UNITED STATES
NUCLEAR REGULATORY COMMISSION
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March 21, 2019

Ms. Michelle P. Catts
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SUBJECT: FINAL SAFETY EVALUATION FOR NEDC-33173P SUPPLEMENT 5 – APPLICABILITY OF GE METHODS TO EXPANDED OPERATING DOMAINS – SUPPLEMENT FOR GNF3 FUEL (EPID: L-2017-TOP-0033)

Dear Ms. Catts:

By letter dated June 8, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17159A680), GE Hitachi Nuclear Energy (GEH) submitted Topical Report (TR) NEDC-33173P Supplement 5 – Applicability of GE Methods to Expanded Operating Domains – Supplement for GNF3 Fuel, to the U.S. Nuclear Regulatory Commission (NRC) staff for review.

By letter dated February 5, 2019, an NRC draft safety evaluation (SE) regarding our approval of NEDC-33173P Supplement 5 was provided for your review and comment (ADAMS Accession No. ML19002A376). By letter dated February 21, 2019, you provided comments on the draft SE (ADAMS Accession No. ML19052A021). The NRC staff's disposition of the GEH comments on the draft SE are discussed in the attachment to the publicly available version final SE enclosed with this letter.

The NRC staff has found that TR NEDC-33173P Supplement 5 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in licensing applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that GEH publish approved proprietary and non-proprietary versions of TR NEDC-33173P Supplement 5, within three months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information (RAIs) and your responses. The approved versions shall include a "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, GEH will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

/RA/

Dennis C. Morey, Chief
Licensing Processes Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Project No. 99902024

Enclosure: Final SE (Non-Proprietary)

SUBJECT: FINAL SAFETY EVALUATION FOR NEDC-33173P SUPPLEMENT 5 – APPLICABILITY OF GE METHODS TO EXPANDED OPERATING DOMAINS – SUPPLEMENT FOR GNF3 FUEL (EPID: L-2017-TOP-0033) DATE: MARCH 21, 2019

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
RELATED TO SUPPLEMENT 5, TO NEDC-33173P-A,
"APPLICABILITY OF GE METHODS TO EXPANDED OPERATING DOMAINS
- SUPPLEMENT FOR GNF3 FUEL"
EPID L-2017-TOP-0033/DOCKET 99902024

1.0 INTRODUCTION

By letter dated June 8, 2017, GE Hitachi Nuclear Energy (GEH, the vendor) submitted Supplement 5, "Supplement for GNF3 Fuel," to topical report (TR) NEDC-33173P, "Applicability of GE Methods to Expanded Operating Domains" (Ref. 1). The supplement documents the applicability of NEDC-33173P, which is also known as the Interim Methods Licensing Topical Report (IMLTR, Ref. 2), to a new fuel design known as GNF3. In response to an U.S. Nuclear Regulatory Commission (NRC) staff request for additional information, GEH submitted Letter M180204, supplementing the IMLTR supplement (Ref. 3). This safety evaluation (SE) refers to Supplement 5 to the IMLTR as IMLTR5.

In the NRC staff SE approving the IMLTR, the NRC staff stated that "the Interim Methods review was applicable to all GE lattices up to GE14" (IMLTR staff SE page 137). Thus, upon completing new fuel designs, GEH submits, for NRC staff review and approval, an IMLTR supplement confirming the IMLTR applicability to that fuel design. Supplement 3 to the IMLTR, for example, addresses IMLTR applicability to GNF2 fuel. The review approach employed in this SE is like that used in the SE for IMLTR3, with some exceptions as noted in Section 3.1, below.

2.0 REGULATORY EVALUATION

The IMLTR provides a basis to establish that the suite of GEH/GNF analytic methods are appropriate for use in expanded operating domains (EODs), which specifically include the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) and the extended power uprate (EPU) operating domains. Both MELLLA+ and EPU are operating enhancements that, together, allow plant operation in conditions of higher thermal power output and reduced core flow, which serve to expand the power-to-flow operating domain. As originally written, the IMLTR provided an interim approach of applying limitations and penalties to account for potentially increased uncertainties in analytic methods, based on limitations in available confirmatory data. Subsequently, GEH has developed newer methods and provided additional data to reduce or eliminate penalties, resulting in changes to the way IMLTR is applied.

The NRC staff review is based on the overarching requirements contained in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.34. The guidance provided in Chapters 4 and 15 of the Standard Review Plan are used. Additional, and more specific, discussion is provided in Section 2.0, "Regulatory Evaluation" of the IMLTR SE, and in Section 2.0, "Regulatory Evaluation," of Appendix K to the IMLTR SE. This discussion is not repeated here.

3.0 TECHNICAL EVALUATION

This evaluation reviews and evaluates the analytic and experimental justification provided in IMLTR5 and follows with a disposition of each of the major topics that are addressed in the SE approving the IMLTR, and again in its Appendix K, which is the SE for the supplement justifying IMLTR applicability to the GNF2 fuel product line.

3.1 Review Scope

The scope of NRC staff review reflects advances made by GEH since the approval of the IMLTR, which are documented in newly approved TRs and in other supplements to IMLTR. The NRC staff stated, in the IMLTR SE, the following:

> If LTR NEDC-33173 is revised or supplemented, the topics addressed in this SE, associated commitments and the limitations and conditions specified in Section 9.0 should be covered, unless GE demonstrates that the limitations are not needed due to changes in the methods or that the additional benchmarking is provided to the NRC staff in another LTR.

Most notably, GNF has obtained approval for NEDC-33256P-A, Revision 1, NEDC-33257P-A, Revision 1, and NEDC-33258P-A, Revision 1, which together comprise “The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance” (Ref. 4). The NRC-approved version of the PRIME TRs was submitted to the NRC staff in 2010. The TRs were found acceptable and applicable to GNF fuel designs, and the conditions and limitations specified in the PRIME TR SE require periodic reconfirmation of the applicability of the PRIME models to current fuel designs. In Appendix A to IMLTR5, GEH stated, regarding Limitation 9.12 from the IMLTR, that “PRIME has been approved and GNF3 utilizes PRIME.” In addition, the text of Limitation 9.12 specifically requires the use of PRIME thermal-mechanical methods, once approved, for plants that reference the IMLTR. Based on the implementation of the PRIME fuel thermal-mechanical methods in the GE suite of fuel performance and safety analyses, the NRC staff did not consider IMLTR applicability to GNF3 with respect to GESTR-M based methods.

3.2 Comparison of GNF3 to Prior Designs

The introduction of an **[ ]** allows the GNF3 design to incorporate several improvements that **[ ]**. Instead of the more recent 10x10 fuel design with **[ ]**

Although the introduction of **[ ]** represents a modest change, the part-length fuel rods remain similarly arranged in comparison to GNF2. **[**

] Figure 1 provides a comparison of the GNF2 and GNF3 lattice designs.

[

]

Figure 1. Comparison between GNF2 and GNF3 lattice designs (pins are not to scale).

Figure adapted from References 5 and 6.

In addition to the above design features, GNF3 also has [

]

From a computational perspective, GNF3 is sufficiently similar to GNF2 that the vendor made no modifications to the nuclear design code system in order to model the new design. Previously, [

] While GNF3 retains similar design features, it did not introduce novel features requiring further code system revision.

3.3 IMLTR Supplement 5 Approach

To confirm applicability of interim methods to the GNF3 fuel design, GEH applied several approaches. These included code-to-code comparisons using MCNP for the neutronic methods, and COBRAG for the thermal-hydraulic methods; comparisons to TIP data from lead use assembly campaigns; and thermal-hydraulic testing at Stern Laboratories. Each of these confirmation efforts is reviewed in this section, while the following sections explain how the confirmation efforts establish that the IMLTR remains applicable to GNF3 fuel.

3.3.1 MCNP Comparisons

Code-to-code comparisons using MCNP were used to confirm computational efficacy of the TGBLA06/PANAC11 nuclear design package.

The vendor assessed TGBLA06 by modeling GNF3 lattices representative of each axial region at beginning and end of cycle conditions, in both controlled and uncontrolled configurations for a variety of moderator densities. Results obtained from TGBLA06 were compared to MCNP results for fission density and infinite lattice reactivity. The differences between the two were aggregated using root mean squares, and the RMS data were plotted for comparison to similar computational differences obtained for prior designs GNF2 and GE14. The results, evaluated in detail below, generally demonstrated that the degree of agreement between TGBLA06 and MCNP was essentially the same as similar comparisons to the prior designs.

In the response to RAI 2 in Reference 2, GEH provided information to show that the lattice designs modeled for GNF3 were comparable to the GE14 and GNF2 lattices used for comparison, and that all lattice designs reflected nuclear characteristics (e.g., enrichment and gadolinia loading) of actual lattices that would be used in EOD plants. In the response to RAI 2, GEH stated, “Given the close geometrical similarities, the existing population of GNF2 lattices were used as an indicator of the future population of GNF3 lattices.” The vendor also stated that GNF2 lattice designs at each elevation were used as the basis for corresponding GNF3 lattices. In Figure 2-1 of the RAI response, **[**

] The supplemental information confirmed that the GNF3 lattice designs considered in the methods evaluation were similar in nature to those used to evaluate the prior GE14 and GNF2 fuel designs. Given the representation of the GNF3 lattices within the population of the prior fuel designs, the NRC staff determined that the lattice designs used to evaluate GNF3 for interim methods applicability were acceptable.

The vendor provided code-to-code comparisons using MCNP and TBGLA06 to show computational consistency in calculating fission density among GE14, GNF2, and GNF3 lattices. In the context of the GEH standard analytic methods using TGBLA06, the process used to generate the MCNP comparisons is described in Enclosure B to Appendix C of the IMLTR.

Figures 2-1 and 2-2 of IMLTR5 illustrate fission density comparisons between TGBLA and MCNP at beginning-of-cycle (BOC) and end-of-cycle (EOC) conditions, respectively. At BOC conditions, **[**

] Meanwhile, at EOC conditions, **[**

] However, a comparison between Figures 2-1 and 2-2 indicated that **[**

][1] Based on its assessment, the NRC staff determined that the RMS differences in fission density for GNF3 were roughly equivalent in magnitude to, and trended similarly with, GNF2 and GE14. This similarity supports a conclusion that the predictive capabilities of TGBLA06 remain consistent when analyzing the GNF3 lattice design.

In its response to RAI 1, GEH provided the tabular data for RMS fission density differences between TGBLA06 and MCNP at **[** **]**, for both GNF2 and GNF3 fuel designs. While the GNF3-specific fission density differences plotted alongside the difference ranges for GNF2 and GE14 designs enabled the staff to confirm that the code-to-code differences among the fuel design were substantially similar, the additional data provided in the RAI response provided a more granular basis to determine whether any adverse or abnormal trending was apparent. Based on side-to-side comparisons of the two fuel designs at the various exposure steps, the NRC staff observed no such abnormal or adverse trends. This data set provided further confirmation of the results depicted in Figures 2-1 and 2-2 of IMLTR5.

Figures 2-3 through 2-5 present infinite lattice reactivity benchmarks between TGBLA06 and MCNP for GNF3, compared to difference ranges for GNF2 and GE14. Figures 2-3 and 2-4 correspond to uncontrolled cases at 0 and 65 GWD/sTU, and Figure 2-5 represents a controlled case at 0 GWD/sTU. These figures included **[** **]**. Similar to the fission density benchmarks, these figures illustrated that the GNF3 comparisons between TGBLA06 and MCNP trended similarly with the prior fuel designs.

The vendor assessed PANAC11 by modeling a **[** **]**. The PANAC11 statepoints were provided to MCNP to analyze the same **[** **]** and provide a comparison. As with TGBLA06, differences between PANAC11 and MCNP were aggregated for the GNF3 designs and compared to similar data for GNF2 and GE14.

In the response to RAI 4, GEH provided **[** **]** The comparison included **[** **]**. The comparison showed **[** **]** that are reflective of the expanded operating domain conditions currently exhibited within the GE14 and GNF2 fuel experience base.

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[1] This trend is reflective of the fact that **[** **]**

In the response to RAI 5, GEH provided additional information describing the comparative process. The process involves **[**

]. The information provided in response to RAI 5 confirmed that **[**

].

GEH evaluated PANAC11 by comparing the RMS difference axially integrated bundle power between PANAC11 and MCNP. The comparison, illustrated in Figure 2-6, showed that GNF3 predictions trended with the predictions for the previous fuel designs.

In evaluating the comparisons supporting applicability of both TGBLA06 and PANAC11, the NRC staff considered that MCNP is a higher order code and can provide a reasonable surrogate for data. It should be noted, however, that the reliance on code-to-code comparisons is acceptable in this respect because of the similarities between the GNF2 and GNF3 designs, and because no changes to the nuclear design codes were needed to model GNF3 relative to GNF2. Given more substantial design differences or the implementation of computer code modifications to support analysis of the new design, comparisons to plant or experimental data would be expected, to confirm the results of the code-to-code comparisons.

3.3.2 Lead Use Assembly Traversing In-Core Probe Data Comparisons

GEH stated that data obtained from TIP measurements in cells containing GNF3 lead use assemblies in a BWR/5 and a BWR/6 indicated no unusual or adverse trends. Should an unusual or adverse trend have been observed, it would have been indicative of a methods issue for the GNF3 design.

In the response to RAI 3 in Reference 3, GEH provided tables of the TIP data applicable to the GNF3 lead use assembly campaigns, from which the summary discussed above was derived. The tabulated TIP data included measurements and statistics from two plants involved in the lead use assembly campaign. Core average calculated-to-measured TIP RMS results were presented for an entire cycle in which the GNF3 assemblies were loaded. In each of the plants, a single GNF3 fuel bundle had been loaded adjacent to a TIP string; the calculated-to-measured axial TIP RMS error and the radial TIP absolute error for these individual TIP strings were also provided.

The NRC staff reviewed the core-average bundle, axial, and nodal TIP RMS results as a function of cycle exposure and confirmed no unusual or adverse trending is exhibited by the data. The NRC staff also reviewed the bundle and axial TIP RMS data for the TIP strings adjacent to the GNF3 lead use assemblies and confirmed the results are within the range of differences predicted for the remaining TIP cells within the core. Because the majority of the remaining core loading for both plants is GNF2 fuel, the results support a conclusion that the nuclear design system is capable of predicting GNF3 performance to a reasonably similar degree of accuracy as the previous GNF2 fuel design.

To further assess the nuclear methods' performance for the GNF3 design, the NRC staff compared the weighted average (averaged across all cases) bundle, axial, and nodal TIP RMS results for both the core-wide and the GNF3-specific TIP strings to those of the historical database. This historical database is presented in the IMLTR, as well as Supplement 2 to the IMLTR (Ref. 7) for the GE14 and GNF2 fuel designs. For this comparison, it is important to note that one of the plants in the GNF3 lead use campaign is equipped with a thermal TIP system. It is known that thermal TIPs may possess a larger measurement uncertainty in comparison to gamma TIPs. Therefore, the gamma TIP data and thermal TIP data were each compared to the respective results within the historical database. The comparisons show the core-wide TIP string and the GNF3 TIP string responses for gamma TIPs are consistent with the historical performance.

For the comparisons of thermal TIP responses, the NRC staff noted a slight inconsistency with the historical performance. The NRC staff attributes this to the sparse thermal TIP data available within the historical database. However, additional thermal TIP data for GE14 and GNF2 fuel designs were provided as part of IMLTR Supplement 6, which is concurrently under review. If the thermal TIP data from IMLTR Supplement 6 are grouped with the historical database thermal TIP data for comparison, the IMLTR5 core-wide TIP string and GNF3 TIP string responses for thermal TIPs also demonstrate consistency in performance. The consistency in performance of both gamma and thermal TIPs supports a conclusion that the nuclear methods' predictive capabilities remain consistent when analyzing the GNF3 lattice design.

3.3.3 Thermal-Hydraulic Qualification

GEH assessed the thermal-hydraulic qualification of its methods relative to GNF3 using several different means. The vendor performed full-scale pressure drop tests, and code-to-code comparisons to evaluate the capability of the Findlay-Dix void correlation to predict void fractions along the height of the GNF3 bundle.

GEH evaluated the applicability of the Findlay-Dix void correlation by performing comparisons between ISCOR09, a parallel channel thermal-hydraulic code, the methods for which are embedded in the PANACEA core simulator, and COBRAG. COBRAG is a sub-channel analysis method that contains a three-field, two-fluid model with interfacial shear, and is thus a higher-order model in comparison to ISCOR09. Figure 2-7 of IMLTR5 depicts channel void fraction as a function of height as predicted by both COBRAG and Findlay-Dix. The figure shows excellent agreement between COBRAG and Findlay-Dix, as was the case with a similar comparison provided for GNF2 fuel in IMLTR Supplement 3. This figure provides evidence that the predictive capabilities of the Findlay-Dix correlation remain applicable and essentially the same when modeling GNF3 fuel relative to GNF2 fuel.

In addition to the code-to-code comparison discussed above, GEH evaluated the GNF3 qualification by comparing the void fraction calculated using Findlay-Dix to that determined using pressure drop measurements in an instrumented test bundle. Figure 2-8 illustrates the GNF3 calculated void fraction error in comparison to prior fuel designs as a function of nodal quality. Meanwhile, Figure 2-9 illustrates the void fraction error estimates for various bundle segments for the GNF3 design specifically. From Figure 2-8, it can be seen that the **[** **]**, while Figure 2-9 shows that **[** **]**. These comparisons complement the code-to-code comparisons with experimentally-based evidence that the Findlay-Dix correlation predicts void conditions in the GNF3 bundle as well as it does prior fuel designs.

3.3.4 Conclusions Regarding GEH's Methods Assessment

Based on the review described in the preceding sections, the NRC staff concluded that GEH has demonstrated that its codes and methods have similar predictive capability when modeling the GNF3 fuel design, as compared to GNF2 and GE14. The remaining sections of this SE relate that demonstration of predictive capability to the considerations addressed in the IMLTR.

3.4 Extrapolation of Neutronic Methods to High Void Fractions

3.4.1 Neutronic Methods Assessment

In its review of GEH's neutronic methods assessment, the NRC staff considered

- Prior trending in terms of methodological capability relative to fuel design upgrades
- Prominence of fuel design changes relative to modeling capability
- Continuity of the means by which GEH assessed the capabilities

When comparing the changes between GE14 and GNF2 to those between GNF2 and GNF3, the staff observes that some features of GNF3 are more similar to GNF2. For example, **[** **]** Thus, while TGBLA06 required modification to model GNF2 relative to GE14, no such modifications were necessary to transition to modeling GNF3.

3.4.1.1 Cold Eigenvalue

The IMTLR discusses the importance of the core simulator's capability to predict the cold eigenvalue. In short, the reactor must be able to remain subcritical with specified margin in the most reactive condition with all control rods inserted except the one with the highest worth. The core simulator is used to demonstrate this capability.

GEH performed **[** **]** code-to-code comparisons, comparing PANAC11 to MCNP, as described in Section 3.3.1, above. GEH performed PANAC11-to-MCNP comparisons of control cells with reflective boundary conditions for each of GE14, GNF2, and GNF3 designs. These comparisons were performed in a critical control rod configuration, in the all rods out configuration, and in the one rod out configuration, in order to evaluate shutdown margin calculative capability. The calculations in the critical configuration compared MCNP-PANACEA differences across fuel product lines to show that GNF3 differences were within those obtained for prior fuel designs GE14 and GNF2, and within the accepted eigenvalue uncertainty contained in the IMLTR. The averaged differences between PANAC11 and MCNP (root mean square deviation) indicated similar performance across all fuel designs and showed no discernible degradation in predictive capability for the GNF3 fuel design. This information thus confirms that PANAC11 is capable of producing acceptable cold eigenvalue predictions.

Given the lack of code system changes needed to model GNF3, its functional similarity with GNF2, and based on the fact that MCNP is a higher order code than PANAC11, the NRC staff determined that the PANAC11/MCNP comparisons provided a reasonable surrogate for data from critical experiments in an operating reactor to evaluate the predictive capabilities for cold critical eigenvalue. Based on the consistent trending of PANAC11/MCNP differences across the fuel product lines, and on the fact that the GNF3 differences were consistent with the eigenvalue uncertainty reported in the IMLTR, the NRC staff determined that GEH nuclear design methods are sufficiently capable of modeling the GNF3 bundle design with regard to cold critical eigenvalue.

3.4.1.2 Hot Eigenvalue

GEH provided TGBLA06 infinite lattice reactivity benchmarks to MCNP, as discussed in Section 3.3.1 of this SE, to demonstrate consistent performance across fuel product lines, regarding reactivity predictions. Differences between MCNP and TGBLA06 for GNF3 were compared to similar differences calculated for the prior, GE14 and GNF2 designs. No discernible trending was apparent for GNF3 data, supporting a conclusion the methods and uncertainties remain applicable to GNF3 fuel.

3.4.1.3 TIP Measurements

GEH stated that data obtained from TIP measurements in cells containing GNF3 lead use assemblies in a BWR/5 and a BWR/6 indicated no unusual or adverse trends. These TIP measurements were evaluated as described in Section 3.3.2.

3.4.1.4 Fission Density Benchmarks

The NRC staff evaluated the fission density benchmarks as described in Section 3.3.1. A satisfactory comparison between TGBLA06 and MCNP across fuel product designs indicated that the GNF3 bundle design can be adequately modeled using TGBLA06.

3.4.2 Evaluation of Neutronic Methods Uncertainties

3.4.2.1 Pin Power Peaking Uncertainty

The fission density benchmarks are similar between GNF2 and GNF3, confirming that the pin power peaking uncertainty remains applicable. These comparisons are described in more detail in Section 3.3.1. Based on acceptable fission density comparisons between TGBLA06 and MCNP across fuel product lines, the NRC staff concluded that the pin power peaking uncertainty remains appropriate for GNF3 fuel.

3.4.2.2 Bundle Power Uncertainty (Four Bundle and Power Allocation Combined)

GEH stated that the **[** **]** approach to assessing the GNF3 design using PANAC11-MCNP comparisons results in the ability to compare integrated bundle powers on a bundle-specific basis. The vendor stated, “Because this power comparison is performed on a bundle specific basis instead of through a combination of TIP comparisons and bundle gamma scans, **[** **]** The NRC staff agrees that this statement is true given the code-to-code approach used for this qualification effort. However, it should be noted that this conclusion is not intended to imply that data-based qualification would not be needed to confirm predictive capabilities on a periodic basis. The present conclusion is based on consideration of the design similarity between GNF2 and GNF3, and the fact that no changes to the nuclear performance code package were needed to model the GNF3 design.

3.4.3 Interim Approach

3.4.3.1 SLMCPR

The neutronic qualification provided in IMLTR Supplement 5 for GNF3 includes a limited set of TIP data and MCNP comparisons. On the basis of its review of these qualification data, the NRC staff has confirmed that the nuclear uncertainties and biases for GNF3 are consistent in magnitude and trend with those for GNF2 and GE14. Therefore, the NRC staff finds that the interim methods approach for assigning uncertainties in the SLMCPR determination as applied at the time this safety evaluation was written is equally applicable to GNF3.

An SLMCPR adder is applied to plants operating in the MELLLA+ operating domain. For power-to-flow ratios less than 42 MW/Mlbm/hr, an adder of 0.01 is applied to the SLMCPR, and for power-to-flow ratios greater than 42 MWth/Mlbm/hr, a 0.02 adder is applied. IMTLR Supplement 6 is concurrently under review, which proposes to eliminate this adder. Any conclusions reached in the NRC staff safety evaluation of IMLTR Supplement 6 will specifically delineate their applicability to GNF3. Such conclusions are not considered within the scope of this review.

3.4.3.2 R-factor

Limitation 6 of the IMLTR requires that the plant-specific R-factor be calculated consistent with the axial void conditions expected for the hot channel operating state. The R-factor methods are described in Section 8 of NEDC-33880P, Revision 0, "GEXL21 Correlation for GNF3 Fuel" (Ref. 8). The NRC staff notes that the LHGR rod power limit for GNF3 exceeds the LHGR limit for GNF2 at low exposure. It is therefore possible that compliance with Limitation 6 may require different assumptions for the R-factor because a higher permissible LHGR could result in increased bundle power, and hence an increased in-channel void fraction, relative to a fuel with a lower LHGR limit. Given a higher LHGR limit for GNF2 relative to GE14, the NRC staff issued an RAI concerning this topic during its review of IMLTR Supplement 3.

However, when comparing differences between GNF3 and GNF2 to differences between GNF2 and GE14, the generic LHGR limit **[** **]**, whereas the allowable LHGR limit for GNF3 **[** **]**. Thus, the LHGR limit for GNF3 is more similar to GNF2 than the GNF2 limit is to GE14. Figure 2, generated from data provided in References 5, 6, and 9, provides a graphical comparison of the LHGR envelopes for the various fuel designs (note the comparison is provided in GWD/MTU, whereas remaining sections of this SE characterize burnup in terms of GWD/STU).

[

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Figure 2. Comparison of fuel rod power-exposure envelopes for various GNF fuel designs.

In the response to RAI 16 associated with IMLTR Supplement 3, the vendor pointed out that its "overall approach in confirming compliance with Limitation 6 is to perform this evaluation on a plant specific basis for plants referencing the IMLTR and confirm that the reference void fraction value… for R-factor determination remains applicable based on the cycle average instantaneous void fraction for the limiting fuel." (Ref. 10). That RAI response also noted that bundle designs used to calculate the R-factor for GNF2 reflected the operating conditions anticipated for the fuel design, including those reflective of the applicable LHGR limit and instantaneous void fractions. To demonstrate the applicability of the R-factor conditions, the vendor also included a sample confirmation performed for an EPU plant in its first load of GNF2 fuel, showing that plant-specific operating conditions were accounted for in the R-factor calculations. In Appendix A to IMLTR5, GEH states that the limitation is implemented for all fuel types, including GNF3, which confirms that GEH will continue to ensure the requisite consistency for the R-factor calculations. The NRC staff interprets this information, in aggregate, to mean that, when introducing the GNF3 design at a plant referencing the IMLTR (i.e., EPU or EPU/MELLLA+ plants), IMLTR Limitation 6 requires that GEH confirm the applicability of the R-factor conditions assumed in Ref. 8, and if they are inapplicable, to reformulate the R-factor consistent with the limiting channel void conditions associated with that plant.

Given (1) the lesser difference between GNF2 and GNF3 relative to that between GNF2 and GE14; (2) the confirmation provided previously for the GNF2 methods applicability review, which indicated that the vendor confirms the applicability of the void fraction assumed in the R-factor calculation on a plant specific basis; and (3) the statement in Appendix A to IMLTR5 stating that Limitation 6 is implemented for all fuel types, including GNF3, the NRC staff determined that the vendor has adequately dispositioned IMLTR Limitation 6, concerning the R-factor, with regard to GNF3 fuel.

3.4.3.3 Operating Limit Minimum Critical Power Ratio

The OLMCPR provides margin to the SLMCPR to ensure that a plant can accommodate an anticipated operational occurrence without challenging the safety limit. As such, it is based on transient analyses, which model the effects of feedback from void reactivity. When simulating transients using TGBLA/PANAC/ODYN/ISCOR, an additive penalty of 0.01 is applied to the OLMCPR to account for the potential bias that a 40-percent void depletion history can impose on the calculated void coefficient.

References 11 and 12 provide information necessary to evaluate the adequacy of this additive penalty relative to the steady-state depletion conditions and GNF3 fuel. In Reference 12, GEH provided comparisons of a generally limiting transient, as modeled in TRACG04P both with and without void reactivity bias correction, and as modeled in ODYN. This evaluation showed that the TRACG04 model **[ ]** and that the ODYN model **[ ]**. Note that this evaluation was performed for GNF2 fuel.

While a similar comparison was not provided for GNF3 fuel, GEH documented its evaluation of the relative bias and uncertainty associated with the void history, for GNF3 fuel, in Reference11. This evaluation included a comparison between GNF2 and GNF3. Despite that the biases and uncertainties for GNF3 fuel were different from those reported for the prior fuel designs, the general trends (as a function of burnup and instantaneous void condition) and magnitudes of the biases and uncertainties were very similar.

In Reference 12, discussing the bias for GNF2 fuel, GEH stated:

> …in the exposure range from about 15 to 25 GWd/STU that corresponds to the limiting CPR bundle for AOO analyses that the void coefficient bias **[ ]**. For exposures less than 15 GWd/STU the PANAC11 standard process as supplied with TGBLA06 nuclear information **[ ]**… These biases… **[ ]**. As the poison is *burned* and the bundles approach their peak reactivity and power, the void coefficient biases… **[ ]**. Void history does not begin to make any discernable difference until the exposure has exceeded about 25 GWd/STU…. At exposures above this point the standard process tends to **[ ]**. A larger void coefficient (in the absolute sense) is conservative because it tends to produce a more dynamic power response and a less favorable CPR response.

An inspection of the response surfaces provided in Figures 1 - 4 of Reference 11 shows that the discussion above is as equally applicable to GNF3 as it is to GNF2. For GNF3, GEH evaluated a greater number of lattices at the same burnup points and instantaneous and historic void conditions than were analyzed for GNF2. Thus, the NRC staff concluded that the comparative evaluation established that void reactivity biases behaved consistently between GNF3 and prior fuel designs, such that one can reasonably infer that the transient performance between the two fuel products would be similar, with all other things being equal. Based on such inference, the NRC staff determined that a comparison between TRACG and ODYN using GNF3 fuel and respective void reactivity bias corrections would exhibit reasonably similar trending as that shown for GNF2, and the ODYN methods remain conservative even without incorporating a correction for the void reactivity bias introduced by depletion at 40 percent void conditions.

3.4.3.4 Loss-of-Coolant Accident Related Nodal Power Limits

The nodal power limits assumed in the emergency core cooling system performance evaluation are, to some extent, derived from the thermal-mechanical operating limits for the fuel product. However, plant-specific analyses are used to demonstrate that, if operated at the thermal-mechanical operating limits, the fuel would remain with the acceptance criteria contained in Paragraph (b) of 10 CFR 50.46. Should this not be the case, more restrictive nodal power limits would be used in the ECCS evaluation. To the extent that GNF3 nodal power limits may exceed those established for GNF2, explicit analyses would be required to account for the increased linear heat rate associated with the higher limits, in order to establish compliance with 10 CFR 50.46 requirements.

Regardless of fuel product, the EOD statepoints must be evaluated in the ECCS performance evaluation, a requirement that does not change for the introduction of GNF3.

Finally, the GNF3 fuel bundle design continues to be a 10x10 fuel matrix with design features that are similar to the GNF2 fuel design, in a way that the NRC staff does not expect to invalidate the assessments supporting applicability of the SAFER/GESTR-LOCA ECCS evaluation model (Ref. 13). Should a licensee opt to use the TRACG04-based ECCS evaluation model, the licensing considerations discussed in Chapter 9, and the conditions and limitations specified in Chapter 10, of the NRC staff SE approving NEDE-33005P-A, Revision 1, specifically including Limitation 1.2, “Fuel System Design Applicability,” apply (Ref. 14).

Based on the considerations discussed above, the NRC staff determined that the IMLTR remains applicable to GNF3, with respect to the LOCA-related nodal power limits.

3.4.3.5 Thermal-Mechanical Performance; Fuel Rod Exposure

Thermal-mechanical performance for GNF3 is evaluated using the PRIME methodology, subject to the limitations established for fuel rod exposure in the PRIME SE. As discussed in Section 3.1 of this SE, GEH’s stated use of PRIME obviated the need for NRC staff to review thermal-mechanical issues with regard to IMLTR applicability to GNF3.

3.4.3.6 Shutdown Margin; Standby Liquid Control System

A favorable conclusion to the reactivity benchmarks discussed in Section 3.3.1 establishes that the computational efficacy of TGBLA06/PANAC11 to evaluate shutdown margin and SLCS capability when modeling GNF3 is essentially equivalent to that for GNF2 and prior designs. In addition to the reactivity benchmarks, further PANAC11/MCNP **[ ]** were compared to assess strong rod worth by evaluating cores with one rod inserted, and cores with all rods withdrawn. Across fuel designs, the PANAC11 indicated consistent predictive capability

3.5 Additional Review Considerations

3.5.1 40 Percent Void Fraction Depletion Assumption

The 40-percent void history depletion assumption has the potential to affect the bias in the void reactivity coefficient. Prior sensitivity studies have shown that ODYN remains sufficiently conservative to offset this effect, while GEH performed additional studies to update the void reactivity bias and uncertainty model in TRACG04. These studies are provided in Reference 11, and reviewed in Section 3.4.3.3 of this SE. The results of these studies showed consistent performance between GNF3 and prior fuel designs. Based on the prior information showing ODYN conservatism, and on the consistency of void reactivity bias and uncertainty among the fuel designs, the NRC staff concludes that the 40 percent void fraction depletion assumption is acceptably compensated when calculating fuel and core performance with GNF3 fuel.

3.5.2 Bypass Voiding

The IMLTR specifies limitations on bypass voiding that must be confirmed on a cycle-specific basis. In accordance with Limitation 17 in the IMLTR, the bypass voiding must be limited to 5 percent at the height of the LPRM D-level. This limitation assures the fidelity of the LPRM signals at Level D, and that the potential for power redistribution due to significant bypass voiding is minimized, as such a phenomenon may not be accurately represented in the analytic methods. GEH stated in Appendix A to IMLTR5 that this limitation will be implemented for all fuel types, including GNF3. Meanwhile, the design of the GNF3 lattice at the bundle periphery is essentially the same as for GNF2. Therefore, the peripheral fuel pins, which would be most sensitive to significant void formation in the bundle periphery, would perform similarly between the two fuel designs. Based on these considerations, the NRC staff determined that GEH has addressed bypass voiding acceptably for the GNF3 fuel design.

3.5.3 Stability

GEH stated, in IMLTR5, that the stability models used to evaluate the various stability solutions imbed the basic bundle nuclear and thermal-hydraulic models from the TGBLA, ISCOR and PANACEA programs. Therefore, GEH stated, stability performance depends on the following parameters: moderator void coefficient, local pin power peaking, **[** **]**, and bundle pressure drop. These significant phenomena were evaluated as discussed in Sections 3.3 and 3.4.3.2 of this SE. Based on the demonstration of consistent computational performance when modeling GNF3 relative to GNF2 and prior designs, the NRC staff concluded that the analytic methods used to evaluate stability performance remain applicable when modeling GNF3 fuel. Meanwhile, Limitation 18 to the IMLTR requires GEH to account for calibration errors up to 5 percent in OPRM cells and 2 percent in LPRM cells. Appendix A to IMLTR5 notes that this will remain the case for GNF3. Based on these considerations, the NRC staff concludes that the IMLTR remains applicable to GNF3 with respect to stability.

3.5.4 Applicability of Thermal-Hydraulic Models

GEH provided comparisons to Stern Labs pressure drop testing and COBRAG confirmatory calculations to demonstrate that the calculational efficacy of the thermal hydraulic models, such as the Findlay-Dix void quality correlation, remains as adequate as when applied to GNF2 and prior designs. No discernible, adverse trending was apparent in the data, and hence the NRC staff determined that the thermal-hydraulic models remain adequate for the GNF3 fuel design. The NRC staff evaluation is described in further detail in Section 3.3.3 of this SE.

4.0 CONCLUSION

The purpose of the IMLTR is to ensure that uncertainties and biases in GEH's analytic methods appropriately account for plant operation in expended operating domains. GEH provided IMLTR5 to demonstrate that such uncertainties and biases currently in use remain applicable to GNF3, such that the operating and safety limits derived from these analytic methods include an appropriate margin for such. The demonstration was based largely on comparisons between the GEH nuclear design methods and MCNP, as augmented by TIP data from GNF3 lead use campaigns, and fuel assembly thermal-hydraulic testing. Given the functional similarity between GNF2 and GNF3, and in consideration of the review described above, the NRC staff has concluded that GEH's demonstration is adequate, and that the IMLTR is applicable to GNF3 fuel.

Based on the preceding considerations, the NRC staff has revised Limitation 22 to the IMLTR. Limitation 22 previously stated:

> For any plant-specific applications of TGBLA06 with fuel type characteristics not covered in this review, GE needs to provide assessment data similar to that provided for the GE fuels. The Interim Methods review is applicable to all GE lattices up to GNF2. Fuel lattice designs, other than GE lattices up to GNF2, with the following characteristics are not covered by this review:
>
> - Square internal water channels water crosses
> - Gd rods simultaneously adjacent to water and vanished rods
> - 11x11 lattices
> - MOX fuel
>
> The acceptability of the modified epithermal slowing down models in TGBLA06 has not been demonstrated for application to these or other geometries for expanded operating domains.
>
> Significant changes in the Gd rod optical thickness will require an evaluation of the TGBLA06 radial flux and Gd depletion modeling before being applied. Increases in Gd loading that result in nodal reactivity biases beyond those previously established will require review before the GE methods may be applied.

Limitation 22 may be revised to state as follows:

> For any plant-specific applications of TGBLA06 with fuel type characteristics not covered in this review, GE needs to provide assessment data similar to that provided for the GE fuels. The Interim Methods review is applicable to all GE lattices up to GNF3. Fuel lattice designs, other than GE lattices up to GNF3, with the following characteristics are not covered by this review

- Square internal water channels water crosses
- Gd rods simultaneously adjacent to water and vanished rods
- 11x11 lattices
- MOX fuel

The acceptability of the modified epithermal slowing down models in TGBLA06 has not been demonstrated for application to these or other geometries for expanded operating domains.

Significant changes in the Gd rod optical thickness will require an evaluation of the TGBLA06 radial flux and Gd depletion modeling before being applied. Increases in Gd loading that result in nodal reactivity biases beyond those previously established will require review before the GE methods may be applied.

5.0 REFERENCES

1. General Electric Hitachi Nuclear Energy (GEH), NEDC-33173P, Supplement 5, Revision 0, “Applicability of GE Methods to Expanded Operating Domains – Supplement for GNF3 Fuel,” M170147, June 2017, Agencywide Document Access and Management System (ADAMS) Package No. ML17159A678.

2. GEH, “Incorporation of Supplement 4 PRIME Implementation Audit Approval into NEDC-33173P-A, Revision 4,” MFN 12-124, November 7, 2012, ADAMS Package No. ML123130130.

3. GEH, “Response to Request for Additional Information NEDC-33173P-A, ‘Applicability of GE Methods to Expanded Operating Domains’ Supplement 5, ‘Supplement for GNF3 Fuel’ (EPID No. L-2017-TOP-0033),” M180204, November 26, 2018, ADAMS Package No. ML18346A067.

4. Global Nuclear Fuel, “Accepted Versions of Global Nuclear Fuel – Americas Topical Reports NEDC-33256P, “The PRIME Model for Analysis of Fuel Rod Thermal – Mechanical Performance Part 1 – Technical Bases,” NEDC-33257P, “The PRIME Model for Analysis of Fuel Rod Thermal – Mechanical Performance Part 2 – Qualification,” and NEDC-33528P, “The PRIME Model for Analysis of Fuel Rod Thermal – Mechanical Performance Part 3 – Application Methodology” MFN 10-046, September 15, 2010, ADAMS Accession No. ML102600248.

5. GNF, “GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II), NEDC-33270P, Revision 9, December 2017,” M170261, December 1, 2017, ADAMS Package No. ML17335A308.

6. GNF, “GNF3 Generic Compliance with NEDE-24011-P-A (GESTAR II), NEDC-33879P, Revision 2, March 2018,” M180059, March 27, 2018, ADAMS Package No. ML18086B181.

7. GEH, “Accepted Versions of NEDC-33173P, Revision 2 and Supplement 2, Parts 1-3 (TAC No. ME1891),” MFN 12-032, April 20, 2012, ADAMS Package No. ML121150469.

8. GNF, “Revision 1 of the GEXL21 Correlation for GNF3 Fuel, NEDC-33880P, November 2017,” M170253, November 7, 2017, ADAMS Package No. ML17311A129.

9. GNF, “GE14 Compliance with Amendment 22 of NEDE-24011-P-A (GESTAR II), NEDC-32868P, Revision 5, May 2013,” MFN 13-028, May 24, 2013, ADAMS Package No. ML13148A320.

10. GEH, “Response to NRC RAIs – NEDC-33173P, Supplement 3,” MFN 09-647, October 20, 2009, ADAMS Package No. ML092990416.

11. GEH, “GNF3 Fuel Product Line Void Coefficient Uncertainty Model,” M170097, April 24, 2017, ADAMS Package No. ML17114A165.

12. GEH, “Response to NRC Request for Additional Information RAI 8 – Re: GE-Hitachi Nuclear Energy Americas, LLC (GEH) Topical Report (TR) NEDC-33173P, Supplement 3, ‘Applicability of GE Methods to Expanded Operating Domains – Supplement for GNF2 Fuel’ (TAC No. ME1815),” MFN 09-647 Supplement 1, November 30, 2009, ADAMS Package No. ML093360138.

13. GEH, “SAFER Model for Evaluation of Loss-of-Coolant Accidents for Jet Pump and Non-Jet Pump Plants,” NEDE-30996P-A, Volume I, “SAFER – Long Term Inventory Model for BWR Loss-of-Coolant Analysis,” October 1987, ADAMS Package No. ML091210245, and Volume II, “SAFER Application Methodology,” October 1987, ADAMS Accession No. ML102350281 (Proprietary reports; no publicly available copies located in ADAMS).

14. GEH, “Accepted Version of NEDE-33005P, Revision 0, ‘Licensing Topical Report TRACG Application for Emergency Core Cooling Systems/Loss-of-Coolant Accident Analyses for BWR/2-6,’” M170037, February 24, 2017, ADAMS Package No. ML17055A387.

Attachment: Resolution of Comments

Principal Contributors: Ben Parks
Kevin Heller

Date: March 21, 2019

Comment Summary for Draft Safety Evaluation for NEDC-33173P Supplement 5, “Applicability of GE Methods to Expanded Operating Domains – Supplement for GNF3 Fuel”

Location	Comment	Comment Resolution
Section 3.3.3 Thermal-Hydraulic Qualification	Page 7: Improve the description of ISCOR09. GEH suggests the following change (Line 19): “…ISCOR, a ~~single-bundle~~ parallel channel thermal-hydraulic code…” *Suggested change shown in the markup.*	Staff accepts change. Change incorporated.
Section 3.4.2.2 Bundle Power Uncertainty (Four Bundle and Power Allocation Combined)	Page 9: Add an end quote for the cited text. GEH suggests the following change (Line 33): “**[** **]** The NRC staff…” *Suggested change shown in the markup.*	Staff accepts change. Change incorporated.
Section 3.4.3.2 R-factor	Page 11: Correct the fuel type. GEH suggests the following change (Line 23): “…GNF2 and GNF3…” *Suggested change shown in the markup.*	Staff accepts change. Change incorporated.
Section 3.4.3.4 Loss-of-Coolant Accident Related Nodal Power Limits	Page 13: Correct the code name. GEH suggests the following change (Line 21): “…use the TRACG-04-based ECCS…” *Suggested change shown in the markup.*	Staff accepts change. Change incorporated.

ATTACHMENT