ENCLOSURE 2

MFN 10-045

Amendment 32 Safety Evaluation Follow-on Items and GNF Response

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 10-045, which has the proprietary information removed. Portions of the document that have been removed are indicated by white space with an open and closed bracket as shown here [[ ]].

<table>
<tr><th>NRC Summary Statement from Amendment 32 Safety Evaluation</th><th>GNF Response</th></tr>
<tr><td>
Audit Finding #1:

Extension [[ ]] requires further LUA operating experience and inspection along with NRC review and approval.
</td><td>
The following provides an update to the experience base for GNF2 through January 2010. As of January 2010, 32 GNF2 LUA bundles have been loaded into each of the following plants:
<table>
<tr><td>KKM</td><td>9/2005</td><td>12-month cycle</td></tr>
<tr><td>Peach Bottom-3</td><td>10/2005</td><td>24-month cycle</td></tr>
<tr><td>Forsmark-3</td><td>5/2006</td><td>12-month cycle</td></tr>
<tr><td>Forsmark-3</td><td>8/2008</td><td>12-month cycle (second set)</td></tr>
<tr><td>Vermont Yankee</td><td>6/2007</td><td>18-month cycle</td></tr>
<tr><td>Gundremmingen-C</td><td>10/2009</td><td>12-month cycle</td></tr>
</table>

The current peak pellet exposure (PPE) of the existing LUAs at KKM is over [[ ]] with bundle average exposure of around [[ ]] The LUAs at Peach Bottom-3 completed their 2nd 24-month cycle in the Fall of 2009 with a bundle average exposure of [[ ]]

Inspections have been performed on LUAs from KKM after each of the four 1-year cycles, after each of the first two, 2-year cycles at Peach Bottom, mid-way through the first cycle at Forsmark, and after one eighteen month cycle at Vermont Yankee.

In addition to performance indicators typically observed during inspections, such as overall mechanical integrity, rod to rod spacing, cladding condition and extent of oxidation, the inspections have also focused on new features, such as locations above partial-length rods on the periphery of the bundle, spacers, rod-regions under spacers, and single-piece water rod diameter transitions. The inspections to date have established that the performance and behavior is as expected. Continued inspections at interim exposures are planned and will reveal any unanticipated behavior for evaluation well before GNF2 reload bundles reach similar exposures. The exposure of the GNF2 LUAs will always lead the reloads by a substantial margin. The experience in the GNF2 LUA program is consistent with the previous GE14 fuel introduction.

In addition to the LUA experience, in 5 reloads of GNF2 a total of 532 bundles have been introduced into the following 4 plants:

KKM 2008,
KKM 2009,
FitzPatrick 2008,
Pilgrim 2009, and
Cofrentes 2009.

All of these reload bundles are operating in their first cycle, except KKM, where the first set of reload bundles completed one cycle, and several bundles were visually inspected in August 2009. The results were normal and similar to those observed for the prior LUAs.
</td></tr>
</table>

NRC Summary Statement from Amendment 32 Safety Evaluation	GNF Response
Audit Findings #2, #6, #7, #8, and #9: 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 [[ ]]	The GNF2 fuel product has been re-designed using the approved PRIME methodology. Enclosure 7 of this submittal includes Revision 3 of the GNF2 Advantage Generic Compliance Report, NEDC-33270P, which has been revised to include the PRIME design basis.
Audit Finding #3: Extension [[ ]] requires further justification for the exposure-dependent strain limits for GNF2 and NRC review and approval.	The exposure dependent strain limits for GNF2 have been incorporated into the GESTAR II Section 2 revision in Enclosure 4. Enclosure 7 of this submittal includes Revision 3 of the GNF2 Advantage Generic Compliance Report, NEDC-33270P, which has been revised to meet the exposure dependent strain limits.
Audit Finding #4: Extension [[ ]] requires further justification, established corrosion limits, and NRC review and approval.	The corrosion limits for GNF2 using Zircaloy 2 cladding are defined in the GESTAR II Section 2 revision included in Enclosure 4 of this submittal. Enclosure 7 of this submittal includes Revision 3 of the GNF2 Advantage Generic Compliance Report, NEDC-33270P, which has been revised to include the GNF2 corrosion limits.
Audit Finding #5: 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.	The allowance for limited fuel melt during local AOOs has been removed in the GESTAR II Section 2 revision in Enclosure 4 of this submittal.

NRC Summary Statement from Amendment 32 Safety Evaluation	GNF Response
Audit Finding #10 Open Item 2: 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.	There are no known occurrences of grid-to-rod fretting failures in GNF BWR fuel designs over several decades of deployment (See S.A. Bhardwaj, P.R. Pandarinathan, "An Overview of Fuel Performance In Water Cooled Reactors," Journal of Nuclear Materials, doi:10.1016/j.jnucmat.2007.09.008). EPRI, INPO, the utilities, and fuel vendors recently jointly developed Fuel Integrity Guidelines Documents to aid in reaching zero-leaker performance throughout the US LWR fleet. As part of that effort, a PWR-specific guideline has been developed for grid-to-rod fretting. BWRs were exempted from this guideline, as there is no experience with this issue being a problem in any vendor's BWR fuel designs of any size array. The inspections of the GNF2 LUAs to date, led by inspections completed August and September 2009 at [[ ]] bundle average burnup, show completely normal indications at the grid locations. In the GNF2 LUAs, over [[ ]] individual fuel rod-to-spacer contact areas have been completed, with no indications of fretting wear or unusual corrosion, through [[ ]] rod avergage exposure. This has included various rod configurations in GNF2; both lengths of partial length rods, threaded tie rods, as well as a mix of edge, central, UO_2, and Gd rods. The LUAs have been exposed to four years (over 31,000 hours) of operation at normal reactor flow and quality conditions. Experience with both GE12 and GE14 includes operation to ~60,000 hours, with no indications of grid-to-rod fretting.

NRC Summary Statement from Amendment 32 Safety Evaluation	**GNF Response**
Audit Finding #10 Open Item 3: 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.	The analysis of the GNF2 water rod has been completed and the following provides a summary of the analysis. The mechanical design adequacy of the GNF2 water rod with respect to shipping and handling loads, specifically [[ ]] defined in the shipping and handling specification, has been analyzed. This analysis was performed using the same approach as documented in ESBWR RAI 4.2-33 (Revised Response to Portion of NRC Request for Additional Information Letter No. 243 Related to ESBWR Design Certification Application, RAI Number 4.2-33, MFN 08-946 Revision 1, March 30, 2009). The GNF2 water rod analysis applied the same modeling assumptions and ANSYS finite element model configuration. When the water rod is subjected to maximum handling and shipping loads, the stress due to axial compression is of primary concern. Because of the long, thin geometry of the water rod, it is necessary to evaluate the buckling behavior in compression. A static structural analysis was run in ANSYS to determine the equivalent stress throughout the water rod. [[ ]] This very localized stress is [[ ]] but does not compromise the integrity of the water rod. A linear buckling analysis was performed in ANSYS. The buckling load was found to be [[ ]] times the applied load. The finite element analysis of the GNF2 water rod demonstrates that the design adequately sustains the design shipping and handling loads.
Audit Finding #10 Open Item 4a: ...... 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.	See Attachment 1 to this Enclosure.
Audit Finding #10 Open Item 4b: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.	[[ ]]

NRC Summary Statement from Amendment 32 Safety Evaluation	GNF Response
Audit Finding #10 Open Item 5: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 [[ ]]	The corrosion and hydriding potential for hydrogen pickup under the Alloy X-750 spacer grid has been discussed in presentations and written responses. Based on GNF2 LUA poolside inspection results through 4 years of operation, and comparison of these results to the prior GNF design with Inconel spacers, GE12, GNF concludes that the performance of GNF2 will not be adversely affected by shadow corrosion and hydriding at spacer locations. The shadow corrosion observed around the spacers of the GNF2 LUAs is consistent with the GE12 and GE14 experience base. The LUA program will continue to provide observations of corrosion in these regions to the end of the design lifetime [[ ]] GNF will continue to examine the under grid locations to ensure that the corrosion and hydriding is well understood and characterized. Attachment 2 to this Enclosure presents a summary of the latest GNF2 inspection results, highlighting areas around Inconel spacers, and information on Hydrogen content at spacers from hotcell exams.

Attachment 1: Applicability of Ramp Test Data to GNF2 Fuel

In the GNF response noted from Attachment 1 Reference 1, the ramp test data provided was obtained largely from tests on 8x8 fuel rods. The GNF2 design is a 10x10 design and has different dimensions than the test data, as shown in Attachment 1 Table 1 below.

From Attachment 1 Table 1, it is noted that the [[ ]] for the GNF2 design and the ramp test fuel rods. In the Attachment 1 Reference 1 response, GNF provided discussion to support application of the ramp test data to the GNF2 design. The discussion first uses Fourier's heat transfer equation to show that pellet temperature and thermal expansion, [[

]] The Attachment 1 Reference 1 discussion then concludes that the ramp test results are applicable to GNF2 fuel rods.

The Attachment Reference 1 GNF response did not explicitly address [[ ]] Extending the initial GNF response, it is noted that [[

]] Based upon the initial GNF response, it is concluded that the stress and strain induced in the cladding due to a power ramp will be comparable for two fuel designs if the strain required to close the pellet-cladding gap is comparable for the two designs.

Attachment 1 Table 1

Comparison of GNF2 and Ramp Test Data (Nominal) Dimensions

	GNF2	Ramp Test
[[		
		]]

GNF has utilized this conclusion in the evolution of its fuel designs. The evolution of the designs is based upon maintaining the proven performance of earlier designs. [[

]] it is concluded that the ramp test data is applicable to the GNF2 design. This conclusion is further supported by noting that the gap strains in Attachment 1 Table 1 do not include the effects of (1) gap closure mechanisms (pellet relocation, pellet swelling and cladding creepdown) and (2) design improvements in the GNF2 design relative to the ramp test design, which will diminish the effect of the already small difference in gap closure strains.

In summary, based upon the small sensitivity of power ramp test results to [[
]] for the GNF2 and ramp tests rods, GNF concludes (1) that the ramp test data is applicable to GNF2 and (2) that the data supports GNF2 operation beyond the first cycle of operation and up to at least [[ ]]

Reference:

1. Letter from A. Lingenfelter (GNF) to U. S. Nuclear Regulatory Commission, "Amendment 32 to NEDE-24011-P-A, General Electric Standard Application for Reactor Fuel (GESTAR II)," FLN-2008-011, October 15, 2008.

Attachment 2 - Corrosion and Hydriding Discussion

In 2008, GNF reported that poolside inspections of GNF2 LUAs through [[ ]] had revealed shadow corrosion observations for the areas under alloy X-750 spacers that were consistent with prior experience with the GE12 fuel design, which had already been operated to end of life discharge exposures in a number of plants, including one LUA campaign to [[ ]] bundle average exposure. [[ ]]

Additional inspections completed since the 2008 report, most notably at KKM and PB3 after ~4 years operating time and exposures of [[ ]] in 2009, continue to indicate the same result. No spalling has been noted to date in shadow-corrosion affected areas under the spacers. The poolside measured liftoff or profilometry results are consistent with expectations and with prior GE12 experience. Attachment 2 Figure 1 and 2 below summarize the data and observations.

Attachment 2 Figure 1 illustrates that the shadow corrosion in GNF2 compares, very similarly, to the prior GE12 experience base. Experience with GNF2 has reached the lower [[ ]]

Attachment 2 Figure 2 is an expanded view of the liftoff (corrosion) measurement trace in the area around an earlier design GE12 spacer, and a currently-operating GNF2 spacer, which [[ ]]

[[

]]

Attachment 2 Figure 1

Quantification Of Shadow Corrosion Under Alloy X-750 Spacers For GNF2 And GE12

[[

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Attachment 2 Figure 2

Expanded View Of A Typical Shadow Corrosion Affected Area Under Alloy X-750 Spacers

Relevant comparison data to quantify the expected shadow corrosion performance in GNF2 is available from hotcell examinations of high exposure GE11 Zircaloy ferrule spacers with Alloy X-750 springs, and from GE12 water rods, with all-X-750 spacers, similar to GNF2.

The visual appearance (See Attachment 2 Figure 3) of shadow oxide beneath spacers is very similar for X-750 springs, or all-X-750 designs. The affected area is larger for all-X-750 designs, because instead of [[

]]

[[

]]

Attachment 2 Figure 3

Spacer Shadow Oxide Visual Appearance

A hydrogen localization is not expected to occur at the spacers, because a gradient to support diffusion of hydrogen away from the shadow corrosion affected areas will be maintained between these areas and the lower hydrogen in the surrounding cladding. GNF has estimated that [[

]] and is illustrated in Attachment 2 Figures 4 and 5. Attachment 2 Figure 4 shows that this rod had enhanced shadow corrosion at the X-750 spacer springs, at various elevations, above the background corrosion level. Attachment 2 Figure 5 shows that, despite shadow oxide of [[ ]] at the springs, there is no detectable difference in hydrogen content when the azimuthally opposite side of the fuel rod is compared to the point just beneath the X-750 springs. No hydrogen localization occurred at the spring contacts, and hydrogen redistribution was effective, as anticipated, due to the diffusivity of hydrogen.

[[

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Attachment 2 Figure 4

Spacer Spring Shadow Oxide Visual Appearance

[[

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Attachment 2 Figure 5

Spacer Spring Local Hydrogen Concentration Comparison

Finally, data from a water rod from a GE12 all-X-750 spacer bundle at [[ ]] can be used to help bound hydrogen content estimates for GNF2 near the spacers. The water rod data is conservative relative to fuel cladding for a number of reasons, including the water rod experiencing two-sided corrosion, higher hydrogen pickup characteristics, the water rod material being less corrosion resistant than the cladding, and the fact that hydrogen behavior in fuel cladding is dominated by the heat generation effect in the cladding. Attachment 2 Figure 6 shows radar plots of local oxide thickness at, and ~2" from, spacer elevations. The ID and OD oxide are about the same, [[ ]] away from spacers, and the ID oxide under the spacer is the same as away. The ID oxide contributed [[ ]] away from the spacer. The maximum oxide thickness observed at the OD, under the spacer, of [[ ]] The shadow corrosion appears to saturate at approximately this exposure. Accounting for the different dimensions of GNF2 cladding vs. the GE12 water rod, and noting the conservatisms above (one-sided vs. two sided corrosion, etc.) the expected maximum hydrogen concentration in a GNF2 fuel rod under an X-750 spacer is less than the [[ ]] noted here. Therefore, it is concluded that this data provides a reasonable upper bound estimate for end of life hydrogen concentration near GNF2 spacers.

[[

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Attachment 2 Figure 6
GE12 Water Rod Corrosion And Hydrogen PIE Data At X-750 Spacers