ENCLOSURE 2

MFN 09-517

NEDO-33173, Supplement 3 – GNF2 Supplement

Non-Proprietary Version

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This is a non-proprietary version of Enclosure 1 to MFN 09-517, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]]

GE Hitachi Nuclear Energy

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Non-Proprietary Information

Licensing Topical Report

Applicability of GE Methods to Expanded Operating Domains - Supplement for GNF2 Fuel

INFORMATION NOTICE

This document is the GE non-proprietary version of NEDO-33173 Supplement 3 which has the proprietary information removed.

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

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EXECUTIVE SUMMARY

NEDC-33173P, *Applicability of GE Methods to Expanded Operating Domains* (Methods LTR) (Reference 1), documents the adequacy of the GEH analytical methods at expanded operating domains (e.g., Extended Power Uprate and MELLLA+). The NRC approved the Methods LTR as documented in its Safety Evaluation dated July 21, 2009 (Reference 3). NEDC-33173P, Section 4.2, "Applicability," states, in part, that the Methods LTR is applicable to current GE BWR fuel designs (i.e., GE14 and earlier). The NRC SE states in Section 8.2 and Limitation 22 that the NRC's review of the Methods LTR is limited to the current GEH fuel designs (i.e., GE14 and earlier). GNF has developed a new fuel design, GNF2, which is described in GNF Report NEDC-33270P, Revision 2, June 2009, "GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II)", (Reference 4). The purpose of this supplement is to document the adequacy of the GEH analytical methods relative to GNF2 fuel when used for expanded operating domains. The GNF2 fuel product design is based on the proven GE12 and GE14 10x10 lattice, water rod and fuel rod design. The major differences between GE14 and GNF2 are an advanced fuel rod spacer design and changes in part length rod placement and length.

The evaluations presented in Sections 2 and 3 demonstrate the adequacy of the GEH methods for GNF2 when used in the expanded operating domains. Further, the assessment in Appendix A documents the applicability the existing limitations in the NRC SE for the Methods LTR (Reference 3) for GNF2 fuel.

The outline and format of the report is identical to the original document NEDC-33173P (Reference 1), in which the methods uncertainty impact on the key core safety parameters is evaluated. This consistent format is chosen to facilitate the clarity and completeness of the supporting information. This Supplement 3 does not depend on other Supplements to NEDC-33173P. Other supplements to NEDC-33173P will support GNF2 fuel, as necessary.

ACRONYMS AND ABBREVIATIONS

Term	Definition
AOO	Anticipated Operational Occurrence
Methods LTR	Applicability of GE Methods to Expanded Operating Domains Licensing Topical Report
APRM	Average Power Range Monitor
ATWS	Anticipated Transient Without Scram
BOC	Beginning Of Cycle
BT	Boiling Transition
BWR	Boiling Water Reactor
BWROG	BWR Owners Group
CDA	Confirmation Density Algorithm
CPPU	Constant Pressure Power Uprate
CPR	Critical Power Ratio
DIVOM	Delta over Initial MCPR Versus Oscillation Magnitude
DSS-CD	Detect and Suppression Solution – Confirmation Density
ΔCPR	Delta Critical Power Ratio
ECCS	Emergency Core Coolant System
EOC	End Of Cycle
EOP	Emergency Operating Procedure
EPU	Extended Power Uprate
FMCPR	Final Minimum Critical Power Ratio
FWCF	Feedwater Controller Failure Event
FWHOOS	Feedwater Heating Out-of-Service
FSAR	Final Safety Analysis Report
GE	General Electric Company
GEH	GE-Hitachi Nuclear Energy
GESTAR	General Electric Standard Application for Reload Fuel
GEXL	GE Boiling Transition Correlation
GSTRM	GESTR Mechanical
HBB	Hard Bottom Burn
HCOM	Hot Channel Oscillation Magnitude
ICPR	Initial Critical Power Ratio
IV	Instantaneous Void
LHGR	Linear Heat Generation Rate
LOCA	Loss Of Coolant Accident
LTR	Licensing Topical Report
LPRM	Local Power Range Monitor
MAPLHGR	Maximum Average Planar Linear Heat Generation Rate

Term	Definition
MCPR	Minimum Critical Power Ratio
MELLLA+, M+	Maximum Extended Load Line Limit Analysis Plus
MNCP	A General Monte Carlo N-Particle Transport Code
NRC	Nuclear Regulatory Commission
ODYN	1-D Transient Model
ODYSY	GE Best-Estimate Frequency Domain Stability Code
OLMCPR	Operating Limit MCPR
OLTP	Original Licensed Thermal Power
OPRM	Oscillation Power Range Monitor
Option II	Stability Detect and Suppress LTS for BWR/2
Option III	Stability OPRM-Based Detect and Suppress LTS
PANACEA	Current GE BWR Core Simulator
PCT	Peak Cladding Temperature
PHE	Peak-Hot Excess
PLR	Part Length Rod
PU	Power Uprate
RAI	Request for Additional Information
RPS	Reactor Protection System
SAFDLs	Specified Acceptable Fuel Design Limits
SDM	Shutdown Margin
SE, SER	Safety Evaluation Report
SLMCPR	Safety Limit MCPR
SLO	Single Loop Operation
TGBLA	Current GE BWR lattice physics code
TIP	Traversing In-Core Probes
TRACG	Transient Reactor Analysis Code (GE proprietary version)
UB	Under Burn
UTL	Upper Tolerance Limit
VH	Void History
1-D	One Dimensional
3-D	Three Dimensional

1.0 INTRODUCTION

1.1 BACKGROUND

NEDC-33173P, *Applicability of GE Methods to Expanded Operating Domains* (Methods LTR) (Reference 1), documents the adequacy of the GEH analytical methods at expanded operating domains (e.g., Extended Power Uprate and MELLLA+). The NRC approved the Methods LTR as documented in its Safety Evaluation dated July 21, 2009 (Reference 3). NEDC-33173P, Section 4.2, "Applicability," states, in part, that the Methods LTR is applicable to current GNF BWR fuel designs (i.e., GE14 and earlier). The NRC SE states in Section 8.2 and Limitation 22, the NRC's review of the Methods LTR is limited to the current GNF fuel designs (i.e., GE14 and earlier). GNF has developed a new fuel design, GNF2, which is described in GNF Report NEDC-33270P, Revision 2, June 2009, "GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II)", (Reference 4). The purpose of this supplement is to document the adequacy of the GEH analytical methods relative to the GNF2 fuel when used at expanded operating domains.

GNF has introduced a new fuel design, known as GNF2, described in Reference 4, based on the GE14 design. The GNF2 and GE14 design parameters are compared in Reference 4 and summarized in Table 1-1. The major differences between GE14 and GNF2 are:

- **Part length rod placement and design.** The GNF2 design contains fourteen part length rods, identical to GE14. However, six of the part length rods are short, about one third of the full rod length, and eight are longer, about two thirds of the full rod length. The positions of the part length rods have changed, with the six short part length rods clustered in the center of the lattice and the eight long part length rods located adjacent to the fuel channel.

- **Fuel rod grid spacer design and placement.** Whereas the GE14 spacer grid is a zircaloy ferrule design with Alloy X-750 springs, the GNF2 spacer grid is based on an egg crate configuration and is made entirely of Alloy X-750. The axial spacer locations have been altered to accommodate the change in part length rod lengths.

Reference 4 provides a description of the GNF2 design and analyses that demonstrate GNF2 meets the requirements specified GESTAR II. GNF2 compliance with GESTAR II has been audited by the NRC staff (Reference 20).

1.2 PURPOSE

The purpose of NEDC-33173P Supplement 3 is to provide the document the adequacy of GEH analytical methods to GNF2 fuel when used in expanded operating domains (e.g., extended power uprates and MELLLA+). This supplement is limited to the application of GEH analytical methods as documented in NEDC-33173P and not to the GNF2 fuel design itself, which meets the GESTAR II requirements for introduction of the fuel product (Reference 4). The applicability of NEDC-33173P to GNF2 fuel is supported by the following technical evaluations:

- The lattice physics code TGBLA06 has been modified to accommodate the changes in part length rod location, with a negligibly small impact on core eigenvalue and pin power predictions. The TGBLA06 changes were reviewed in a NRC Audit Report (Reference 20) and found to be consistent with the conclusions stated above.

- The modified TGBLA06 code has been compared to MCNP Monte Carlo results and exhibits similar pin power, criticality, and void coefficient biases as established for previous 9x9 and 10x10 lattice designs. These comparisons support the continued use of current Interim Methods biases for pin power and void coefficient for GNF2 applications.

- The accuracy of the ISCOR and TASC thermal hydraulic models, which are relevant to methods based analyses and embedded in all the GEH thermal hydraulic steady state and transient models, is supported by full-scale critical power and pressure drop tests. The correlation uncertainties are incorporated into SLMCPR evaluations in accordance with NRC-approved procedures. (Reference 5)

- Cold shutdown measurements and analysis carried out on a core containing four GNF2 lead use assemblies (LUA) have shown prediction accuracy consistent with past experience. Results obtained for local critical experiments (i.e., in-reactor demonstrations) near the LUA are consistent with past experience. The cold Critical results were also reviewed and found to be adequate in the NRC Audit Report (Reference 20).

- Full GNF2 reloads are operating in two BWR/4s and a BWR/3. Three TIP measurements have been completed over the first 4000 MWD/MT of cycle exposure for the BWR/4. The simulation of these TIP measurements have been completed and show agreement between calculation and measurement, with both radial and axial root mean square (RMS) values well below values in Reference 1.

1.3 ANALYSIS PROCESS

The approach used to confirm the applicability of GEH Methods to the GNF2 fuel design follows the same process used in the original Methods LTR (Reference 1).

The subsequent sections of this supplement to the Methods LTR provide a review of GEH methodologies, uncertainties, and biases for acceptability to GNF2 applications for expanded operating domains (e.g., CPPU, EPU, and MELLLA+). This format and outline is identical to the original Methods LTR (Reference 1). The impact of uncertainty parameters of interest is identified and their applicability to GNF2 analysis is evaluated. The adequacy of the existing margin, and, as applicable, augmented margin for each of these safety parameters is provided.

The GEH Nuclear Methods are based on three levels of detail, as indicated below:

- **The Individual Fuel Rod:** Individual fuel rod analysis concerns heat transfer, stress conditions, and fission gas buildup in an individual fuel rod. The GNF2 fuel rod design is nearly identical to GE14. The pellet diameter is slightly larger and the cladding slightly thinner. The current design basis for GNF2 fuel included in Reference 4 is based on the GSTRM methodology (Reference 1). Consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the GNF2 design basis as documented in Reference 26 pending the approval of the PRIME methodology currently under review (Reference 18).

- **The Bundle Lattice:** The most significant differences between GNF2 and GE14 occur at the lattice level. The first, which involves the lattice physics code, TGBLA, is that there are two part length rod lengths, and these part length rods (vanished rods) are in different positions in the lattice. The TGBLA06 code has been updated to accommodate the change in vanished rod locations. The output of the TGBLA code is transferred to the core-wide simulation programs in the form of lattice average nuclear parameters and pin power peaking factors. The second significant change involves the design and location of the fuel spacer grids. Fuel spacer design and location have affect on bundle pressure drop and critical power performance. Both pressure drop and critical power performance have been measured at the Stern Laboratory full-scale thermal-hydraulic test facility and correlated with NRC-approved correlations. The thermal-hydraulic output consists of pressure drop and critical power correlations based on the above-mentioned Stern Laboratory tests. The information characterizing the nuclear and thermal-hydraulic differences are incorporated in TGBLA (lattice physics).

- **Core Wide Models:** The core wide models use the lattice average nuclear parameters, critical power correlation, pressure drop correlation, and limits established by the fuel rod performance models to construct a three dimensional power distribution and establish overall core wide margin to limits. The steady state core simulator model (PANACEA), transient models (ODYN and TRACG), and stability model (ODYSY) all use lattice average outputs from TGBLA and thermal-hydraulic correlations. The overall uncertainties assigned to the steady-state core-wide models, the transient models, and stability models are entirely determined by the uncertainties in the detailed lattice and fuel rod models.

The justification for using GEH analytical methods in GNF2 applications at expanded operating domains focuses on the physics and thermal-hydraulic impact of the GNF2 design changes reflected in the lattice model TGBLA and the thermal-hydraulic correlations.

Section 2 focuses on the evaluation of the effect of the TGBLA and thermal-hydraulic uncertainties in the determination of safety parameters for CPPU and EPU applications.

Section 3 extends the Section 2 basis to the MELLLA+ operating domain. The analysis presented in Sections 2 and 3 of this document confirm that the Fuel Design Limits and Associated Methods for GNF2 analysis are identical to Table 1-1 of Reference 1 with one clarification. The current thermal-mechanical design basis for GNF2 fuel included in Reference 4 is based on the GSTRM methodology. Consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the thermal-mechanical design basis as documented in Reference 26 pending the approval of the PRIME methodology currently under review (Reference 18). The conclusions regarding the applicability of the revised Limits and Methods table appears below as Table 1-2. Appendix A provides an assessment of the limitations in the NRC SE (Reference 3) relative to GNF2 fuel.

Table 1-1 GE14 and GNF2 Parameters

Fuel Assembly	**GE14**	**GNF2**
Total number of fuel rods	92	No Change
Full length	78	No Change
Partial length	14 total, Single Length	14 total, Two Lengths
Long Part Length Rod (LPLR)	14	8
Short Part Length Rod (SPLR)	0	6
Lattice Array	Figure 2-2	Figure 2-2
Rod to rod pitch (cm)	[[	]]
Number of water rods	2	No Change
Typical Assembly weight (kgU)	[[	
BWR/2-3 Full Length Rod (mm)		
BWR/4-6 Full Length Rod (mm)		
Long Part Length Rod (LPLR) (mm)		
Short Part Length Rod (SPLR) (mm)		
Fuel Rod		
Cladding material		
Typical BWR/2-3 Assembly active fuel length (mm)		
Typical BWR/4-6 Assembly active fuel length (mm)		
LPLR Active Fuel Length (mm)		
SPLR Active Fuel Length (mm)		
Cladding tube diameter, outer (cm)		
Cladding tube wall thickness (cm)		
Pellet diameter, outer (mm)		
Fuel pellet density (PD) standard		
Fuel column Geometric Staking Factor (GSF) standard		
Helium Backfill Pressure BWR/2		
Helium Backfill Pressure BWR/3-6		
Fuel column stack density (g/cc)		
Water Rod		
Cladding material		
Cladding diameter, outer (cm)		
Cladding wall thickness (cm)		]]
Spacer		
Number of spacers	8	No Change
Axial locations	See Reference 22 Page 14	See Figure 2-5 of Reference 4
Material	Zircaloy ferrule and bands with Alloy X-750 springs	Alloy X-750

[1] [[ ]]
[2] Gd_2O_3 Concentration, percent by weight (GC)

Table 1-2 Fuel Design Limits and Associated Methods

Limit	Primary Technology	Description	Evaluation Frequency & Notes
SLMCPR	SLMCPR, PANACEA	The SLMCPR is a MCPR value at which 99.9% of the fuel rods in the core are expected to avoid BT. This value considers the core power distribution and uncertainties.	The limit is evaluated on a plant/cycle specific basis (i.e., each core design).
OLMCPR	ODYN, TRACG, PANACEA	The OLMCPR is additional margin above the SLMCPR to account for the MCPR change due to AOOs. Adherence to the limit assures that in the event of an AOO, 99.9% of the fuel rods are expected to avoid BT.	The limit is evaluated on a plant/cycle specific basis. The FSAR transients that are limiting or potentially limiting with respect to pressure and fuel thermal limits are analyzed for each reload. Transients are confirmed to be within the LHGR basis.
SDM	PANACEA	SDM is maintained regardless of the core design (the value of the limit does not vary with core characteristics like SLMCPR or OLMCPR). The shutdown margin requirement assures that the reactor can be brought and held subcritical with the control system alone. Most BWRs have a TS value of 0.38%. The "working definition" of SDM is the quantity of reactivity needed to reach criticality in a xenon free core with the strongest worth control rod fully withdrawn and all other control rods inserted.	Each core is designed to conform to this limit. SDM margin is demonstrated on a plant/cycle specific basis.
LHGR	GSTRM (current)/ PRIME (future)	LHGR Operating Limits represent an envelope of acceptable linear heat generation rates, as a function of exposure, designed to maintain fuel integrity during normal operation, including Anticipated Operational Occurrences. The LHGR limits reflect the application of SAFDLs on the following fuel performance parameters: • Fuel temperature • Cladding stress • Cladding strain • Cladding fatigue usage • Fuel rod internal pressure • Cladding creep	LHGR Operating Limits are developed generically for each fuel product line (e.g., GE14). They are determined from thermal-mechanical considerations and independent of any particular core design. The current LHGR operating limits for GNF2 fuel included in Reference 4 are based on the GSTRM methodology. Consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the LHGR operating limits for GNF2 fuel as documented in Reference 26 pending the approval of the PRIME methodology currently under review (Reference 18).
MAPLHGR	SAFER	MAPLHGR is a an average planar linear heat generation rate limit that is a product of the plant ECCS-LOCA evaluation performed to demonstrate compliance with 10CFR50.46 acceptance criteria.	ECCS-LOCA evaluations are performed as plant specific, cycle independent analyses. These analyses are typically performed for each initial introduction of new fuel product lines. The analysis output is a Licensing Basis PCT and a set of parameters that are confirmed every cycle to ensure applicability of the analysis.
Stability	ODYSY TRACG	There are several accepted stability solutions, each designed to protect the SLMCPR. The solutions include prevention and detect and suppress strategies, as well as combinations of both elements.	The stability methodologies are applied and/or confirmed for every reload (every cycle).
Exposure	GSTRM (current)/ PRIME (future)	The licensed exposure limit is a result of the LHGR evaluation methodology discussed above.	The exposure limit is developed generically for each fuel product line from thermal-mechanical considerations. It is independent of the core design. The current LHGR operating limits for GNF2 fuel included in Reference 4 are based on the GSTRM methodology. Consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the LHGR operating limits for GNF2 fuel as documented in Reference 26 pending the approval of the PRIME methodology currently under review (Reference 18).

2.0 SAFETY PARAMETERS INFLUENCED BY UNCERTAINTIES

2.1 INTRODUCTION

Section 2 of Reference 1 listed the safety parameters influenced by nuclear, thermal hydraulic, and thermal mechanical methods uncertainties and biases. These safety parameters are unchanged for GNF2 fuel design.

The analysis presented in Section 2 of Reference 1 showed that the allowances for methods uncertainties are adequate to ensure that the fuel design limits are met for fuel designs up to and including GE14 for power uprate conditions. The analysis presented in this section extends this conclusion to the GNF2 fuel design and that Table 1-2 is applicable for power uprate conditions.

2.2 CRITICAL POWER

The components of the critical power (SLMCPR and OLMCPR) are unchanged for GNF2 fuel design.

2.2.1 Safety Limit Critical Power Ratio (SLMCPR)

The methods and uncertainties used to evaluate the SLMCPR have been validated in Reference 1 by considering pin and bundle power combined with critical power, void fraction, and pressure drop correlations. These topics are covered below, with emphasis on GNF2 results.

2.2.1.1 Fuel Parameters That Affect SLMCPR

Table 2-1 and Table 2-2 of Reference 1 contain a summary of the uncertainties relevant to the evaluation the SLMCPR. These parameters are unchanged for GNF2.

2.2.1.2 Treatment of Fuel Parameter Uncertainties

The bundle power is a combination of [[
]] Uncertainties in local pin power peaking, [[
]] are explicitly included in the SLMCPR determination and considered separately, then cumulatively in Section 2.2.1.2 of Reference 1. The extension of these uncertainties to the GNF2 design is discussed below.

Pin Power Peaking

A key method related uncertainty is the local (pin) peaking factor uncertainty. This value is primarily associated with the lattice code TGBLA (Reference 8). The 1σ uncertainty was evaluated to be [[ ]] in NEDE-32601P-A (Reference 5), based on comparisons with MCNP Monte Carlo evaluations. The overall pin peaking uncertainty, including operational, flux gradient, and manufacturing effects was confirmed by comparison to pin gamma scan measurements performed in an 8x8 lead use assembly. The data presented in NEDE-32601P and in the RAI responses were for the most part based on GE14 and earlier fuel designs. TGBLA06-MCNP (Reference 9) comparisons carried out on other vendor's fuel designs show results consistent with those obtained with the GE designs. The results in NEDE-32601P-A show the overall TGBLA06 pin power accuracy to be similar for the Non-GE designs and the GE 9x9 and 10x10 designs.

While the fundamental methodology for TGBLA06 is not changed from that approved by the NRC, the TGBLA06 ECP required a modification to model the GNF2 part length rod configuration. [[

]] The change in the Dancoff factor and the impact on the qualification basis has been audited by the NRC staff, and documented in Reference 20.

Figure 2-1 and Figure 2-2 demonstrate the applicability of TGBLA06 to GNF2 using direct comparisons to Monte Carlo (MCNP) at 0.0 and 65 GWD/MT lattice exposure. The RMS deviation (see Reference 1 for definition) between the TGBLA06 and Monte Carlo fission density distribution is plotted vs. lattice moderator density. [[

]] For reference, the average difference range is provided for a set of GE14 10x10 lattices. The TGBLA/ MCNP RMS differences are computed for each GE14 lattice and for each moderator density. For each density, the differences are averaged and the standard deviation is evaluated. The dashed lines in the graph represent the average GE14 difference with the standard deviation added and subtracted. The small impact of analyzing the GNF2 designs is demonstrated by the fact that the GNF2 differences are within or less than the differences calculated for the GE14 lattices. As stated in Reference 1, GEH uses [[

]] The consistency of the GNF2 TGBLA06 to MCNP comparisons with previous designs justify the use of GE14 pin power uncertainties for GNF2 R-factor and LHGR evaluations.

Four Bundle Power

The second component of power uncertainties affecting the SLMCPR is the four-bundle power surrounding a TIP string. GNF has continued to provide the NRC with BWR fleet information on the consistency of integral TIP comparisons on periodic basis, e.g., in fuel technology updates. These comparisons provide the basis for the [[ ]] in Table 2-2 of Reference 1. In 2005, GNF provided a data for uprated plants loaded primarily with 10x10 fuel in methods related RAI responses on the MELLLA+ docket (Reference 1). The results of plant tracking studies performed with the current methods are summarized in Table 2-5 of Reference 1, which yield an overall [[ ]]. The TIP RMS metric is defined in Reference 1. Examination of this data confirms the applicability and conservatism of the original [[ ]] uncertainty documented in GEH's approved topical reports (Reference 5, NEDC-32601P-A and Reference 6, NEDC-32694P-A) describing the SLMCPR methodology, for uprated power densities as high as 62 KW/liter.

GNF2 lead use assemblies have been operating in three BWR/4s, and in a European BWR design for up to three cycles and three plants in reload quantities. The TIP data for the four lead use assemblies in two BWR/4 plants have been analyzed in an NRC audit report (Reference 20) and revealed no unusual behavior. The first two full GNF2 reloads are currently operating in BWR/4 and BWR/3 non-EPU plants. Currently, a total of three TIP measurements at the BWR/4 are available for analysis through the first [[ ]] of the cycle. The results are summarized in Table 2-2. This table shows the TIP comparisons, indicating agreement with an average radial RMS difference of [[ ]], which is less than the [[ ]] average in Table 2-5 of Reference 1.

This particular BWR/4 has 31 TIP strings and 560 bundles. The batch fraction for this GNF2 reload is 164 bundles, or 29%. Twelve of the TIP strings have no GNF2 bundles immediately adjacent to them, sixteen TIP strings have two GNF2 adjacent bundles, and three strings have three GNF2 adjacent bundles. It is instructive to look at the radial bias in each of these three groups to see if the GNF2 bundles are influencing the radial bias. The results summarized in Table 2-3 show that there is a small range in mean bias [[ ]] between the three groups of TIP strings, indicating that the simulation of GNF2 bundles is quite consistent with simulation of GE14 bundles, which constitute the remaining bundles in the core. Figure 2-3 provides further evidence of the consistency of the GNF2 simulation, showing the BWR/4 critical eigenvalue and the projected eigenvalue, based on previous GE14 experience. The tracking eigenvalue is within 0.1% of the projected value. The design allowance for the difference between actual and projected critical eigenvalue is [[ ]] which indicates consistent performance for this first reload introduction of GNF2 into an operating reactor.

Bundle Power

[[ ]] is a component of the total bundle power uncertainty. The total bundle power uncertainty for application within GEH's approved SLMCPR determination process consists of the component uncertainties in Table 4.2, page 4-2 in NEDC-32694P-A. [[

]] The bundle power allocation factor for a new fuel design is most sensitive to changes in the reactivity of each lattice as a function of moderator density and fuel exposure. Reference 1 contains a significant amount of data comparing TGBLA06 and MCNP reactivity response to a variety of moderator density and exposures. These same comparisons have been completed for GNF2 lattices. The comparisons are displayed in Figure 2-4 at BOL exposure and in Figure 2-5 at 60 GWD/MTU exposure. The reactivity difference between TGBLA06 and MCNP are plotted versus moderator density. The TGBLA/ MCNP reactivity differences are computed for each GE14 lattice and for each moderator density. For each density, the differences are averaged and the standard deviation is evaluated. The dashed lines in the graph represent the average GE14 difference with the 1σ standard deviation added and subtracted from the mean. The results for the five GNF2 lattice types are plotted individually. The results show that the GNF2 biases are consistent with the other 10x10 results including the trends with void fraction. This consistent behavior justifies the use of the current methods procedures and uncertainties for the GNF2 fuel design.

Thermal-Hydraulic Methods

The introduction of various PLR rod heights, such as in GNF2, or other axially varying features, such as axially varying thick/thin channels, can be readily handled by the steady-state and transient analysis programs because model parameters can be varied axially to account for changes in the number of rods, water rod diameters, etc. in the lattice at different axial locations. The single bundle thermal-hydraulic code, ISCOR09, employs both the void correlation and pressure drop correlation combined with the mass and energy solution to the heat transfer equations. The ISCOR09 methods are embedded in the PANACEA steady state three-dimensional simulator and the stability analysis tools. [[

]] This difference is also accommodated within the core methods methodology.

Void Correlation

The GEH void correlation has been shown to be applicable for existing GNF BWR fuel designs, including 10x10 lattices with part length rods (Reference 1). [[

]]

Qualification of GNF2 has been evaluated with full-scale experimental pressure drop data (Reference 4) Correct prediction of the pressure drop requires an accurate prediction of the void fraction throughout the length of the bundle. In addition, the void fraction correlation is indirectly qualified via comparison with sub-channel analysis methods as show in Figure 2-6. Therefore, the GEH Findlay-Dix void fraction correlation (Reference 7), which forms the basis for currently approved methodologies, is applicable to GNF2 fuel designs.

Pressure Drop

The GNF2 fuel assembly design incorporates the use of nickel-based, Ni-Cr-Ti alloy grid type spacers with flow wings to improve critical power performance. The pressure drop characteristics of the GNF2 spacers are based on the pressure drop data from full-scale testing of the GNF2 fuel assembly as documented in Reference 4. Production spacers were used in the full-scale test assembly with no modifications. The measured pressure drops include static head, wall friction, acceleration pressure drop, and form losses. The loss coefficients were evaluated in a manner consistent with the steady-state thermal-hydraulic analysis methodology documented in Section 4.2 of GESTAR II. The test assembly and the measurement scheme for obtaining differential pressures are shown in Figure 2-7. Test data were obtained at [[

]]

Measured pressure drops across the bundle height from [[ ]] are compared to the predictions in Figure 2-8. The comparison of the predicted versus measured pressure drop for [[ ]] tests over a range of thermal-hydraulic conditions resulted in a mean error for the [[

]] It is instructive to note from Figure 2-8 that the same small pressure drop error is maintained over the entire range of bundle powers. The zero bundle power results, shown as the green diamonds in the Figure, represent the single-phase portion of the pressure drop, are consistent with all the data. The pressure drop correlation is able to accurately model the split between single phase and two phase pressure drop, which is an important characteristic in the thermal hydraulic stability. The ISCOR09 model with the pressure drop correlation also predicts the axial pressure profile in the bundle. Figure 2-9 compares the measured and calculated accumulated pressure drop for a high power and moderate flow condition. The intermediate pressures are taken from the pressure taps shown in Figure 2-7. The pressure profile shows that the effects of the part length rods and advanced spacers are accurately simulated by the ISCOR09 model, the steady state, stability, and transient analysis tools.

The GNF2 fuel assembly hydraulic characteristics have been developed and confirmed by the test comparisons discussed above. These GNF2 hydraulic characteristics are used in all analysis models and methods where the fuel assembly hydraulics are needed. For cores of mixed assembly types, the hydraulics are uniquely represented for each assembly type. Therefore, the flow-pressure drop characteristics for each fuel assembly type (including GNF2) present in a plant are included in all plant cycle-specific analyses for the calculation of the Operating Limit Minimum Critical Power Ratio.

Critical Power Correlation

The GNF2 fuel assembly has a different part length rod configuration and spacer design relative to previous fuel designs. The new correlation, GEXL17, has been established based on significant new data for the GNF2 fuel design.

The GEXL17 (Reference 21) database was obtained from Stern Laboratory tests of full-scale GNF2 bundle simulations. A statistical analysis has been performed for the GNF2 database used to develop the GEXL17 correlation, consisting of [[ ]] data points for [[ ]] different local peaking patterns. This correlation statistics were based on [[ ]] data points. The GEXL17 correlation is valid for GNF2 fuel over the following range of state conditions:

- Pressure: [[ ]]
- Mass Flux*: [[ ]]
- Inlet Subcooling: [[ ]]
- R-factor*: [[ ]]

The GEXL17 Application Range is documented in Figure 2-10.

In addition, there is an additive constant applied to each fuel rod location [[ ]] For GNF2, the additive constants used in the design process are provided in Reference 4. The terms that comprise the form of the correlation have been previously approved by the NRC and have been in use for the past seven GE fuel product designs.

Based on the [[ ]] data points used to develop and verify the GEXL17 correlation statistics, the mean ECPR, μ, was determined to be [[ ]], with a standard deviation, σ, of [[ ]]. In addition to the overall statistic mentioned above the GEXL17 correlation is accurate over the entire flow range. The ECPR statistics are shown as a function of bundle flow in Figure 2-11. The average ECPR is within [[ ]] over the entire flow range expected in EPU and MELLLA+ operation, ensuring accurate CPR modeling of both steady state and transient operation.

2.2.1.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of SLMCPR as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. This conclusion is based on the following:

- The TGBLA06 nuclear evaluations have been shown to yield similar pin power and reactivity behavior relative to MCNP benchmark calculations as the previously documented GE14 analyses (Reference 1).

- Initial TIP data for the first GNF2 application shows agreement with current GEH methods. This agreement with operating TIP data and consistent eigenvalue behavior relative to GE14 experience for the BWR/4 indicates that no change in methods or procedures is required for GNF2 analysis.

- Full-scale thermal-hydraulic pressure drop and critical power tests have been performed and correlated with NRC-approved correlations. The GNF2 GEXL17 critical power correlation uncertainty is incorporated into the determination of the SLMCPR. The range of the pressure drop and critical power test data is sufficient to cover thermal-hydraulic conditions present during EPU and MELLLA+ operations. The correlation forms and implementation methods remain unchanged for GNF2.

2.2.2 Operating Limit Critical Power Ratio (OLMCPR)

The analysis of anticipated operational occurrences (AOOs) examines the change in critical power ratio relative to the initial conditions and determines the most limiting event. The definition of the OLMCPR is unchanged for GNF2.

2.2.2.1 Fuel Parameters That Affect OLMCPR

Reference 1 contains a detailed discussion of the fuel parameters that affect OLMCPR. These parameters are unchanged for GNF2.

2.2.2.2 Treatment of Fuel Parameter Uncertainties

A new fuel design can potentially affect transient response. The three most important parameters are:

- **Core Axial Power Shape:** As stated in Reference 1, the core axial power shape can influence the transient response. Uncertainties in the axial power shape are not directly included in the transient response uncertainty. Rather, the input conditions for the transient are developed in a way that ensures that the axial shape is conservative and is not influenced by the GNF2 design.

- **Void and Moderator Density Reactivity Response:** Both the ODYN and TRACG transient methodologies (References 10, 11, and 12) have established application ranges for void coefficient uncertainty. The basis for these methodologies rests upon a comparison of calculations for a wide variety of plant transients in which the nominal void coefficient is used. The acceptable performance of these codes relative to the data justifies that no large errors in void coefficient exist. As described in Section 2.2.1.2 above, TGBLA06 and MCNP have been utilized to generate reactivity differences for representative GE14 and GNF2 10x10 lattices for the full range of instantaneous void conditions. Differences have also been evaluated for cold conditions. Figure 2-4 and Figure 2-5 show the TGBLA06/MCNP bias as a function of moderator density. The GNF2 results follow the same trend with moderator density as the GE14 results, and therefore yield similar void coefficient biases. The consistent moderator density behavior between hot zero void and cold conditions ensure consistent behavior for cold water events as well.

- **Thermal-Hydraulic Behavior:** Transient conditions require both the critical power and pressure drop correlations be accurate for the full range of flow conditions. This accuracy is demonstrated in Figure 2-8 for the GNF2 pressure drop correlation and in Figure 2-11 for the GEXL17 critical power correlation.

The Reference 1 assumption of [[ ]] void coefficient bias and a 2σ void coefficient uncertainty of [[ ]] is justified for GNF2, given the similarity of GNF2 to GE14 and the consistency of the TGBLA06/MCNP comparisons shown above.

Because inputs to the OLMCPR analysis are conservative, and the pressurization transients that typically establish the limiting ΔCPRs are conservatively analyzed by TRACG or ODYN, the conservatisms in the process of determining OLMCPRs is appropriate and sufficient for application to GNF2.

2.2.2.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of OLMCPR as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. For applications that utilize TGBLA06 based modeling (PANAC11, ODYN, TRACG, and ODYSY), the TGBLA06/MCNP GNF2 comparisons showed a behavior consistent with GE14 behavior. The GNF2 thermal-hydraulic correlations are robust and accurately describe pressure drop and critical power margins over the entire flow range.

Table 2-1 GNF2 Axial Regions

Name	Description	Axial Zone Length
[[		
		]]

Table 2-2 TIP Comparisons for BWR/4 With GNF2 Reload

[[					
					]]

Table 2-3 Effect of GNF2 Bundles on TIP Radial Bias

[[									
									]]

Figure 2-1 TGBLA06 Fission Density Benchmark for GNF2, at BOC

[[

]]

Figure 2-2 TGBLA06 Fission Density Benchmark for GNF2, at 65 GWD/MT

[[

]]

Figure 2-3 Core Eigenvalue tracking for BWR/4 Containing GNF2 Reload

[[

]]

Figure 2-4 TGBLA06 Reactivity Benchmark for GNF2, at BOC (GE14 1σ uncertainty band, dashed line)

[[

]]

Figure 2-5 TGBLA06 Reactivity Benchmark for GNF2, at high exposure (GE14 1σ uncertainty band, dashed line)

[[

]]

Figure 2-6 Axial Void Calculation on GNF2 at High Power Conditions from the Findlay-Dix Correlation and Sub-channel Based Calculation

[[

]]

Figure 2-7 Spacer Test Configuration

[[

]]

Figure 2-8 GNF2 Calculated vs. Measured Delta –P

[[

]]

Figure 2-9 GNF2 ΔP (Calculated or Measured) Versus Elevation

[[

]]

Figure 2-10 Mass Flux vs. R-Factor Plane

[[

]]

Figure 2-11 GEXL17 ECPR as a Function of Bundle Flow

[[

]]

2.3 SHUTDOWN MARGIN (SDM)

The required Technical Specifications for Shutdown Margin are unchanged for GNF2.

2.3.1 Fuel Parameters That Affect SDM

The fuel parameters that affect SDM are unchanged for GNF2.

2.3.2 Treatment of Fuel Parameter Uncertainties

A shutdown margin demonstration experiment is performed at the beginning of each operating cycle. This demonstration is performed in the cold, or most reactive criticality condition. The demonstration configuration attempts to simulate the most reactive rod out condition. In order to obtain a critical condition, other rods are also withdrawn. The 3D simulator (Reference 8) is used to calculate the demonstration condition. Reference 1 presented the results of 39 critical experiments performed over five cores, for which multiple cold critical experiments were performed on the same core. The standard deviation of the critical eigenvalues for the cores in Reference 1 relative to the average obtained for the same core is [[ ]]. This standard deviation can be compared to the Technical Specification allowance of 0.38% Δk/k., indicating that for application to high power density cores, the data supports the continued use of the current Technical Specification limit.

The ability to predict shutdown margin for GNF2 applications has been evaluated through a series of local critical measurements in a 240 bundle BWR/4 operating with annual cycles. Four GNF2 lead use assemblies were inserted at the beginning of cycle 33. In all, a series of 22 local cold critical measurements were performed in cycles 32 through 35. Results from Cycles 33 and 34 have been previously audited by the NRC staff as part of the generic Amendment 22 Audit for GNF2 (Reference 20). The results are summarized in Table 2-4.

Local critical results where the fully withdrawn rod is adjacent to a GNF2 bundle are shown in the shaded rows. An important cold shutdown methods metric is the difference between the projected keff and the actual keff evaluated from the measurement. For these data, the average difference between the projected and actual keff for the non-GNF2 criticals is [[ ]] with a standard deviation of [[ ]]. The GNF2 criticals yield an average difference of [[ ]] with a standard deviation of [[ ]]. These results are well within the range of projected–measured results detailed in Reference 1. The standard deviation of the 22 differences is [[ ]] essentially equal to the value of [[ ]] obtained in Table 2-10 of Reference 1. The distribution of differences is illustrated graphically in Figure 2-12. The red part of the bar represents the GNF2 results and the blue part represents the remaining criticals. These results show the consistency between the two sets of criticals and that there is no significant cold critical bias change for GNF2 bundles.

2.3.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of Shutdown Margin as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. This evaluation is based on the consistent shutdown predictions for the 240-bundle BWR/4, in which local critical experiments have been carried out near GNF2 lead use assemblies. Consistent TGBLA06/MCNP reactivity data have also been obtained for cold conditions.

Table 2-4 Summary of Local Cold Critical Measurement for Plant A

Cycle	Case	Cycle Exposure	Temp (ºF)	Period (sec)	Projected keff	Actual keff
35	COLD_L01	0	86	24	[[	
35	COLD_L02	0	86	55		
35	COLD_L03	0	86	70		
35	COLD_L04	0	86	40		
34	COLD_L01	0	92	60		
34	COLD_L02	0	92	50		
34	COLD_L03	0	92	60		
34	COLD_L04*	7567	97	80		
34	COLD_L05	7567	97	55		
34	COLD_L06*	7567	95	55		
33	COLD_L01	0	86	70		
33	COLD_L02	0	86	40		
33	COLD_L03	0	86	70		
33	COLD_L04	7738	108	40		
33	COLD_L05*	7738	108	28		
33	COLD_L06*	7738	108	30		
32	COLD_L01	0	91	80		
32	COLD_L02	0	91	20		
32	COLD_L03	0	91	30		
32	COLD_L04	7718	99	40		
32	COLD_L05	7718	99	60		]]

* Local critical results where the fully withdrawn rod is adjacent to a GNF2 bundle are shown in the shaded rows.

Figure 2-12 Frequency Distribution of Cold Critical Eigenvalue Differences

[[

]]

2.4 FUEL ROD THERMAL-MECHANICAL PERFORMANCE

For each GNF fuel design, thermal-mechanical based linear heat generation rate limits (LHGR Operating Limits) are specified for each fuel rod type (for both UO_2 and gadolinia-bearing rods) such that, if each rod type is operated within its LHGR limit, the thermal-mechanical design and licensing criteria, including those which address response to anticipated operational occurrences (AOOs), are explicitly satisfied and fuel rod integrity is maintained. The licensing criteria for determining thermal-mechanical design have not changed for GNF2.

2.4.1 Fuel Parameters That Affect Thermal-Mechanical Limits

The fuel parameters that affect thermal-mechanics limits have not changed for GNF2.

2.4.2 Treatment of Fuel Parameter Uncertainties

The impact of the GNF2 design on the uncertainty in local peaking and three-dimensional power distribution is discussed in Section 2.2.1.2 of this document, where the revised uncertainties as shown in Table 2-11 of Reference 1 are shown to be appropriate for GNF2 analysis. The GNF2 fuel pellet and rod diameter design is almost identical to the GE14 fuel rod design. The differences are summarized in Table 1-1. GNF2 fuel rods, however, operate at a higher peak power, while still maintaining the same peak discharge exposure. The current design basis for GNF2 fuel included in Reference 4 is based on the GSTRM methodology. Consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the LHGR operating limits for GNF2 fuel as documented in Reference 26 pending the approval of the PRIME methodology currently under review (Reference 18).

2.4.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of thermal-mechanical limits as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. The standard GE methodology for determining LHGR limits includes conservative consideration for, and provides reasonable assurance of adequate margin to address, the power uncertainties in question and is not affected by the GNF2 design. The current approved GSTRM provide an appropriate basis for the use of GNF2 in the EPU and MELLLA+ extended operating domains; although PRIME will be used as the basis for GNF2 thermal-mechanical design basis consistent with Limitation 9.12 (See Appendix A). The GSTRM basis for GNF2 (Reference 26) does not require the incremental penalty applied to the GE14 design by Appendix F of Reference 3 (See Appendix A).

2.5 LOCA RELATED NODAL POWER LIMITS

The purpose of the maximum average planar linear heat generation rate (MAPLHGR) limits is to assure adequate protection of the fuel during a postulated loss-of-coolant accident (LOCA) with the defined operation of the emergency core cooling system (ECCS). This is unchanged for GNF2.

2.5.1 Fuel Parameters That Affect LOCA Related Nodal Power Limits

The fuel parameters that affect LOCA related nodal power limits are unchanged for GNF2.

2.5.2 Treatment of Fuel Parameter Uncertainties

The ECCS-LOCA analysis follows the NRC-approved SAFER/GESTR application methodology documented in Volume III of NEDE-23785-1-PA (Reference 13). The analytical models used to perform ECCS-LOCA analyses are documented in Volume II of NEDE-23785-1-PA (Reference 14) together with NEDE-30996P-A (Reference 15) and NEDC-32950P (Reference 16). Reference 1 contains a discussion of the relationship of peak power uncertainties and their application to fuel parameter analysis. The analysis presented in Section 2.2.1.2, showing the uncertainty in pin and bundle power for GNF2 is the same as for GE14 and previous designs.

2.5.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of thermal-mechanical limits as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. The conservatism of the present ECCS-LOCA methodology used to determine MAPLGHR limits adequately considers the effects of the uncertainties in local and bundle power and provides adequate and reasonable assurance that those limits provide adequate margin to protect the fuel.

This assurance is extended to GNF2. The ECCS-LOCA methodology is fully capable of simulating the necessary features of the GNF2 fuel design and design basis uncertainties for the design GE14 fuel design are adequate and applicable to GNF2 analyses.

2.6 STABILITY

Thermal-hydraulic stability analyses are performed to assure that the SLMCPR is protected in the event of a thermal-hydraulic instability event. Specific analyses are associated with each of the long-term stability solutions. These long-term solutions include Option I-D, Option II, Option III, and Enhanced Option I-A. The stability analyses and the applicability of these stability solution Options remain unchanged for GNF2.

2.6.1 Fuel Parameters That Affect Stability

The fuel parameters identified previously in Reference 1 are unchanged for GNF2.

2.6.2 Treatment of Fuel Parameter Uncertainties

Reference 1 provides the treatment of the fuel parameter uncertainties for each of the long-term stability solutions is unchanged for GNF2. Sections 2.6.2.1 through 2.6.2.4 of Reference 1 discuss the stability impact of nuclear and thermal hydraulic uncertainties for each of the four stability long-term solutions listed above, namely Option 1-D, Option II, Option III, and Enhanced Option I-A. In general, the stability models used to evaluate the options and issues described above imbed the basic bundle nuclear and thermal hydraulic models from the TGBLA, ISCOR and PANACEA programs. Other transient models are consistent with these basic models. Stability performance depends on the following parameters:

- **Moderator void coefficient**: The TGBLA06/MCNP comparisons for the GNF2 design show the same bias with moderator density as previous 10x10 designs. There is no change in moderator void coefficient bias and uncertainty with GNF2.

- **Local pin power peaking**: The TGBLA06/MCNP comparisons for the GNF2 design also show the same pin power accuracy for GNF2 as previous 10x10 designs, and the same stability uncertainty impact as previous designs.

- [[ ]]: The GNF2 reactivity biases relative to Monte Carlo results are consistent with previous 10x10 designs, showing no change needed in stability impact for [[ ]].

- **Bundle pressure drop**: The bundle pressure drop model is based on GNF2 full-scale pressure drop measurements. In addition to the total bundle pressure drop, the axial pressure profile is accurately modeled (see Figure 2-9) by the ISCOR model, which is embedded in the stability evaluations.

2.6.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of Stability as specified in Table 1-2 can be used for the GNF2 design under EPU conditions. All models related to stability have the same uncertainties for the GNF2 design as the GE14 design, and are acceptable for GNF2-related stability analysis.

2.7 LICENSED EXPOSURE

Although GE14 fuel is licensed to a peak pellet exposure limit of [[ ]], the GNF2 fuel design is licensed to a peak pellet exposure limit of [[ ]] (Reference 4), based on the existing GSTRM methodology basis. GEH anticipates updating the peak pellet exposure limit for GNF2 fuel to [[ ]] when the new PRIME methodology is applied (Reference 18) (See Appendix A).

This licensed peak pellet exposure limit is specified and applied in the process computer to assure that fuel is not operated beyond its analyzed basis. In this application, the best estimate value of the local exposure condition is monitored against the specified exposure limit.

2.7.1 Fuel Parameters That Affect Pellet Exposure

The fuel parameters that affect pellet exposure are unchanged for GNF2.

2.7.2 Treatment of Fuel Parameter Uncertainties

The overall pin power uncertainties are unchanged for GNF2 (Section 2.2.1.2).

2.7.3 Adequacy of Existing Treatment and Alternate Approach

The design limits and methods associated with evaluation of licensed exposure as specified in Table 1-2 can be used for the GNF2 design under expanded operating domains. As noted previously, the current approved GSTRM (Reference 26) provide an appropriate basis for the use of GNF2 in the EPU and MELLLA+ extended operating domains. However, consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the GNF2 design basis once PRIME is approved.

3.0 EXTENSION OF SAFETY PARAMETER BASES TO THE MELLLA+ OPERATING DOMAIN

3.1 INTRODUCTION

MELLLA+ operation allows the reactor to be at full power down to 80% flow (Reference 2). Like extended power uprate (EPU), these conditions increase the amount of steam voids in the core. The total steam void level in a given bundle is a direct function of the power to flow ratio. Raising the average bundle power (EPU) or lowering the flow (MELLLA+) have the same effect, and for the most part raise similar technical issues. The use of GNF2 fuel does not change the application of the GEH methods for MELLLA+.

3.2 CRITICAL POWER

3.2.1 Safety Limit Critical Power Ratio (SLMCPR)

Section 3.2.1 of Reference 1 describes the process for determining the SLMCPR for MELLLA+ operating conditions. This analysis has shown that use of uncertainties at rated conditions is appropriate for MELLLA+ conditions. Design limits and methods associated with evaluation of SLMCPR as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions. The justification for the use of GEH Methods for GNF2 SLMCPR evaluations is given in Section 2.2.1.

3.2.2 Operating Limit Critical Power Ratio (OLMCPR)

MELLLA+ evaluation procedures require consideration of OLMCPR values for each limiting corner of the power flow map. If changes are required to account for OLMCPR at different flow points, this change is reflected in the process computer algorithm for MFLCPR (ratio of bundle critical power to OLMCPR) for each bundle. The same conservatisms apply for the nuclear inputs to the transient evaluations. The sensitivities remain the same as those evaluated at the full power conditions and are unaffected by GNF2 fuel. Design limits and methods associated with evaluation of OLMCPR as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

3.3 SHUTDOWN MARGIN

The data in Section 2.3 of Reference 1 supports a 2σ demonstration margin criteria of 0.38% $\Delta k/k$. A series of cold critical experiments performed on a BWR/4 containing GNF2 lead use assemblies appears in Section 2.3.2 of this report shows that this shutdown margin accuracy is maintained with local critical measurements near GNF2 lead use assemblies. Design limits and methods associated with evaluation of shutdown margin as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

3.4 FUEL ROD THERMAL MECHANICAL PERFORMANCE

The fuel rod thermal-mechanical analyses explicitly address the variation in the axial power distribution that may occur as a result of spectral shift operation, and therefore the specified LHGR operating limits and exposure limit are directly applicable to MELLLA+ operation and unaffected by GNF2 fuel design. Design limits and methods associated with evaluation of Fuel Rod Thermal Mechanical Performance as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

3.5 LOCA RELATED NODAL POWER LIMITS

There are no differences in the ECCS-LOCA methodology between EPU and MELLLA+ except that for MELLLA+ the ECCS-LOCA analyses are performed for at least two additional state points. These are unchanged for GNF2. Design limits and methods associated with evaluation of LOCA related Nodal Power Limits as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

3.6 STABILITY

The GE BWR Detect and Suppress Solution – Confirmation Density (DSS-CD) (NEDC-33075P) is a licensed stability solution for operation in the MELLLA+ domain (Reference 17). The GNF2 pressure drop and critical power correlations described in Section 2.2.1.2 are accurate to low flow conditions and accurately represent the pressure profile in the fuel bundle. Design limits and methods associated with evaluation of Stability as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

3.7 LICENSED EXPOSURE

The current approved GSTRM (Reference 26) and provide an appropriate basis for the use of GNF2 in the MELLLA+ operating domain. However, consistent with Limitation 9.12 (See Appendix A), GEH anticipates updating the GNF2 design basis once PRIME is approved. Design limits and methods associated with evaluation of Licensed Exposure as specified in Table 1-2 can be used for the GNF2 design under MELLLA+ conditions.

4.0 LICENSING APPLICATION

4.1 OVERVIEW

The purpose of this supplement is to extend the application of Reference 1 to GNF2 fuel.

4.2 APPLICABILITY

The Applicability of GE Methods to Expanded Operating Domains LTR basis is applicable to current GEH BWR product lines licensed with GEH nuclear and safety analysis methods. The Methods LTR is applicable to plants that include current GNF fuels including GNF2. The application of these codes complies with the limitations, restrictions and conditions specified in the approving NRC SER for each code.

The parameters establishing the Applicability of GEH Methods to Expanded Operating Domains applicability envelope are:

Parameter	Generic Value
BWR Product Line	BWR/2-6
Fuel Product Line	GE and non-GE fuel designs using square arrays of fuel rods, including 7x7, 8x8, 9x9, and 10x10 designs and GNF2
Licensing Methodology	GEH Nuclear and Safety Analysis Methods
Operating Domain	CPPU, EPU, with MELLLA+ including currently licensed operating domains (e.g., ELLA, MELLLA) and operational flexibility features
Maximum Rated Power Level	120% OLTP
Stability Solution	GE Stability Solutions

4.3 PLANT SPECIFIC APPLICATION PROCESS

Each plant seeking to apply the Methods LTR must provide information supporting the application that demonstrates that the plant parameters are within the applicability definition in Section 4.2.

5.0 SUMMARY AND CONCLUSION

The evaluations presented in Sections 2 and 3 demonstrate the adequacy of the GEH methods for GNF2 when used in the expanded operating domains. Further, the assessment in Appendix A documents the applicability of the limitations in the NRC SE for the Methods LTR (Reference 3) for GNF2 fuel.

Safety Limit Critical Power Ratio (SLMCPR)

SLMCPR evaluation procedure and methods are not changed due to introduction of GNF2 fuel.

Operating Limit Critical Power Ratio (OLMCPR)

OLMCPR evaluation procedure and methods are not changed due to introduction of GNF2 fuel.

Shutdown Margin (SDM)

The Technical Specification (TS) limit for the SDM of 0.38 % $\Delta k/k$ is not increased for CPPU or EPU and MELLLA+ applications where GNF2 is utilized. The SDM evaluation procedure and methods are unchanged due to the introduction of GNF2 fuel.

Fuel Rod Thermal-Mechanical Performance

The licensing criteria for fuel rod thermal-mechanical performance are unchanged. The current approved GSTRM (Reference 26) fuel methodology provides an appropriate basis for the use of GNF2. However, consistent with Limitation 9.12 (See Appendix A), the GNF2 design basis will be updated once PRIME is approved.

LOCA Related Nodal Power Limits

The LOCA evaluation procedure and methods are unchanged due to introduction of GNF2 fuel.

Stability

The stability evaluation procedure and methods are unchanged due to introduction of GNF2 fuel.

Licensed Exposure

The licensing criteria for fuel rod maximum licensed exposure are unchanged. The current approved GSTRM (Reference 26) fuel methodology provides an appropriate basis for the use of GNF2. However, consistent with Limitation 9.12 (See Appendix A), the GNF2 design basis will be updated once PRIME is approved.

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Appendix – A

Limitations from Safety Evaluation for LTR NEDC-33173P

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
9.1	TGBLA/PANAC Version	The neutronic methods used to simulate the reactor core response and that feed into the downstream safety analyses supporting operation at EPU/MELLLA+ will apply TGBLA06/PANAC11 or later NRC-approved version of neutronic method.	Unchanged	EPU/MELLLA+ applications utilizing GNF2 fuel will use TGBLA06/PANAC11 or later NRC-approved version of neutronic methods.
9.2	3D Monicore	For EPU/MELLLA+ applications, relying on TGBLA04/PANAC10 methods, the bundle RMS difference uncertainty will be established from plant-specific core-tracking data, based on TGBLA04/PANAC10. The use of plant-specific trend line based on the neutronic method employed will capture the actual bundle power uncertainty of the core monitoring system.	Not Applicable	EPU/MELLLA+ applications utilizing GNF2 fuel will not use TGBLA04/PANAC10 as the neutronic methods. See Limitation 9.1.
9.3	Power to Flow Ratio	Plant-specific EPU and expanded operating domain applications will confirm that the core thermal power to core flow ratio will not exceed 50 MWt/Mlbm/hr at any state point in the allowed operating domain. For plants that exceed the power-to-flow value of 50 MWt/Mlbm/hr, the application will provide power distribution assessment to establish that neutronic methods axial and nodal power distribution uncertainties have not increased.	Unchanged	This limitation is not dependent on fuel type. Consistent with Reference 23.

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
9.4	SLMCPR1	For EPU operation, a 0.02 value shall be added to the cycle-specific SLMCPR value. This adder is applicable to SLO, which is derived from the dual loop SLMCPR value.	Unchanged	In Reference 24, GEH committed to justify the use of GE's analytical methods for expanded operating domains, up to and including MELLLA+, without the use of the temporary adders based on specific gamma scan data. This data is applicable to the GNF2 fuel type. Until such time the data is reviewed and approved by the NRC, the SLMCPR adder remains applicable to GNF2 fuel.
9.5	SLMCPR2	For operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state point, a 0.03 value shall be added to the cycle-specific SLMCPR value.	Unchanged	In Reference 24, GEH committed to justify the use of GE's analytical

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
				methods for expanded operating domains, up to and including MELLLA+, without the use of the temporary adders based on specific gamma scan data. This data is applicable to GNF2 fuel type. Until such time the data is reviewed and approved by the NRC, the SLMCPR adder remains applicable to GNF2 fuel.
9.6	R-Factor	The plant specific R-factor calculation at a bundle level will be consistent with lattice axial void conditions expected for the hot channel operating state. The plant-specific EPU/MELLLA+ application will confirm that the R-factor calculation is consistent with the hot channel axial void conditions.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.7	ECCS-LOCA 1	For applications requesting implementation of EPU or expanded operating domains, including	Unchanged	This limitation will be implemented for

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
		MELLLA+, the small and large break ECCS-LOCA analyses will include top-peaked and mid-peaked power shape in establishing the MAPLHGR and determining the PCT. This limitation is applicable to both the licensing bases PCT and the upper bound PCT. The plant-specific applications will report the limiting small and large break licensing basis and upper bound PCTs.		all fuel types, including GNF2.
9.8	ECCS-LOCA 2	The ECCS-LOCA will be performed for all state points in the upper boundary of the expanded operating domain, including the minimum core flow state points, the transition state point as defined in Reference 2 and the 55 percent core flow state point. The plant-specific application will report the limiting ECCS-LOCA results as well as the rated power and flow results. The SRLR will include both the limiting state point ECCS-LOCA results and the rated conditions ECCS-LOCA results.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.9	Transient LHGR 1	Plant-specific EPU and MELLLA+ applications will demonstrate and document that during normal operation and core-wide AOOs, the T-M acceptance criteria as specified in Amendment 22 to GESTAR II will be met. Specifically, during an AOO, the licensing application will demonstrate that the: (1) loss of fuel rod mechanical integrity will not occur due to fuel	Unchanged	This limitation will be implemented for all fuel types, including GNF2.

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
		melting and (2) loss of fuel rod mechanical integrity will not occur due to pellet–cladding mechanical interaction. The plant-specific application will demonstrate that the T-M acceptance criteria are met for the both the UO_2 and the limiting GdO_2 rods.		
9.10	Transient LHGR 2	Each EPU and MELLLA+ fuel reload will document the calculation results of the analyses demonstrating compliance to transient T-M acceptance criteria. The plant T-M response will be provided with the SRLR or COLR, or it will be reported directly to the NRC as an attachment to the SRLR or COLR.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.11	Transient LHGR 3	To account for the impact of the void history bias, plant-specific EPU and MELLLA+ applications using either TRACG or ODYN will demonstrate an equivalent to 10 percent margin to the fuel centerline melt and the 1 percent cladding circumferential plastic strain acceptance criteria due to pellet-cladding mechanical interaction for all of limiting AOO transient events, including equipment out-of-service. Limiting transients in this case, refers to transients where the void reactivity coefficient plays a significant role (such as pressurization events). If the void history bias is incorporated into the transient model within the code, then the additional 10 percent margin to the fuel centerline melt and the 1 percent cladding	Unchanged	This limitation will be implemented for all fuel types, including GNF2.

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
		circumferential plastic strain is no longer required.		
9.12	LHGR and Exposure Qualification	In MFN 06-481, GE committed to submit plenum fission gas and fuel exposure gamma scans as part of the revision to the T-M licensing process. The conclusions of the plenum fission gas and fuel exposure gamma scans of GE 10x10 fuel designs as operated will be submitted for NRC staff review and approval. This revision will be accomplished through Amendment to GESTAR II or in a T-M licensing LTR. PRIME (a newly developed T-M code) has been submitted to the NRC staff for review (Reference 18). Once the PRIME LTR and its application are approved, future license applications for EPU and MELLLA+ referencing LTR NEDC-33173P must utilize the PRIME T-M methods.	Unchanged	This limitation will be implemented for GNF2. In Reference 25, GEH provided supplement to NEDC-33173P describing the implementation of the PRIME code models into the downstream safety analysis codes, and the schedule to complete the implementation. That supplement is applicable to GNF2 fuel.
9.13	Application of 10 Weight Percent Gd	Before applying 10 weight percent Gd to licensing applications, including EPU and expanded operating domain, the NRC staff needs to review and approve the T-M LTR demonstrating that the T-M acceptance criteria specified in GESTAR II and Amendment 22 to GESTAR II can be met for steady-state and transient conditions. Specifically, the T-M application must demonstrate that the T-M acceptance criteria can be met for TOP and MOP conditions that bounds the response of plants	Unchanged	This limitation will be implemented for all fuel types, including GNF2. GEH has no current plans to apply 10 weight percent Gd to GNF2 fuel.

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
		operating at EPU and expanded operating domains at the most limiting state points, considering the operating flexibilities (e.g., equipment out-of-service). Before the use of 10 weight percent Gd for modern fuel designs, NRC must review and approve TGBLA06 qualification submittal. Where a fuel design refers to a design with Gd-bearing rods adjacent to vanished or water rods, the submittal should include specific information regarding acceptance criteria for the qualification and address any downstream impacts in terms of the safety analysis. The 10 weight percent Gd qualifications submittal can supplement this report.		
9.14	Part 21 Evaluation of GESTR-M Fuel Temperature Calculation	Any conclusions drawn from the NRC staff evaluation of the GE's Part 21 report will be applicable to the GESTR-M T-M assessment of this SE for future license application. GE submitted the T-M Part 21 evaluation, which is currently under NRC staff review. Upon completion of its review, NRC staff will inform GE of its conclusions.	Not applicable.	The current approved GSTRM and the future PRIME fuel methodologies both provide an appropriate basis for the use of GNF2 in the EPU and MELLLA+ extended operating domains. The GSTRM basis for GNF2 (Reference 26) does not require the incremental penalty applied to the

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
				GE14 design by Appendix F of the Methods LTR SE (Reference 3).
9.15	Void Reactivity 1	The void reactivity coefficient bias and uncertainties in TRACG for EPU and MELLLA+ must be representative of the lattice designs of the fuel loaded in the core	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.16	Void Reactivity 2	A supplement to TRACG /PANAC11 for AOO is under NRC staff review (Reference 19). TRACG internally models the response surface for the void coefficient biases and uncertainties for known dependencies due to the relative moderator density and exposure on nodal basis. Therefore, the void history bias determined through the methods review can be incorporated into the response surface "known" bias or through changes in lattice physics/core simulator methods for establishing the instantaneous cross-sections. Including the bias in the calculations negates the need for ensuring that plant-specific applications show sufficient margin. For application of TRACG to EPU and MELLLA+ applications, the TRACG methodology must incorporate the void history bias. The manner in which this void history bias is accounted for will be established by the NRC staff SE approving NEDE-32906P, Supplement 3, "Migration to	Unchanged	This limitation will be implemented for all fuel types, including GNF2.

Limitation Number from NRC SER	Limitation Title	Limitation Text	Disposition	Comments
		TRACG04/PANAC11 from TRACG02/PANAC10," May 2006 (Reference 19). This limitation applies until the new TRACG/PANAC methodology is approved by the NRC staff.		
9.17	Steady-State 5 Percent Bypass Voiding	The instrumentation specification design bases limit the presence of bypass voiding to 5 percent (LRPM levels). Limiting the bypass voiding to less than 5 percent for long-term steady operation ensures that instrumentation is operated within the specification. For EPU and MELLLA+ operation, the bypass voiding will be evaluated on a cycle-specific basis to confirm that the void fraction remains below 5 percent at all LPRM levels when operating at steady-state conditions within the MELLLA+ upper boundary. The highest calculated bypass voiding at any LPRM level will be provided with the plant-specific SRLR.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.18	Stability Set points Adjustment	The NRC staff concludes that the presence bypass voiding at the low-flow conditions where instabilities are likely can result in calibration errors of less than 5 percent for OPRM cells and less than 2 percent for APRM signals. These calibration errors must be accounted for while determining the set points for any detect and suppress long-term methodology. The calibration values for the different long-term solutions are	Unchanged	This limitation will be implemented for all fuel types, including GNF2.

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		specified in the associated sections of this SE, discussing the stability methodology.		
9.19	Void-Quality Correlation 1	For applications involving PANACEA/ODYN/ISCOR/TASC for operation at EPU and MELLLA+, an additional 0.01 will be added to the OLMCPR, until such time that GE expands the experimental database supporting the Findlay-Dix void-quality correlation to demonstrate the accuracy and performance of the void-quality correlation based on experimental data representative of the current fuel designs and operating conditions during steady-state, transient, and accident conditions.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.20	Void-Quality Correlation 2	The NRC staff is currently reviewing Supplement 3 to NEDE-32906P, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10," dated May 2006. The adequacy of the TRACG interfacial shear model qualification for application to EPU and MELLLA+ will be addressed under this review. Any conclusions specified in the NRC staff SE approving Supplement 3 to LTR NEDC-32906P will be applicable as approved.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.
9.21	Mixed Core Method 1	Plants implementing EPU or MELLLA+ with mixed fuel vendor cores will provide plant-specific justification for extension of GE's analytical methods or codes. The content of the plant-specific application will cover the topics	Not applicable	The purpose of the supplement is to address GNF2 fuel, not mixed fuel vendor cores. Therefore, this limitation

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		addressed in this SE as well as subjects relevant to application of GE's methods to legacy fuel. Alternatively, GE may supplement or revise LTR NEDC-33173P for mixed core application.		is not applicable to this supplement.
9.22	Mixed Core Method 2	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 GE14. Fuel lattice designs, other than GE lattices up to GE14, 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 the lattice Gd loading that result in nodal reactivity biases	Comply	This supplement is intended to address this limitation for GNF2 fuel. GNF2 does not use: • Square internal water channels water crosses • Gd rods simultaneously adjacent to water and vanished rods • 11x11 lattices • MOX fuel GNF2 fuel does not have significant changes in the Gd rod optical thickness or in Gd loading that would result in nodal reactivity bias beyond those previously established for GE14 fuel.

		beyond those previously established will require review before the GE methods may be applied.		
9.23	MELLLA+ Eigenvalue Tracking	In the first plant-specific implementation of MELLLA+, the cycle-specific eigenvalue tracking data will be evaluated and submitted to NRC to establish the performance of nuclear methods under the operation in the new operating domain. The following data will be analyzed: • Hot critical eigenvalue, • Cold critical eigenvalue, • Nodal power distribution (measured and calculated TIP comparison), • Bundle power distribution (measured and calculated TIP comparison), • Thermal margin, • Core flow and pressure drop uncertainties, and • The MIP Criterion (e.g., determine if core and fuel design selected is expected to produce a plant response outside the prior experience base). Provision of evaluation of the core-tracking data will provide the NRC staff with bases to establish if operation at the expanded operating domain indicates: (1) changes in the performance of nuclear methods outside the EPU experience base; (2) changes in the available thermal margins; (3) need for changes in the uncertainties and NRC-approved criterion used in the SLMCPR methodology; or (4) any anomaly that may require corrective actions.	Unchanged	This limitation will be implemented for the first plant-specific implementation of MELLLA+, independent of fuel type.

9.24	Plant Specific Application	The plant-specific applications will provide prediction of key parameters for cycle exposures for operation at EPU (and MELLLA+ for MELLLA+ applications). The plant-specific prediction of these key parameters will be plotted against the EPU Reference Plant experience base and MELLLA+ operating experience, if available. For evaluation of the margins available in the fuel design limits, plant-specific applications will also provide quarter core map (assuming core symmetry) showing bundle power, bundle operating LHGR, and MCPR for BOC, MOC, and EOC. Since the minimum margins to specific limits may occur at exposures other than the traditional BOC, MOC, and EOC, the data will be provided at these exposures.	Unchanged	This limitation will be implemented for all fuel types, including GNF2.