May 28, 2015

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
GE-Hitachi Nuclear Energy
P.O. Box 780 M/C A-18
Wilmington, NC 28401

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION REGARDING REVIEW OF LICENSING TOPICAL REPORT NEDE-33376P, "APPLICATION OF NSF TO GNF FUEL CHANNEL DESIGNS" (TAC NO. MF0742)

Dear Mr. Head:

By letter dated February 13, 2013, Global Nuclear Fuel – Americas, LLC (GNF) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review Topical Report NEDE-33798P, Revision 0, "Application of NSF [niobium, tin, iron] to GNF Fuel Channel Designs" (Agencywide Documents Access and Management System Accession No. ML130450514). Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. Enclosed with this letter is a non-proprietary version of our Request for Additional Information (RAI). On May 4, 2015, James Harrison, GEH Vice President, Fuels Licensing, Regulatory Affairs, and I agreed that the NRC staff will receive your response to the enclosed RAI questions within 21 days of receipt of this letter. If you have any questions regarding the enclosed RAI questions, please contact me at (301) 415-1002.

Sincerely,

/RA/

Joseph A. Golla, Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosure:
RAI Questions (Non-Proprietary)

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ADAMS Accession No.: ML15125A034 **NRR-106**

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DATE	05/18/2015	5 /20/2015	5/26/2015	5/28/2015	5/28/2015

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<u>REQUEST FOR ADDITIONAL INFORMATION (RAI) QUESTIONS</u>

<u>BY THE OFFICE OF NUCLEAR REACTOR REGULATION</u>

<u>NEDE-33798P, REVISION 0, “APPLICATION OF NSF [NIOBIUM TIN IRON] TO</u>

<u>GNF [GLOBAL NUCLEAR FUEL] FUEL CHANNEL DESIGNS”</u>

<u>GLOBAL NUCLEAR FUEL – AMERICAS, LLC (TAC NO. MF0742)</u>

RAI-1 NSF Alloy Composition

Section 2.2 of NEDE-33798P defines the nominal composition and allowable ranges of major alloying elements. Current practice is to define nominal along with a tight range for manufacturing tolerance. While the American Society for Testing and Materials (ASTM) allows a broader range, it also comes with required periodic testing. Further justification is required for the proposed ranges.

a) With respect to corrosion rates, a similar Zr-Nb-Sn-Fe alloy shows dramatic differences between 1.2 percent - 0.6 percent Sn. This is contrary to a portion of your justification. Please describe the influence of Sn on the expected corrosion of NSF channels within the proposed ranges.

b) Section 2.2.3 provides no discussion of the potential effect of alloying composition on shadow corrosion. On a similar note, there is no discussion on hydrogen uptake. Please describe the influence of alloying composition on hydrogen uptake and shadow corrosion induced bow.

c) According to Table 2-1, the nominal composition of NSF includes 1.0 percent Sn, and 0.12 percent O. GNF provided strength data for a nominal composition. In the Licensing Topical Report (LTR) for Ziron cladding, GNF indicated that the YS and UTS for Ziron cladding was likely **[** **]** Table 2-2 of NEDE-33798P lists an allowable minimum content of **[** **]** Sn and **[** **]** O.

   i. Describe the impact of these minimum ranges of Sn and O on TS and UTS.
   ii. Describe the impact of these minimum ranges of Sn and O on creep rate and channel bulge calculations.
   iii. Describe the impact of these minimum ranges of Sn and O on maximum channel distortion predictions (bow and bulge).
   iv. Identify any post-irradiated data from NSF lead channels at these lower ranges.

RAI-2 Range of Applicability

Section 4 of NEDE-33798P is titled “Applicability.” Besides the discussion of allowable range of alloying elements in Section 2.2.3 of NEDE-33798P, there is no attempt to define a range of applicability of NSF material to GNF channel designs. Are further limitations necessary based on the extent of in-reactor experience and empirical database? For example, is a limit on residence time, neutron fluence (or equivalent fuel burnup), and/or effective control blade exposure (ECBE) necessary?

RAI-3 Hydrogen Pickup and Corrosion

Figures 2-12 and 2-20 of NEDC-33798P provide measured oxide thickness and absorbed hydrogen for NSF and Zry-2 channels.

a) Does GNF have experience with Zry-4 channels? If so, describe the relationship between Zry-4 and NSF channels with respect to oxidation and hydrogen absorption.

b) Figure 2-12 shows a single data point and one standard deviation for NSF corrosion. The NSF data point sits just above the maximum corrosion data point for Zry-2. Beneath the NSF data point is a Zry-2 data point, i.e., at the same exposure time (~5.83 years).

   i. Describe the basis (e.g., local maximum, average) of the Zry2 Design Upper Bound curve, which is given by equations 2-32, 2-33 and 2-34 in the LTR.
   ii. Describe the relationship (i.e., irradiation conditions, fluence) between the NSF data point and the Zry-2 data points around ~5.83 years.

c) Figure 2-20 shows hydrogen absorption as a function of hydrogen generated for a NSF channel and a Zry-2 channel operated in symmetric core locations.

   i. Describe the higher hydrogen generated in the NSF channel.
   ii. Describe how hydrogen absorption is affected by duty, fluence, and water chemistry (e.g., HWC, NMCA, OLNM).
   iii. Identify any differences between operations of these two channels (e.g., ECBE).

d) Please provide any data for NSF oxidation and hydrogen uptake taken since this topical report was submitted.

e) In MFN 12-074, GNF states, "The measured oxide thickness of NSF after **[**
]For comparison, the measured oxide thickness of Zircaloy-2 channels after **[**
]." The statement appears to refer to the data expressed in the following figure and table:

[

TABLE I. Oxide Thickness Measurements of Zircaloy-2, NSF and Zircaloy-4 Channels

Channel Material (GWd/MTU) [inch-days]	Elevation (in/mm)	Non-Blade Side		Blade Side	
		Outer Surface (μm)	Inner Surface (μm)	Outer Surface (μm)	Inner Surface (μm)
Zr-2	120/3048	10.2	14.6	9.1	16.7
(49.2)	90/2286	9.5	14.5	13.4	18.1
[4222]	55/1397	9.5	14.4	9.1	17.2
	20/508	9.9	5.9	4.7	10.7
	Ave.	10	12	9	16
NSF	120/3048	22.8	36.4	19.1	34.4
(49.1)	90/2286	22.6	34.9	24.7	38.4
[4222]	55/1397	27.6	33.2	30.7	27.7
	20/508	11.7	18.6	19.7	18.3
	Ave.	21	31	24	30

]

Figure. MFN 12-134, p. 77 (78 of 82 in pdf)

(**Table I.**, Paul E. Cantonwine, Yang-Pi Lin, Dan R. Lutz, David W. White, and Kevin L. Ledford, "BWR Corrosion Experience on NSF Channels," Paper 8465, Topfuel 2013, Charlotte, September 15-19, 2013.)

i. The oxidation rate for NSF seems to be a factor of 2 or 3 times that of Zry-2. Are these results obtained under the same irradiation conditions and duty level? What is the expected corrosion thickness after 8 years of operation?
ii. GNF measurements indicate that the inside oxide thickness is greater than the outside thickness. In Equation 2-31 (LTR), what corrosion thickness is used – inside or outside?

f) The LTR does not address high temperature corrosion for NSF channels under accident conditions.

i. Describe the expected peak channel temperature history during the limiting Boiling Water Reactor (BWR) Loss of Coolant Accident (LOCA).
ii. Describe the predicted corrosion and channel performance under these conditions.
iii. Provide weight gain vs time for NSF and Zry-2 material (see Figure B-15 of NEDC-33353P, Revision 0) for the above conditions, or 1000°C.

RAI-4 Channel bow, creep and oxidation

a) MFN 12-134 provided significant background for the NSF channel performance. The shadow corrosion-induced bow data for NSF channels is limited relative to the Zry-2 data presented on page 75. Please provide this figure with only the NSF LUC data compared to the Zry-2 control channels that operated under similar conditions to the NSF channels.

b) Please provide measured creep data for NSF and Zry-2 at same temperature and differential pressure.

c) Describe the maximum ECBE and fluence for a GNF BWR channel under normal controlled operation throughout its lifetime (i.e., not suppressed).

RAI-5 Channel Growth

Figure 2-13 of NEDE-33798P provides NSF and Zry-2 channel growth data, as well as NSF and Zry-2 irradiation growth data from BOR-60.

a) Correlate fluence to assembly average exposure for the NSF channel data.
b) Describe the irradiation conditions, particularly ECBE, for the NSF and Zry-2 channel growth data.
c) The maximum fluence reported for NSF channel data is about **[** **]** Please provide any data for NSF channels at higher fluences.
d) What is the expected maximum fluence for NSF channels in 6 and 8 years of operation?
e) Describe the difference in growth behavior between the NSF BOR-60 data and the NSF channel data.

RAI-6 Calculating CPR with NSF Channels

a) Section A.2.2 of NEDE-33798P states, "Fast fluence (E>1MeV) gradient induced bow results from differential growth of channel material on opposite channel faces." In Section 3.1.5, GNF states, "NSF channels do not bow significantly as a function of exposure, . . ."

   i. Given that the data in Figure 2-13 show much the same growth behavior for Zry-2 and NSF channels, would not the differential growth be similar, and therefore the fluence-induced bow?
   ii. Describe the magnitude of bow that would be considered "significant."

b) Figure 3-1 of NEDE-33798P provides calculated values of CACABO for 12 cycles of NSF cores.

   i. For the data presented in Figure 3-1, please provide the channel type (e.g., 120/75, 100/60), the irradiation conditions for the calculated cases, including cell lattice (D, C, S), core power density, cycle length (EFPD) and ECBE at the beginning and end of the cycle. As part of the response, please indicate if the cycle is first, second, or third cycle.
   ii. Please provide the CACABO values for a Zry-2 channel as a function of cycle exposure for Cycle F in Figure 3-1.
   iii. Please provide the CACABO values for a Zry-2 channel as a function of cycle exposure for the case in Figure 3-1 with maximum ECBE.

c) Figure A-6 of NEDE-33798P provides predicted versus measured fluence bow for NSF channels with **[** **]**

   i. Please provide P vs M fluence bow data for NSF channels with **[** **]** and M-P as a function of burnup (ref: Figures A-7 and A-8).

ii. Please provide the same data for corresponding Zry-2 channels, i.e., Zry-2 channels with the same or similar irradiation conditions to the same burnup and ECBE as the NSF channels.

iii. In equation A-17 of NEDE-33798P, a weighting factor 'f' is used in conjunction with the controlled time (i.e., time for which the control blade is inserted adjacent to the channel). Please provide an example of how the weighting factor is used for cases where a channel is 1) controlled for two cycles, 2) controlled in the first cycle and uncontrolled in the second cycle, and 3) uncontrolled in the first cycle and controlled in the second cycle.

d) Figure A-8 of NEDE-33798P provides M-P fluence versus exposure. On this figure, the data points for NSF channels with **[**

] What is the predicted and M-P fluence bow for NSF channels with **[** **]** and exposure up to maximum approved burnup levels of GNF fuel assemblies?

RAI-7 Sample Calculation on Channel Bow

a) Please provide sample plots for bow (including FLUBOW, SHADBOW, CHANBOW, BOCELL, CACABO) of Zry-2 and NSF channels as a function of burnup for channels that exhibit different amounts of ECBE and different cycles of operation.

b) In MFN 12-134, on page 72, GNF compares the measured-predicted (M-P) for fluence bow for NSF and Zr-2 channels. The NSF channels seem to have bounds on M-P of fluence bow of **[** **]** In another figure, Figure A-8 from the LTR, the M-P range **[** **]**

Pages 43-45 of MFN 12-134 mentions the uncertainty of channel bow is accounted for in the bundle R-factor calculation, and GNF states, **[**

]

On page 45 of MFN 12-134, GNF states (in NEDO-32601P**), [**

] With regard to FLN 2004-030, GNF indicates that **[**

].

These uncertainties apparently apply to Zr-2 channels.

Please provide a statement or explanation of how the R-factor uncertainty will be developed for and applied to NSF channels.

RAI-8 Measured and Predicted Bow

With respect to the Figure (M vs P, Limerick Lead Use Channel Inspections after 3rd cycle) on page 74 of MFN 12-134 (page 75 of 82 in pdf), please provide M vs P of bow for NSF LUC channels from Hatch 2 (Cycle 20-22) and Perry and Clinton.

RAI-9 Expanded Lead Use Channel Program

GNF proposed an expanded LUC program for NSF channels – MFN 12-074. The NRC approved the expanded program (March 29, 2013, ML13106A068).

a) Please provide an update on the status of current NSF LUA and expanded NSF LUC programs.

b) Please provide the ECBE, EFPD and exposure (assembly burnup) for the channels in the following table.

c) Update the figure below, Inferred Shadow Bow versus ECBE, with the latest data.

RAI-10 Future Surveillance / Reporting Program

The enhanced LUC program was approved to expedite data collection to support batch approval of NSF channels. Depending on the response to RAI-9 above, additional NSF in-reactor data may be necessary. In similar, past situations, the NRC has accepted a surveillance program which mandates data collection, confirmation of empirically-based models or performance, reporting requirements, and, where necessary, actions to ensure safe operation. The NRC has been willing to accept this approach when large quantities of lead use prototypes will continue to lead batch application such that compensatory action would be possible to avoid safety issues.

a) Please propose a surveillance program for the collection of NSF channel growth and distortion data and the confirmation of fluence gradient-induced bow and shadow corrosion-induced bow models. As part of this response, describe a process for updating models, implementing models, and reporting. The NRC is looking for assurance that existing fuel management guidelines, compensatory measures, and augmented control blade surveillances are not minimized prior to achieving high confidence NSF models.

b) Similar to above, for the core-average, cell-average bow input to the channel-bow dependent critical power ratio calculation.

Unit	Type - Lattice	Cycle Inserted	Number of Channels	Year Beginning	Year Discharge
[					
					]

[

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Figure MFN 12-134, p. 75 (76 of 82 in pdf)