrences of grid to rod fretting failures in GNF BWR fuel designs over several decades of deployment. To date, inspections on GNF2 LUAs have shown no abnormal indications near grid locations. The NRC staff finds the application of GESTAR II and use of GNF2 fuel for the [[ ]]acceptable based on the limited LUA operating experience (especially fuel rod wear inspections under grid straps). Extension beyond the [[ ]] requires further justification that assembly design features (e.g., introduction of mixing vanes) do not introduce fuel rod vibration and the potential for grid-to-rod fretting and NRC review and approval.

In a third open item, the NRC staff requested information related to the inclusion of water holes in the water rod structural analysis. In its response, GEH concluded that while the water rod holes were not explicitly modeled in the finite element analysis (FEA), the amount of conservatism in the structural calculations assuming all loads are applied at the minimum water rod diameter offsets the reduced cross-sectional effect of both sets of water rod holes. During a recent ESBWR audit, the NRC staff questioned similar engineering judgments for the GE14E fuel design. GEH, following its corrective action program, is performing detailed FEA calculations (modeling the water rod holes) to investigate its conclusion. The GNF2 fuel design does not introduce any new design features which exacerbate this potential problem. As such, the NRC staff considers this issue to be generic in scope and not specific to its approval of Amendment 32 or the GNF2 fuel design.

In a fourth open item, the NRC staff requested information related to the applicability of power ramp test results to GNF2 fuel. In its response, GEH stated that current GNF2 fuel designs have the standard barrier cladding design. Historically, the inclusion of the zirconium barrier has been an effective method on minimizing vulnerability to pellet cladding interaction (PCI)/stress corrosion cracking (SCC). A comparison of power ramp test results with barrier cladding (Figure 1 of Reference 1) shows that PCI/SCC failure would not be expected at or below the GNF2 rod power envelope. In its response, GEH provides a discussion of the applicability of the power ramp test results to the GNF2 design. GEH states that the local cladding stresses are driven by the change in local power (and resulting pellet strain) and independent of rod diameter and cladding thickness. One item not discussed is the initial pellet-to-cladding gap size between the older test rods and GNF2. For a given power change, initial gap size will impact cladding stresses. This item requires further investigation prior to removing the [[ ]]limit.

The GNF2 design includes a non-barrier option. Due to the limited scope of this review and schedule restrictions, the NRC staff was unable to reach a safety finding with respect to the acceptability of a non-barrier GNF2 fuel rod design. Hence, the staff's approval of Amendment 32 for GNF2 is limited to the zirconium barrier fuel rod design.

In a fifth open item, the NRC staff requested information related to local cladding hydrogen concentration near the Alloy X-750 grid spacers. In its response, GEH concludes that the performance of GNF2 will not be adversely affected by shadow corrosion and hydriding at spacer locations, especially given the rod exposure limit. Based upon anticipated corrosion (and hydrogen pickup) during the limited rod exposure, the NRC staff finds this response

acceptable. However, further data needs to be provided to justify extended [[
]]

As indicated in Table 1 of Reference 1, Audit Findings #11 through #22 do not require any actions or response.

Table 2 of Reference 2 provides "Commitments to Changes in GESTAR II and the GNF2 Compliance Report." The commitments include changes to GESTAR II to incorporate the PRIME thermal-mechanical methodology (currently under NRC staff review) and to address audit findings. Since these commitments involve future changes to an NRC-approved TR, they are outside the NRC staff's review of Amendment 32 and must be submitted separately for NRC staff review and approval.

Based upon the disposition of the GNF2 audit findings above, the NRC staff finds the application of GESTAR II and use of GNF2 fuel for the [[
]] acceptable. As noted above, extension [[ ]] requires further justification and NRC review and approval.

4.0 LIMITATIONS AND CONDITIONS

Licensees referencing TR NEDE-24011-P-A/NEDO-24011-A, for batch loading of GNF2 fuel assemblies must ensure compliance with the following conditions and limitations:

1. The GNF2 fuel assembly design is approved for [[
]]

2. The NRC staff review and approval is limited to the zirconium barrier GNF2 fuel rod design.

3. The application of GESTAR II to the GNF2 fuel assembly design is approved for [[
]]

5.0 CONCLUSION

Based upon its review described above, the NRC staff finds Amendment 32 to NEDE-24011-P-A/NEDO-24011-A, entitled "General Electric Standard Application for Reload Fuel (GESTAR II)," acceptable. Licensees referencing Topical Report NEDE-24011-P-A/NEDO-24011-A need to comply with the conditions listed in Section 4.0 of this SE.

6.0 REFERENCES

1. Letter from A. Lingenfelter (GNF) to U.S. Nuclear Regulatory Commission, AAmendment 32 to NEDE-24011-P-A, General Electric Standard Application for Reactor Fuel (GESTAR II)," FLN-2008-011, October 15, 2008 (ADAMS Package Accession No. ML082910505).

2. Letter from A. Lingenfelter (GNF) to U.S. Nuclear Regulatory Commission, AGNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II), NEDC-33270P,

March 2007, and GEXL17 Correlation for GNF2 Fuel, NEDC-33292P, March 2007," FLN-2007-011, March 14, 2007 (ADAMS Accession No. ML070780335).

3. NRC Memorandum, "Audit Report for GNF2 Advanced Fuel Assembly Design GESTAR II Compliance Report," September 2008 (ADAMS Package Accession No. ML082690382).

4. Letter from J. Post (GEH) to U.S. Nuclear Regulatory Commission, APart 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M," MFN 07-040, January 21, 2007 (ADAMS Package Accession No. ML072290203).

5. Letter from D. Porter (GEH) to U.S. Nuclear Regulatory Commission, APart 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M – Supplement 1," MFN 07-040 Supplement 1, January 4, 2008 (ADAMS Accession No. ML080100670).

6. Letter from D. Porter (GEH) to U.S. Nuclear Regulatory Commission, APart 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M – Supplement 2," MFN 07-040 Supplement 2, August 28, 2008 (ADAMS Package Accession No. ML082420309).

7. Letter from A. Lingenfelter (GNF) to U.S. Nuclear Regulatory Commission, AGNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II), NEDC-33270P, Revision 1, August 2008," FLN-2008-008, August 29, 2008 (ADAMS Accession No. ML082460763).

7. Letter from H. Nieh (USNRC) to A. Lingenfelter (GNF), "Final Safety Evaluation for Global Nuclear Fuel (GNF) Amendment 30 to Topical Report (TR) NEDE-24011P-A/NEDO-24011-A, 'General Electric Standard Application for Reload Fuel (GESTAR II)'," February 11, 2008 (ADAMS Accession No. ML080310007).

Principle Contributor: P. Clifford

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