ENCLOSURE 2

M190069

Comment Summary Table and Draft SE Markup

Non-Proprietary Information

**IMPORTANT NOTICE**

This is a non-proprietary version of Enclosure 1, 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 [[ ]].

**Comment Summary for Draft Safety Evaluation for NEDC-33173P Supplement 6, “Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty”**

**Note:** Page numbers shown in this table reflect the page numbers in this enclosure. Due to suggested changes in the Safety Evaluation (SE) and the addition of proprietary marking, these page numbers differ from the page numbers in the draft SE sent to GEH for review.

| Location | Comment |
|---|---|
| Section 1.1<br>Background | Page 4:<br>It is unusual to call out this one component of the integrated power uncertainty and not the other one (four bundle power, of P4B), particularly because the majority of this work was developed to directly demonstrate that the P4B does not change as a function of power-to-flow ratio. Recommend including discussion of the P4B term here.<br><br>GEH suggests the following change (Line 35):<br>“…[[ ]] the four-bundle power uncertainty ($\sigma_{P4B}$), and the…”<br><br>*Suggested change shown in the markup.* |
| Section 1.1.1<br>Interim Methods Licensing Topical Report NEDC-33173P-A | Page 5:<br>It is not a given that EPU or 24-month cycles will lead to flatter core radial power distributions at the limiting point in the cycle.<br><br>GEH suggests the following change (Line 6):<br>“…the average bundle power can increase~~s~~, leading…”<br><br>*Suggested change shown in the markup.* |

| Location | Comment |
|---|---|
| Section 1.1.1<br>Interim Methods Licensing Topical Report NEDC-33173P-A | Page 5:<br>While this statement is generally true for the critical power ratio (CPR), it is not always true for linear heat generation rate (LHGR), where the thermal-mechanical operating limit (TMOL) curve has an exposure dependence. The highest kw/ft rod in the core does not necessarily have the least margin to its limit.<br>And with regard to the core design of extended power uprate (EPU) and non-EPU plants, the margin to limits is controlled through bundle nuclear design and core loading strategies. The amount of margin to the limit in operation is not directly a function of whether or not a plant is EPU or non-EPU.<br><br>GEH suggests the following change (Lines 9-10):<br>"Since the maximum powered bundles can set the thermal limits, EPU operation can reduce~~s~~ the margins to the thermal limits."<br><br>*Suggested changes shown in the markup.* |
| Section 1.1.1<br>Interim Methods Licensing Topical Report NEDC-33173P-A | Page 5:<br>Would be more accurate to state "all bundles"<br><br>GEH suggests the following change (Line 16):<br>"~~The maximum powered~~All bundles must meet the thermal limits…"<br><br>*Suggested change shown in the markup.* |
| Section 1.1.1<br>Interim Methods Licensing Topical Report NEDC-33173P-A | Page 5:<br>Would be more accurate to state "all bundles"<br><br>GEH suggests the following change (Lines 18-19):<br>"Since the ~~high-powered bundle's~~ ability to operate within the thermal limits of all bundles is…"<br><br>*Suggested changes shown in the markup.* |

| Location | Comment |
|---|---|
| Section 1.1.2<br>Supplement 2 to NEDC-33173P-A | Page 10:<br>This value can be higher for some plants, up to ~57 MWt/(lbm/hr) at the limiting point on the curve.<br><br>GEH suggests the following change (Line 32):<br>"…for MELLLA+ operation is up to ~~50~~~57 MWt/(Mlbm/hr)"<br><br>*Suggested change shown in the markup.* |
| Section 3.1<br>Bundle Power Uncertainty | Page 14:<br>Recommend ending the sentence with "if a statistically significant trend exists".<br><br>GEH suggests the following change (Line 10):<br>"…historically established value and if a statistically significant trend exists."<br><br>*Suggested change shown in the markup.* |
| Section 3.1.1<br>Assessment of Core TIP Data | Page 14:<br>Correct the power density for Peach Bottom Units 2 and 3.<br><br>GEH suggests the following change (Line 24):<br>"…BWR/4 with power densities of ~~58.4~~59.43 kW/L,…"<br><br>*Suggested change shown in the markup.* |

**DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION FOR THE REVIEW OF TOPICAL REPORT NEDC-33173P SUPPLEMENT 6, "APPLICABILITY OF GE METHODS TO EXPANDED OPERATING DOMAINS – REMOVAL OF THE SAFETY LIMIT MINIMUM CRITICAL POWER RATIO (SLMCPR) PENALTY"**

**EPID: L-2017-TOP-0040/DOCKET 99902024**

**GE-HITACHI NUCLEAR ENERGY AMERICAS LLC.**

## 1.0 INTRODUCTION

By letter dated September 15, 2017 (Ref. 1), General Electric (GE) Hitachi Nuclear Energy (hereafter GEH) submitted Licensing Topical Report (LTR) NEDC-33173P, Supplement 6, Revision 0, "Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty" (Ref. 2) to the U.S. Nuclear Regulatory Commission (NRC) for review and approval for licensing applications. NEDC-33173P, Supplement 6, Revision 0 (Supplement 6) is the sixth supplement to the interim methods LTR (IMLTR) NEDC-33173P-A, Revision 4, "Applicability of GE Methods to Expanded Operating Domains" (Ref. 3). Supplement 6 seeks removal of the SLMCPR penalty imposed on plants operating in the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) expanded operating domain. The SLMCPR penalty for plants operating with GEH methods in the MELLLA+ domain was introduced in the NRC review of the IMLTR. Initially set at a value of 0.03, the SLMCPR penalty was subsequently reduced in the NRC review of NEDC-33173P-A, Revision 0, Supplement 2, "Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Confrentes" (Supplement 2, Reference 4) to the current values of 0.01 for power-to-flow (P/F) ratios less than 42 MWt/(Mlbm/hr) and 0.02 for P/F ratios greater than 42 MWt/(Mlbm/hr).

### 1.1 Background

The IMLTR provides the basis for the application of the suite of GEH and Global Nuclear Fuel (GNF) computational methods to perform safety analyses relevant to extended power uprate (EPU) and MELLLA+ operating domain licensing. During its review of the IMLTR, the NRC staff identified concerns regarding the power distribution uncertainties applied in the calculation of the safety and operating limits. These power distribution uncertainties include the bundle [[ ]] the four-bundle power uncertainty ($\sigma_{P4B}$), and the overall pin power peaking uncertainty ($\sigma_{peak}$). In its safety evaluation (SE) of the IMLTR, the NRC staff imposed penalties on the SLMCPR to account for inadequate qualification of these component uncertainties for modern fuel designs operating under conditions of expanded operating domains, such as EPU or MELLLA+ (Ref. 3). The penalties imposed on SLMCPR were partially relaxed during the NRC staff review of Supplement 2. Supplement 6 seeks to remove the remaining SLMPCR penalties.

To better inform the technical evaluation that is to follow, it is beneficial to review the history of the penalties applied to the SLMCPR in the EPU and MELLLA+ operating domains. The discussion presented in the following subsections discusses the origins and subsequent relaxations thus far approved of the SLMCPR penalties.

### 1.1.1 Interim Methods Licensing Topical Report NEDC-33173P-A

The IMLTR provides the basis for the application of the suite of GEH and GNF computational methods to EPU and MELLLA+ operating domains. To implement EPU and maintain a 24-month cycle, a higher number of maximum powered bundles are loaded into the core and the average bundle power can increase~~s~~, leading to a flatter core radial power distribution. Due to an increased two-phase pressure drop and higher coolant voiding, the coolant flow in the maximum-powered bundles decreases. This leads to higher bundle P/F ratios and higher exit void fractions. Since the maximum powered bundles can set the thermal limits, EPU operation can reduce~~s~~ the margins to the thermal limits. For MELLLA+ operation, plants operate at EPU power levels at lower core flow conditions. Therefore, the number of bundles operating at higher P/F conditions, and consequently higher exit void fractions, increases.

There are no direct limits on the operating bundle powers, operating bundle P/F ratio, or void fractions. Instead, the core design and the operating strategy employed are constrained by thermal limits. ~~The maximum powered~~All bundles must meet the thermal limits so that the technical specification safety limits or the specific fuel design limits are not violated during steady-state, transient, and accident conditions. Since the ~~high powered bundle's~~ ability to operate within the thermal limits of all bundles is analytically determined, it is important that the analytical tools being utilized are applied within the ranges for which they were derived and benchmarked. It is for this reason that the NRC staff, as part of its review of the IMLTR, assessed the applicability of GEH's analytical methods and codes used to predict EPU and MELLLA+ responses during steady-state, transient, and accident conditions.

One of the areas the NRC staff assessed was the extrapolation of neutronic methods to high (greater than 70 percent) void fractions. The neutronic parameters feed into almost all codes that are used to perform the steady-state, transient, and accident condition analyses and establish the core operating thermal limits. Therefore, the accuracy of the methods used to calculate the neutronic parameters affects the analyses supporting operation at EPU and MELLLA+ conditions. During the IMLTR review, the NRC staff examined confirmatory data comparisons between GEH's lattice physics code TGBLA06 (Ref. 6) and the HELIOS lattice physics code as well as core-tracking data validation, specifically, traversing in-core probe (TIP) comparisons versus increasing power density and void fraction.

Boiling water reactors (BWRs) are instrumented with TIP strings, and each TIP string is surrounded by four fuel bundles. The TIP readings provide a means to assess the normalized axial power shape along the length of the four bundles surrounding the individual TIP string. Therefore, for a given TIP string, the measurement is a response to the combined influence of the surrounding four bundles. GEH's core simulator PANAC11 models the response of the instrument to the appropriate particle species (thermal neutrons or gamma rays) at the detector location to produce a simulated signal. For TIP comparisons, this simulated detector response is compared to the relative strength of the measured signal.

GEH relies heavily on these TIP-measured and calculated four-bundle power comparisons and on code-to-code comparisons (e.g., TGBLA06 to MCNP) to benchmark its neutronic methods. However, during its assessment of the extrapolation of the neutronic methods to high void fraction, the NRC staff concluded that, while these TIP data provide a basis to determine the uncertainty associated with predicting the power of the four-bundle group (i.e., the four-bundle power uncertainty $\sigma_{P4B}$), they do not provide bases to ascertain the accuracy of the individual bundle-by-bundle prediction. This is because the TIP readings are predominantly due to the power response of the four surrounding bundles, even in the highly voided top of the fuel bundle. Additionally, because the TIP readings only provide [[ ]]. Furthermore, the TIP data does not provide a means to validate the overall pin power peaking uncertainty (i.e., $\sigma_{peak}$).

All three of these uncertainties are applied in the thermal limits calculations, as indicated in the NRC-approved GEH SLMCPR methodology TR NEDC-32601P-A (Ref. 7) and the associated uncertainty treatments TR NEDC-32694P-A (Ref. 8). It was, therefore, necessary to determine the continued applicability of their values for purposes of assessing the extrapolation of neutronic methods to higher void fractions. [[ ]]. This value was validated to be appropriate for application to more recent fuel designs during the NRC staff review of the IMLTR. The values associated with the [[ ]] and the overall pin power peaking uncertainty $\sigma_{peak}$ of [[ ]], respectively, were originally established within the SLMCPR methodology and uncertainty treatment TRs (NEDC-32601P-A and NEDC-32694P-A). However, the TIP data provided in the IMLTR do not provide a means to verify these values remain applicable.

The SLMCPR methodology and uncertainty treatment TRs established the values for [[ ]] and $\sigma_{peak}$ using bundle and pin gamma scan data from legacy fuel designs. Gamma scanning is a non-destructive method used to determine the relative fission product inventory in nuclear fuel, which is directly related to the core power distribution just prior to removal of the fuel from the core. During the IMLTR review, the NRC staff investigated the then-available and applicable gamma scan data and qualification database for GEH's neutronic methods. This investigation identified that a comprehensive qualification of GEH's steady-state neutronic method had, at the time, last been performed in 1985. Based on the differences in the current fuel and core designs and operating strategies in comparison to the historically available measurement data, the NRC staff concluded that additional gamma scans of contemporary fuel were necessary to demonstrate the established values for [[ ]] and $\sigma_{peak}$ remained applicable. In order to capture the uncertainties in the neutronic methods for operation in MELLLA+, GEH committed to a benchmark program wherein the vendor would gamma scan bundles and pins that had been operated as close as possible to MELLLA+ conditions; the associated data would be used to qualify the nuclear methods uncertainties.

Given that the specific measurement data would not be available for some time, GEH opted for an interim approach. Within the IMLTR, GEH proposed statistically treating the then-available GE 7×7 and GE 8×8 pin and bundle gamma scans to determine conservative values for the overall pin power peaking and [[ ]]. GEH determined the mean and uncertainty of the then-available axial pin power gamma scan data and determined the 95-percentile upper tolerance limit. This tolerance limit was defined as the mean bias plus 2σ uncertainty based on the peak power rods. By using the upper tolerance limit in the

SLMCPR and uncertainty treatment methodologies, the overall pin power peaking uncertainty $\sigma_{peak}$ increased from [[ ]][1]. GEH propagated the higher overall pin

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[1] The overall pin power peaking uncertainty is actually [[ ]]. The change observed in the overall pin power peaking uncertainty when utilizing the 95-percentile upper tolerance limit is the result of a change in one of these components, specifically [[

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power peaking uncertainty in the SLMCPR calculation, resulting in an increase of the SLMCPR by 0.01 ΔCPR. Similarly, by using the 95-percentile upper tolerance limit for the available bundle gamma scan data, [[ ]] Thus GEH, in the IMLTR, proposed adding a combined value of 0.02 to the cycle-specific SLMCPR values calculated for core configurations operating at EPU and MELLLA+ conditions.

In assessing the acceptability of this approach, the NRC staff concluded that an adder of 0.02 was adequate for the cycle-specific SLMCPR for plants implementing EPU operation. However, for plants implementing MELLLA+ operation, the NRC staff concluded an additional 0.01 value would be included for a total adder of 0.03 for the cycle-specific SLMCPR. The additional 0.01 SLMCPR adder for MELLLA+ operation was meant to account for potential changes in both the pin and bundle power uncertainties due to the higher bundle P/F ratios (indicative of higher void fraction and harder neutron spectrum) in the MELLLA+ operating domain. The NRC staff imposed the use of a 0.02 adder for EPU operation and a 0.03 adder for MELLLA+ operation in Limitations 4 and 5, respectively, of the SE for the IMLTR. These penalties on SLMCPR were to remain applicable until such time as GEH's neutronic methods could be confirmed against appropriate measurement data from the gamma scan benchmark program.

### 1.1.2 Supplement 2 to NEDC-33173P-A

In Supplement 2, GEH provided the results of bundle scan campaigns and pin-wise gamma scan campaigns to validate, respectively, [[ ]] and established overall pin power peaking uncertainty for newer (10×10) fuel designs. This effort was undertaken to address the cycle-specific SLMCPR penalties stemming from the aforementioned uncertainties.

To validate [[ ]], two bundle-wise gamma scan campaigns were performed at Confrentes Nuclear Power Plant (CNC), a high power density (58.6 kW/L) BWR/6 plant in Spain (Ref. 4 and Reference 9). The campaigns were across two cycles, one cycle at stretch power uprate (SPU) conditions and another cycle at EPU conditions, and the scanned bundles were distributed throughout the core in sets of neighboring bundles. The NRC staff found the gamma scan data are, to a reasonable extent, representative of the void and spectral conditions expected at MELLLA+ conditions, and when both cycles of data are considered together, the average [[ ]][2]. This is well within the established value of [[ ]]. Assessments of bundle, axial, and nodal TIP uncertainties in comparison to the historical qualification database were also performed, and [[ ]] was observed. Based on this, the NRC staff approved a reduction of the SLMCPR adder imposed by Limitations 4 and 5 by a margin of 0.01.

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[2]The reduction in uncertainty is expected; [[ ]] utilized in the SLMCPR calculation is based on qualification of the TGBLA04/PANAC10 code suite, and the improved TGLBA06/PANAC11 code suite was qualified with a [[ ]]. GEH has chosen to continue using the historically established uncertainty value.

To validate the overall pin power peaking uncertainty, a pin-wise gamma scan campaign was performed at James A. Fitzpatrick Nuclear Power Plant (JAF), a BWR/4 plant with a power density of 51.2 kW/l. The campaign was conducted for GE14 fuel assemblies depleted at JAF under SPU conditions during Cycles 16 and 17. The NRC staff found the pin-wise gamma scan data representative of bundles depleted at P/F ratios and exit void fractions consistent with EPU operation. For conservatism, the NRC staff compared the pin-wise gamma scan results to a smaller uncertainty criterion of [[ ]] instead of the established [[ ]]. The more restrictive uncertainty criterion was determined by reassessing the derivation of the established $\sigma_{peak}$ when ignoring [[ ]], and it was adopted during examination of the pin-wise gamma scan data because it allowed the NRC staff to limit its review of the [[ ]] of the scanned bundles. The NRC staff found that the $\sigma_{peak}$ uncertainties determined from the pin-wise gamma scan data are within the more restrictive criterion of [[ ]]. Assessments of overall pin power peaking uncertainty as a function of axial height were also performed. Axial height serves as a surrogate to visualize any trending as a function of void fraction. [[ ]] were observed. Based on this, the NRC staff approved a reduction of the SLMCPR adder imposed by Limitations 4 and 5 by an additional margin of 0.01.

The reduction of the SLMCPR adder by a total margin of 0.02 effectively removed the SLMCPR adder at EPU conditions, and the NRC staff therefore removed Limitation 4 in the approval of Supplement 2. For MELLLA+ conditions, the 0.03 SLMCPR adder imposed by Limitation 5 was reduced to 0.01. This remaining 0.01 adder is the additional margin the NRC staff imposed in the IMLTR review to account for, in part, the potential changes in both pin and bundle power uncertainties with the higher void fractions and harder neutron spectra that are characteristic of operation in MELLLA+ conditions.

The pin-wise and bundle-wise gamma scan data in Supplement 2 was supplied to demonstrate the continued applicability of established pin and bundle power uncertainties at both EPU and MELLLA+ conditions. However, the NRC staff could not conclude the supplied gamma scan data encompassed the range of void fractions and spectral conditions present at MELLLA+ operation. Specifically, the CNC core flow ranges did not extend as low as those proposed for domestic BWRs at MELLLA+ conditions, and the bundles from which the JAF pin-wise gamma scans were taken did not experience average exit void fractions in the expected range for limiting bundles operating at MELLLA+ low-flow conditions. Additionally, the provided gamma scan data was limited to P/F ratios up to 42 MWt/(Mlbm/hr), whereas the expected range of P/F ratios for MELLLA+ operation is up to ~~50~~ ~57 MWt/(Mlbm/hr). Therefore, the NRC staff modified Limitation 5 such that a cycle-specific SLMCPR adder of 0.01 would be imposed for MELLLA+ applications with P/F ratios up to 42 MWt/(Mlbm/hr), and a cycle-specific SLMCPR adder of 0.02 would be imposed for MELLLA+ applications with P/F ratios above 42 MWt/(Mlbm/hr).

## 2.0 REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations* (10 CFR) establishes the fundamental regulatory requirements with respect to the reactivity control systems. Specifically, 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 10, "Reactor Design", states in part, that "the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded…."

Section 4.2 of NUREG-800, The Standard Review Plan (SRP) (Ref. 5) specifies the acceptance criteria for the evaluation of the fuel design limits as it relates to the thermal limits. SRP Section 4.4 provides guidance on the review of the thermal-hydraulic design in meeting the requirement of GDC 10 and the fuel design criteria established in SRP Section 4.2. For the critical power correlation, there should be a 95 percent probability at 95 percent confidence level that the hot rod in the core does not experience a departure from nucleate boiling or boiling transition (BT) condition during normal operation or anticipate operational occurrence (AOOs), or, for the critical power ratio (CPR) correlations, the minimum critical power ratio (MCPR) is to be established such that 99.9 percent of the fuel rods in the core would be expected not to experience BT during normal operation or AOOs. SRP Section 4.4 also states that the uncertainties in the values of process parameters, core design parameters, and calculational methods used in the assessment of the thermal margin should be treated with at least 95 percent probability at a 95 percent confidence level.

The regulation at 10 CFR 50.34, "Contents of applications; technical information," provides requirements for the content of safety analysis reports for operating reactors. The purpose of the IMLTR is to provide a licensing basis that allows the NRC to issue SEs for expanded operating domains including constant pressure power uprate, EPU, and MELLLA+ applications. The SE for the IMLTR approves the use of GEH/GNF methods for expanded operating domains. Licensees applying for EPU or MELLLA+ license amendments may refer to the IMLTR as a basis for the LAR regarding the applicability of GEH/GNF methods to the requested changes.

In its SE for the IMLTR, the NRC staff specified its approval by including several limitations and conditions. Licensees referencing the IMLTR must demonstrate compliance with the limitations and conditions to ensure that the licensee-specific application of the IMLTR is within the scope of the NRC staff's approval.

Limitation 5 of the IMLTR, as modified by Supplement 2, imposes an additive penalty of 0.01 to the cycle-specific SLMCPR for MELLLA+ applications at P/F ratios up to 42 MWt/(Mlbm/hr) and an additive penalty of 0.02 for P/F ratios greater than 42 MWt/(Mlbm/hr). Removal of this limitation requires NRC review and approval.

## 3.0 TECHNICAL EVALUATION

### 3.1 Bundle Power Uncertainty

As indicated in the NRC-approved GEH SLMCPR methodology TR NEDC-32601P-A and the associated uncertainty treatments TR NEDC-32694P-A, the uncertainty in the bundle power is factored into thermal limit calculations, such as the cycle-specific SLMCPR. [[

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The uncertainty associated with predicting the four-bundle power via simulated TIP is typically derived by averaging the readings from all string nodes across the core for a given exposure. The bundle (also referred to as radial because of the axially integrated nature of the measurement), axial, and nodal TIP uncertainties are in fact weighted averages of the nodal TIP string data (e.g., calculated and measured) across the core and for all exposures. In the GEH methodology, [[ ]]. The original value associated with $\sigma_{P4B}$ of [[ ]] was validated to be appropriate for application to more recent fuel designs during the NRC staff review of the IMLTR.

The uncertainty associated with the [[ ]] surrounding the TIP cell was originally determined to be [[ ]], based on [[ ]] in the original NEDC-32694P-A evaluation. Via additional bundle-wise gamma scan data provided in Supplement 2, this value for the [[ ]] was validated for 10×10 fuel designs and operation at EPU conditions.

Because [[ ]] was not validated for operation beyond EPU conditions, it remains a contributor to the cycle-specific SLMPCR adder for MELLLA+ operation. In an effort to demonstrate the established [[ ]] remains applicable to MELLLA+ conditions and remove the cycle-specific SLMPCR adder, GEH presents within Supplement 6 the results of TIP measurement campaigns for several cores across several cycles preceding entry into and within the MELLLA+ operating domain.

As discussed in Section 1.1.1, because TIP readings only provide relative four-bundle powers, they cannot be used to ascertain the accuracy of bundle-by-bundle power prediction, nor can they be used to establish [[ ]]. Bundle-wise gamma scan campaigns of fuel assemblies depleted at MELLLA+ conditions are necessary to determine these values.

However, TIP data can provide insight as to whether uncertainties previously established via historical bundle-wise gamma scan campaigns ought to remain applicable. In the present case of Supplement 6, GEH uses TIP data in lieu of bundle-wise gamma scan data to justify the continued use of the historically established [[ ]] in the MELLLA+ operating domain. This approach has its basis in the relationship between the predicted versus measured TIP response and [[ ]]. GEH identified this relationship in the response to request for additional information (RAI) 25-2 of the IMLTR, documented in MFN 05-029 (Ref. 3):

> [[ ]] If the TIP response continues to confirm the methods adequacy, it is statistically improbable that the [[ ]] would need to be revised.

The NRC staff agrees with this assessment. [[ ]] The resulting four-bundle power as measured by the TIP would then deviate from the predicted response. [[

]]. However, while the NRC staff agrees with GEH's assessment, it is important to note that the use of trends in TIP data is qualitative in nature and not quantitative. A statistically significant, adverse trend in bundle TIP uncertainties may be indicative of an adverse trend in [[ ]]. The supplied TIP data cannot quantify the change in the magnitude of the [[ ]] and, as a result, one cannot demonstrate it remains comparable to the historically established value and if a statistically significant trend exists.

### 3.1.1 Assessment of Core TIP Data

In Supplement 6, GEH presents radial, axial, and nodal TIP data for four plants with histories of MELLLA+ operation. The TIP data is provided in the form of RMS differences between calculated and measured TIP signals. These RMS values have been normalized to the plant-specific average RMS over all the cycles evaluated to effectively remove plant-specific biases and allow direct examination of possible trending among the four plants. The TIP data span several cycles preceding entry into and within the MELLLA+ operating domain, and each of the radial, axial, and nodal RMS data are plotted versus core P/F ratio, exposure, core average void fraction, and average bundle exit void fraction. The four plants from which the TIP data were gathered are: Monticello, a BWR/3 with a power density of 48.3 kW/L, 100 percent GE14 fuel, and a thermal TIP (neutron sensitive) system; Peach Bottom Units 2 and 3, each a BWR/4 with power densities of ~~58.4~~59.43 kW/L, 100 percent GNF2 fuel, and gamma TIP (gamma-ray sensitive) systems; and Nine Mile Point Unit 2, a BWR/5 with a power density of 59.0 kW/L, a mix of fuels with approximately 58 percent GE14 and 42 percent GNF2, and a thermal TIP system.

While axial and nodal RMS offer insight into the performance of GEH's neutronic methods at MELLLA+ conditions, the radial RMS is of concern for the present discussion for two reasons. First, the radial RMS is used to determine $\sigma_{P4B}$ (the trending of which is indicative of [[ ]]), and second, the shape-adapted core thermal power distribution is used to set thermal limits, including MCPR, and [[ ]]. The NRC staff assessment of the axial and nodal RMS is provided in Section 3.2.

#### 3.1.1.1 Radial TIP RMS Versus Exposure

Examination of the radial RMS versus exposure reveals a [[ ]]. This would indicate [[ ]]. Within Supplement 6, GEH indicates that this [[ ]] is expected and is observed regardless of the extended MELLLA+ domain. While the NRC staff agrees that the [[ ]] is observed in both non-MELLLA+ and MELLLA+ data and is, therefore, not a sole result of operating in the MELLLA+, an [[ ]] could be indicative of difficulty in the neutronic methods to accurately predict plutonium accrual and removal, which will be exacerbated by operation at MELLLA+ conditions due to the greater amount of plutonium generated by the harder neutron spectrum that is present. Given that the higher P/F ratios that are typical of MELLLA+ operation exhibit increasingly harder neutron spectra, a possible [[ ]] could ultimately manifest, which would be in opposition to GEH's approach of demonstrating continued applicability of the historically established [[ ]] value. Therefore, the NRC staff requested an explanation for the [[ ]] in RAI-3 (Ref. 10).

In the response to RAI-3, GEH provided [[ ]]. GEH indicated that no discernible exacerbation of [[ ]] is observed when comparing the non-MELLLA+ data to the MELLLA+ data. GEH concludes that, given the consistent behavior between non-MELLLA+ and MELLLA+ data, the phenomena underlying the [[ ]] will not ultimately manifest as [[ ]] with increasing P/F ratio. [[ ]] were included with each of the supplied data plots, and the NRC staff compared these [[ ]] for each set of non-MELLLA+ and MELLLA+ data. The [[ ]] between the non-MELLLA+ and MELLLA+ data are nearly identical. [[ ]]. The [[ ]] does not appear to be operating-domain dependent. Therefore, the NRC staff agrees with GEH's conclusion that [[ ]] will not manifest with increasing P/F ratio.

### 3.1.1.2 Radial TIP RMS Versus Core Power-To-Flow Ratio

The core P/F-ratio is routinely used as a proxy for void fraction and spectral conditions because void fraction increases and the neutron spectrum becomes harder with increasing core P/F ratio. Both of these are exacerbated at MELLLA+ operation, with maximum bundle exit void fractions approaching values greater than 90 percent. The NRC staff examined the plots of radial RMS versus core P/F ratio, and did not identify any obvious adverse trending, either before entry into the MELLLA+ operating domain or after. Comparison of the MELLLA+ RMS TIP data to that of the non-MELLLA+ data shows the spread of data is largely consistent from pre- to post-MELLLA+ operation.

Examination of the radial RMS TIP plots indicates approximately [[ ]] are associated with MELLLA+ operation, with [[ ]] of these data points associated with P/F ratios greater than 42 MWt/(Mlbm//hr). Given that GEH's approach to removing the SLMCPR adder is to demonstrate no adverse trends exist in radial TIP RMS at these higher P/F ratios, the NRC staff requested justification via RAI-4 that the number of data points provided is statistically sufficient. GEH's response to this RAI indicates the data points above the P/F ratio of 42 MWt/(Mlbm//hr) are a subset of the overall TIP RMS data used to assess trends, and that the use of 42 MWt/(Mlbm//hr) as a delimiter exists only because it was identified as the upper bound on previously submitted TIP RMS measurement data (i.e., Supplement 2). The P/F ratio of 42 MWt/(Mlbm//hr) does not reflect or imply any expected discontinuity of physical data, and therefore the entirety of the data population should be used when assessing trends. The NRC staff agrees with this assessment, albeit with one caveat: because MELLLA+ operation exhibits higher void fractions and harder neutron spectra as a result of increased power densities and reduced core flows, comparing TIP RMS data between non-MELLLA+ and MELLLA+ operation provides insight into the neutronic methods' performance between the operating domains. Therefore, in the present case, MELLLA+ TIP RMS data should be examined for trending by itself and in comparison to non-MELLLA+ data. In light of this, the NRC staff finds that count of [[ ]] associated with MELLLA+ operation, while on the smaller side, is reasonably sufficient to assess trending within the MELLLA+ operating domain due to the span of the P/F-ratios it encompasses.

While the plots of radial TIP RMS versus P/F ratio do not appear to indicate any adverse trending in TIP response, they are not sufficiently detailed for NRC staff to conclude this is actually the case. Such a conclusion requires a thorough statistical analysis of the TIP RMS source data. Additionally, as mentioned above, the TIP RMS data were normalized to the plant-specific average RMS over the cycles evaluated. GEH indicates there are many ways in which each individual plant can yield consistently higher or lower errors in bundle power prediction by way of TIP measurements (e.g., thermal versus gamma TIP type, TIP alignment, failed TIPs, heat balance discrepancies, plant operation and flow miscalibration), and the normalization was performed to show bundle power predictability across the fleet. For purposes of comparing performance between plants, the NRC staff finds this approach acceptable. However, the NRC staff observes that this is a deviation from the manner in which GEH has historically presented TIP data, by using RMS percent. Therefore, the NRC staff requested the normalized and non-normalized radial, axial, and nodal TIP RMS data be tabulated. GEH supplied this tabulated data in their response to the RAI-5.

The NRC staff converted the supplied non-normalized radial RMS TIP data to RMS percent, performed ordinary least squares linear regressions, and analyzed the residuals to identify any statistically significant trending with increasing P/F ratio. These regression analyses were performed on the aggregate of the radial TIP RMS percent data as well as on MELLLA+ and non-MELLLA+ subsets of the data. The analyses demonstrated [[ ]]. The NRC staff did identify [[ ]], indicating an increasing accuracy in overall TIP response. It is therefore not counter to GEH's approach of demonstrating continued applicability of the historical [[ ]]. Breaking down the MELLLA+ data into plant-specific subsets and performing additional analyses revealed the downward trend is associated with the TIP data collected from Monticello. For the remaining plants, the plant-specific MELLLA+ TIP data is very consistently behaved. Figure 3-1, below, illustrates this.

[[

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**Figure 3-1:** Radial TIP RMS% versus Core Power-To-Flow-Ratio for MELLLA+ Data

Comparisons of overall radial TIP RMS percent data trending between the non-MELLLA+ and MELLLA+ operating domains indicate consistent behavior between both: [[ ]] across the entire range of core P/F ratios that exhibits an approximate [[ ]] in RMS percent. When the aggregate data spanning both operating domains is examined, a similar [[ ]] is also observed. This consistent behavior supports GEH's assertion that the neutronic methods performance is comparable regardless of the operating domain.

### 3.1.1.3 Radial TIP RMS Versus Exit Void Fraction

The NRC staff examination of the plots of radial RMS versus average exit void fraction yielded the same observations as the P/F ratio plots. The staff did not identify any obvious adverse trending (either before entry into the MELLLA+ operating domain or after), and comparison of the MELLLA+ RMS TIP data to that of the non-MELLLA+ data shows the spread of data is largely consistent from pre- to post-MELLLA+ operation.

The NRC staff converted the non-normalized radial RMS TIP data supplied by GEH in the RAI-5 response to RMS percent, performed ordinary least squares linear regressions, and analyzed the residuals to identify any statistically significant trending with increasing average exit void fraction. These regression analyses were performed on the aggregate of the radial TIP RMS percent data as well as on MELLLA+ and non-MELLLA+ subsets of the data. The analyses demonstrated [[ ]]. The NRC staff did identify [[ ]], indicating an increasing accuracy in overall TIP response. It is, therefore, not averse to GEH's approach of demonstrating continued applicability of the historical [[ ]]. Breaking down the

MELLLA+ data into plant-specific subsets and performing additional analyses revealed the plant-specific MELLLA+ TIP data is very well-behaved. Figure 3-2, below, illustrates this.

[[

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**Figure 3-2:** Radial TIP RMS% versus Core Average Exit Void Fraction for MELLLA+ Data

Comparisons of overall radial TIP RMS percent data trending between the non-MELLLA+ and MELLLA+ operating domains indicate consistent behavior between both: [[ ]] exists across the entire range of core average exit void fractions. The magnitude of the trend's slope changes from the non-MELLLA+ data subset to the MELLLA+ data subset, with the MELLLA+ data subset trend exhibiting [[ ]]. When the aggregate data spanning both operating domains is examined, a very slight [[ ]] is observed. This is a result of the relative abundance of MELLLA+ data obtained from Monticello compared to non-MELLLA+ data. The trend is not statistically significant, and represents only a [[ ]] percent across the range of exit void fractions. It is virtually flat. This reasonably supports GEH's assertion that the neutronic methods performance is comparable regardless of the operating domain.

#### 3.1.1.4 Comparison of TIP RMS Data to Experience Base

The well-behaved nature of the radial TIP RMS percent MELLLA+ data and the consistent behavior of the data across the operating domains are indicative of the [[ ]]. However, a key element in the relationship between the predicted versus measured TIP response and [[ ]] as expressed by GEH in the MFN 05-029 RAI 25-2 response of the IMLTR (and discussed in Section 3.1 of this SE) is that the TIP response continues to confirm the methods adequacy. The NRC staff agrees with this statement and interprets it to apply not only across operating domains within a given dataset, but also from one dataset to another. In other words, the TIP performance as demonstrated by the Supplement 6 TIP RMS data must be comparable to the historical TIP performance as presented in the NEDC-32694P-A, IMLTR, and Supplement 2 evaluations.

Table 3.1 of the original NEDC-32694P-A evaluation presents the historical TIP data. The currently accepted four-bundle power uncertainty $\sigma_{P4B}$ of [[ ]] was determined in NEDC-32694P-A by performing a weighted average of this historical TIP data. For comparison, the NRC staff determined the value of $\sigma_{P4B}$ for the Supplement 6 TIP RMS percent data using the same calculation as in the original NEDC-32694P-A evaluation, weighting the number of data points and TIP strings appropriately for each plant. The calculation yielded a $\sigma_{P4B}$ value of [[ ]]. This is greater than the accepted value and is inconsistent with the expected reduction in $\sigma_{P4B}$ when using the improved TGLBA06/PANAC11 code suite as observed in the IMLTR and Supplement 2 evaluations; Table 2-5 of the IMLTR and Table 3-1 of Supplement 2 indicate $\sigma_{P4B}$ values of [[ ]] and approximately [[ ]], respectively.

Given the analysis results discussed above, the NRC staff further investigated the Supplement 6 TIP data, beginning with the four-bundle power uncertainty $\sigma_{P4B}$. While the calculated Supplement 6 $\sigma_{P4B}$ value of [[ ]] exceeds the accepted value from the NEDC-32694P-A evaluation, it is possible the Supplement 6 result may represent a slightly different value from the same uncertainty distribution as the original result. The NRC staff performed an independent 2-sample t-test between the two datasets to determine if this was the case. The analysis results showed the t-value for the datasets is approximately 3.1, exceeding the critical value of 1.97 for significance level of 5 percent (performing the same analysis while not assuming equal variances between the datasets exacerbated the results). Therefore, it cannot be reasonably concluded that the Supplement 6 $\sigma_{P4B}$ result is from the same uncertainty distribution as the original NEDC-32694P-A result; the two results are not comparable.

While performing the independent 2-sample t-test, the NRC staff observed a portion of the Supplement 6 radial TIP RMS percent data belonging to a single plant possessed significantly greater RMS percent values than the rest of the data. This suggests at least one of the plant-specific datasets is from a significantly different uncertainty distribution as compared with the rest of the data. To explore this, the NRC staff performed a series of one-way analysis of variance (ANOVA) tests on various combinations of the four plant-specific datasets. The results of these ANOVA tests demonstrated the radial TIP RMS percent datasets from Monticello and Nine Mile Point Unit 2 are significantly different from the Peach Bottom Units 2 and 3 datasets, and the Peach Bottom Units 2 and 3 datasets are substantially similar.

Examination of the Monticello and Nine Mile Point Unit 2 datasets indicates they are comprised of larger radial TIP RMS percent values, with means of [[ ]], respectively, as compared to the Peach Bottom datasets, each of which have a mean of approximately [[ ]]. This difference drives the calculated σP4B for the aggregate of the Supplement 6 data higher than expected.

An explanation for the differences in average radial TIP RMS percent lies in the nature of the TIP systems employed by the various plants comprising the datasets: Peach Bottom Units 2 and 3 utilize gamma TIPs while Monticello and Nine Mile Point Unit 2 utilize thermal TIPs. This is the primary difference between the plants within the Supplement 6 data. It is known that thermal TIPs possess a greater sensitivity (wider variability) than that of gamma TIPs, and it has been observed they produce slightly larger power distribution uncertainties compared to gamma TIPs. It is because of this sensitivity the NRC staff indicated within the SE for the IMLTR (Ref. 3) that, for EPU/MELLLA+ applications involving plants with thermal TIPs, the plant-specific TIP core-tracking data should be evaluated against compiled EPU Reference Plant core-tracking data with the objective of determining whether power distribution uncertainties need to be increased for cores with thermal TIPs installed.

However, it should be noted that the four-bundle power uncertainty as described in NEDC-32694P-A is a modeling uncertainty. In other words, it is an uncertainty due solely to the calculational variability of the code methods when predicting bundle power, making it equally applicable to both thermal TIP and gamma TIP plants. Ideally, its value should not contain a measurement uncertainty component. Nevertheless, the original NEDC-32694P-A evaluation quantifying $\sigma_{P4B}$ makes use of comparisons to measured TIP data, suggesting the $\sigma_{P4B}$ value of [[ ]] contains a measurement uncertainty component. This is confirmed in GEH's response to RAI II.3 of the NEDC-32694P-A review, which identifies the integral TIP measurement uncertainty was estimated to be [[ ]]. After examining the NEDC-32694P-A evaluation, it is the NRC staff's understanding that GEH utilized data obtained from the more precise of the two TIP measurement systems (gamma TIPs) in order to minimize the measurement uncertainty component.

In light of this, the NRC staff reached two conclusions. First, given the $\sigma_{P4B}$ value of [[ ]] is representative of a calculational uncertainty that is equally applicable to both thermal and gamma TIP plants, the thermal TIP data of Supplement 6 demonstrates there exists a larger instrumentation measurement uncertainty for thermal TIPs than that which appears to be currently incorporated into GEH's methods. Further assessment of this measurement uncertainty is discussed in Section 3.1.1.5 of this SE. Second, for purposes of assessing continued methods adequacy via comparison of power distribution uncertainties between the Supplement 6 data and the historical database, the Supplement 6 gamma TIP and thermal TIP data should be respectively compared to the historical gamma TIP and thermal TIP data. This is further discussed below.

The NRC staff recalculated the Supplement 6 weighted average $\sigma_{P4B}$ using only the radial gamma TIP RMS percent data from the Peach Bottom Units 2 and 3 datasets. The updated value for $\sigma_{P4B}$ using gamma TIPs is [[ ]], which matches the accepted value of [[ ]] and is comparable to the historic database. Similarly, the NRC staff recalculated the Supplement 6 weighted average $\sigma_{P4B}$ using only the radial thermal TIP RMS percent data from the Monticello and Nine Mile Point, Unit 2 datasets. The updated value for $\sigma_{P4B}$ using thermal TIPs is [[ ]]. The historic database value for radial thermal TIP RMS percent is [[ ]], and is determined from the Plant E data as tabulated in GEH's MFN 05-029 RAI 25-2 response of the IMLTR. The Supplement 6 radial thermal TIP RMS percent value and the historic database value are reasonably comparable. These results indicate the Supplement 6 gamma TIP performance is consistent with the historic TIP performance and supports the continued adequacy of the neutronic methods.

#### 3.1.1.5 Assessment of Thermal TIP Measurement Uncertainty

As discussed in Section 3.1.1.4 of this SE, the thermal TIP datasets of Supplement 6 have significantly different uncertainty distributions compared to those of the gamma TIP datasets and exhibit larger radial TIP RMS percent means. Thermal TIP data is under-represented in the historical database; the NRC staff was only able to identify "Plant E" of the IMLTR data as a thermal TIP plant. It was with the assessment of the power distributions for this data that the NRC staff initially concluded thermal TIPs may yield higher power distribution uncertainties.

This was documented by the NRC staff in the SE for the IMLTR along with the recommendation that future EPU/MELLLA+ TIP data be examined to assess the need for increased uncertainties for cores with thermal TIP systems. However, given that the historical $\sigma_{P4B}$ value of [[ ]] is representative of a calculational uncertainty that is equally applicable to both thermal and gamma TIP plants, the Supplement 6 thermal TIP data demonstrates there exists a larger instrumentation measurement uncertainty for thermal TIPs than for gamma TIPs.

The NRC staff examined the SLMCPR methodology presented in NEDC-32601P-A and identified that a [[ ]] are utilized in SLMCPR evaluations. However, to the best of the NRC staff's knowledge, these uncertainty values are based upon gamma TIPs. To ensure thermal limits are properly determined for cores operating with thermal TIPs in the MELLLA+ domain, the larger thermal TIP measurement uncertainty evidenced by the Supplement 6 data must be quantified and applied in the GEH methods.

In the absence of additional thermal TIP data specifically taken with the purpose of quantifying the measurement uncertainty (e.g., repeated readings for a single power level or comparisons of thermal TIP responses located along an axis of symmetry), the NRC staff issued RAI-7 requesting quantification of thermal TIP measurement uncertainties or justification that the TIP integral instrument and TIP random reading uncertainties, as tabulated in Table 2.1 of NEDC-32601P-A, are applicable to thermal TIP plants.

In its response to RAI-7, GEH first clarified that the instrument uncertainty value of 2.6 percent is a statistical super position of the TIP geometrical uncertainty of 2.3 percent and the random reading uncertainty of 1.2 percent. GEH's response also indicated that the source of both the random and geometrical TIP signal uncertainties is Oyster Creek, which utilizes a thermal TIP system. Therefore, the instrument uncertainty of 2.6 percent is conservative when applied to gamma TIP detectors and representative of thermal TIP detectors. The NRC staff finds this response acceptable.

### 3.1.2 Conclusions for Core TIP Data

As discussed in Section 3.1.1.2, the radial TIP RMS percent data presented for Supplement 6 does not exhibit any statistically significant adverse trending with core P/F ratio. The observed trending is favorable and consistent across operating domains for both thermal and gamma TIPs. Additionally, as discussed in Section 3.1.1.4, $\sigma_{P4B}$ is a modeling uncertainty due solely to the calculational variability of the code methods, making it equally applicable to both thermal TIP and gamma TIP plants. Statistically significant differences between thermal TIP datasets and gamma TIP datasets are due to the differences in the instrumentation measurement uncertainty. Comparisons of the radial gamma TIP RMS percent data presented in Supplement 6 (which minimizes the instrumentation measurement uncertainty) to the historical database for radial gamma TIPs shows consistent results. Likewise, comparison of the radial thermal TIP RMS percent data of Supplement 6 to Plant E of the historical database also shows consistent results. This demonstrates the continued neutronics methods adequacy for the prediction of the four-bundle power uncertainty.

Therefore, the NRC staff finds that the radial TIP RMS percent data and trending analyses provide reasonable assurance the [[ ]] is not increasing with void fraction and the harder neutron spectral conditions in MELLLA+ applications and therefore neither is the [[ ]]. The historically established values for these uncertainties remain applicable at MELLLA+ conditions within the range of P/F ratios examined. On this basis, the NRC staff approves the reduction of the SLMCPR adder for MELLLA+ applications by a margin of 0.005. Additionally, the radial TIP RMS percent data provided in Supplement 6 covers P/F ratios up to 50 MWt/(Mlbm/hr) without exhibiting any statistically significant adverse trending. On this basis, the NRC staff approves a reduction of the SLMCPR adder for P/F ratios greater than 42 MWt/(Mlbm/hr) by an additional margin of 0.005 for a total reduction of 0.01. Limitation 5 has been updated to reflect these changes.

## 3.2 Overall Pin Power Peaking Uncertainty

The cycle-specific SLMCPR adders applied above and below P/F ratios of 42 MWt/(Mlbm/hr) are to account for, in part, the potential changes in both pin and bundle power uncertainties with the higher void fractions and harder neutron spectral conditions that are characteristic of operation in MELLLA+ conditions. The discussion presented in Supplement 6 for removal of the SLMCPR adders focuses on bundle power uncertainty and does not address overall pin peaking uncertainty. Therefore, justification for full removal of the penalty is incomplete. In RAI-1, the NRC staff commented on this and sought justification that the overall pin power peaking uncertainty does not change with increasing P/F ratios.

In response to RAI-1, GEH indicated the NRC staff's SE for Supplement 2 discusses how postulated anomalies associated with the prediction of pin power distributions at MELLLA+ conditions could manifest if modeling assumptions are not valid, but that these anomalies would affect the overall transport solution methodology and would be observable in detailed TIP comparisons. Ergo, the behavior in overall pin power peaking uncertainty may be assessed via the TIP data of Supplement 6. The NRC staff agrees. While TIP data does not provide a means to quantify the overall pin power peaking uncertainty, if the overall transport solution methodology were unable to effectively model the harsher conditions present at MELLLA+ operation, then the trending in pin power distribution would be adversely affected and manifest in TIP data comparisons, primarily those of the radial TIP RMS percent because the data are derived from axially integrated bundle powers. As discussed in Section 3.1.1.2 and

Section 3.1.1.3 of this SE, the radial TIP RMS percent comparisons are very good; no statistically significant adverse trending with increasing core P/F or average exit void fraction is observed. This supports GEH's assertion that the historically established value for the overall pin power peaking uncertainty remains applicable for MELLLA+ applications.

### 3.2.1 Assessment of Continued Accuracy of Nuclear Methods

Because of the qualitative nature of the approach discussed above for the removal of those portions of the SLMCPR adders due to uncertainty in overall pin power peaking, the NRC staff chose to further assess the continued accuracy of the nuclear methods. To do so, the NRC staff determined the Supplement 6 axial and nodal TIP RMS percent uncertainties and compared the results to the historical data. The NRC staff's understanding of GEH's response to RAI SRXB-A-27 (Ref. 11) of the IMLTR is that the acceptance criteria for power distribution uncertainties obtained from core-tracking data is [[ ]]. Although the nodal RMS criterion is not reflected in any licensing analysis, GEH indicated any nodal RMS values over [[ ]] observed consistently require further examination as well as review of the nuclear methods accuracy.

The weighted axial TIP RMS percent and nodal TIP RMS percent for the Supplement 6 dataset are [[ ]], respectively. Both of these uncertainties exceed the respective acceptance criteria, and they are inconsistent with the historical database's axial and nodal TIP RMS percent uncertainties of approximately [[ ]], respectively. Regarding the nodal TIP RMS percent data, approximately 65 percent of the values exceed the acceptance criterion.

While no adverse trending is observed in the Supplement 6 axial and nodal TIP RMS percent data versus core P/F ratio and average exit void fraction, the overall higher uncertainties with respect to the historical database indicate the nuclear methods accuracy may require reassessment. The NRC staff inquired about the axial and nodal uncertainties in RAI-6.

GEH provided a detailed response to RAI-6. As an initial point of discussion, GEH's response clarified the NRC staff's understanding regarding the axial and nodal power distribution acceptance criteria by indicating the cited [[ ]] uncertainty is not actually an acceptance criterion, nor is it associated with axial TIP RMS percent. The cited [[ ]] uncertainty actually refers to the overall nodal RMS percent results for the reference BWRs presented within the IMLTR. In other words, it was only a statement of observation. After further examination of the context surrounding the development of RAI SRXB-A-27 (from which the [[ ]] value was cited), the NRC staff agrees with this statement.

As a second point of discussion, GEH's response indicated the [[ ]] criterion for nodal TIP RMS percent cited from RAI SRXB-A-27 was not intended to be applied as an acceptance criterion on a plant-specific basis and exceeding this value consistently in a subset of nuclear plants does not signify inadequacy of the nuclear methods for the purpose of SLMCPR evaluations. In support of this statement, GEH's response emphasizes that the use of an average RMS over a number of plants is the appropriate approach for quantifying overall methods performance and associated uncertainty because of the plant-to-plant variability that is often observed in TIP comparisons. The NRC staff agrees with this assessment; given the variability that can exist in TIP comparisons from plant-to-plant, care should be taken when applying a TIP-related acceptance criterion on a plant-specific basis (or a sufficiently small subset) because it may not be appropriate.

GEH's response does not directly specify what constitutes a subset of nuclear plants. Strictly speaking, the population of plants involved in a TIP data collection campaign can be considered a subset by comparison to the operating fleet. Turning to precedent, the NRC staff notes the TIP data from a population of 4 nuclear plants was used to validate the continued adequacy of GEH's nuclear methods for the purpose of SLMCPR evaluations in the original review of the IMLTR. Specifically, the response to MFN 05-029 RAI-25 determines the average weighted radial TIP RMS percent uncertainty using [[ ]] collected from 4 plants across 7 cycles and compares the result to the [[ ]] acceptance criterion established in NEDC-32694P-A. By comparison, Supplement 6 presents a larger database comprised of [[ ]] collected from 4 plants across a total of 14 cycles. Thus, the NRC staff finds the comparison of the Supplement 6 TIP dataset to historical method performance observations is appropriate and the concern regarding the inconsistency in results to be valid.

The Supplement 6 dataset contains a larger portion of thermal TIP data compared to that of the historical database. Additionally, as discussed in Section 3.1.1.5 of this SE, thermal TIPs possess a higher measurement uncertainty. To assess if these observations might contribute to the inconsistencies between the Supplement 6 and historical method performances, the NRC staff grouped the Supplement 6 axial and nodal TIP RMS percent data into thermal and gamma TIP sets. The weighted axial thermal TIP RMS percent uncertainty is [[ ]] and the weighted nodal thermal TIP RMS percent uncertainty is [[ ]]. These results are consistent with the historical IMLTR and Supplement 2 axial and nodal thermal TIP uncertainties of approximately [[ ]], respectively. In contrast, the weighted axial and nodal gamma TIP RMS percent uncertainties are not consistent with the historical data; the Supplement 6 weighted axial and nodal gamma TIP RMS percent uncertainties are [[ ]], respectively, and the historical axial and nodal gamma TIP RMS percent uncertainties are approximately [[ ]], respectively. The results suggest [[ ]].

GEH's response to RAI-6 includes a similar analysis of the Supplement 6 TIP dataset. Axial and nodal TIP RMS percent uncertainties for the entire Supplement 6 dataset are presented as well as the uncertainties for thermal and gamma TIPs individually. The results of the analysis are consistent with those of the NRC staff's, and GEH makes note of the same observations: 1) the axial and nodal RMS percent uncertainties for the Supplement 6 [[ ]] are consistent with the historically reported values and 2) the axial and nodal RMS percent uncertainties for the Supplement 6 [[ ]] the historically reported values.

Anticipating the latter observation as a possible source of concern for the NRC staff, GEH's response to RAI-6 stressed that care should be taken when trying to compare a subset of TIP comparisons from a new population of plants to historical method performance observations on an absolute basis so as not to assign differences that are expected in plant-to-plant variability to differences in methods behavior. As an example, GEH indicated the [[ ]] plants from which the Supplement 6 data are sourced, [[ ]] both before and after implementation of extended operating domains. If a degradation of nuclear methods accuracy had occurred at any point, whether within the extended operating domains or not, [[ ]] TIP uncertainties would be observed more generally across the nuclear fleet.

In support of these statements, the response to RAI-6 included three evaluations, 1) comparisons of TIP statistics from a new plant similar to the Supplement 6 [[ ]] plants, 2) comparisons of TIP statistics for the Supplement 6 [[ ]] plants prior to and after implementation of extended operating domains, and 3) updated evaluations of TIP statistics for the plants discussed in MFN 05-029 RAI-25. Each of these is discussed below. The first evaluation introduces a new plant, referred to as "Plant F". Plant F is extremely similar to [[ ]], and a rated power density of 56.8 kW/L. The average nodal TIP RMS percent uncertainty for this plant is [[ ]], which is consistent with the historical results. Given the substantially similar design of Plant F to [[ ]], the results support the assertion that [[ ]].

The second evaluation provides comparisons of the [[ ]] nodal TIP RMS percent uncertainty prior to and after the implementation of extended operating domains. The comparisons show no trending from cycle-to-cycle. The magnitude of nodal TIP RMS percent uncertainty from the comparisons ([[ ]]) is also comparable to that of the NRC staff analysis discussed above [[ ]]. These results provide additional support that [[ ]], and they are not a result of the implementation of expanded operating domains.

In the final evaluation, the nodal TIP statistics for the plants from MFN 05-029 RAI-25 are updated and compared to the original results. The updated nodal TIP RMS percent uncertainties are all within approximately 1 percent of the historical values. The results support the continued nuclear methods accuracy across the nuclear fleet.

Based on the three [[ ]] evaluations presented in the response to RAI-6, the NRC staff finds [[ ]], are not the result of implementing expanded operating domains and, in the present case, the nodal statistic exceeding GEH's internal [[ ]] acceptance criterion does not signify inadequacy of the nuclear methods for the purpose of SLMCPR evaluations. Noting the axial and nodal [[ ]] RMS percent uncertainties are consistent with the historical database, the NRC staff therefore also finds the axial and nodal TIP performance of the Supplement 6 dataset are indicative of the continued adequacy of the nuclear methods performance.

Given the axial and nodal TIP performance of the Supplement 6 dataset and the lack of statistically significant adverse trending of radial TIP RMS percent with increasing core P/F or average exit void fraction, the NRC staff finds there is reasonable assurance the historically established value for the overall pin power peaking uncertainty remains applicable for MELLLA+ applications within the range of P/F ratios examined. On this basis, the NRC staff approves the reduction of the SLMCPR adder for MELLLA+ applications by a margin of 0.005. Additionally, the radial RMS percent data provided in Supplement 6 covers P/F ratios up to 50 MWt/(Mlbm/hr) without exhibiting any statistically significant adverse trending. On this basis, the NRC staff approves a reduction of the SLMCPR adder for P/F ratios greater than 42 MWt/(Mlbm/hr) by an additional margin of 0.005 for a total reduction of 0.01. Limitation 5 has been updated to reflect these changes.

## 4.0 <u>CONDITIONS AND LIMITATIONS</u>

The NRC staff has revised IMLTR SE Limitation 5 as follows.

Limitation 5 in Section 9.0 of the IMLTR SE as updated in Section 4.0 of the Supplement 2 SE states:

> 5. SLMCPR 2
>
> For operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state-point, a 0.01 value shall be added to the cycle-specific SLMCPR value for power-to-flow ratios up to 42 MWt/(Mlbm/hr), and a 0.02 value shall be added to the cycle-specific SLMCPR value for power-to-flow ratios above 42 MWt/(Mlbm/hr).

On the basis of the subject review as presented within this SE, the NRC staff finds that Supplement 6 provides the additional data and analyses needed to justify, with reasonable assurance, that the original power distribution uncertainties used in GEH's nuclear methods are applicable to MELLLA+ operation within the range of P/F ratios examined (i.e., 50MWt/(Mlbm/hr). Therefore, the NRC staff has revised Limitation 5 in Section 9.4 of the IMLTR SE, as updated in Section 4.0 of the Supplement 2 SE, as follows:

> 5. SLMCPR 2
>
> For operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state-point, a 0.01 value shall be added to the cycle-specific SLMCPR value for P/F ratios greater than 50 MWt/(Mlbm/hr).

## 5.0 CONCLUSIONS

In Supplement 6, GEH presents radial, axial, and nodal TIP data for four plants with histories of MELLLA+ operation. The TIP data span several cycles preceding entry into and within the MELLLA+ operating domain, and each of the radial, axial, and nodal RMS data are plotted versus core P/F ratio, exposure, core average void fraction, and average bundle exit void fraction. These data were provided to demonstrate there is no increase in four-bundle power uncertainty and overall pin power peaking uncertainty as a function of void fraction and spectral conditions in the MELLLA+ operating domain for GEH's interim methods. Demonstrating no adverse trending in these uncertainties will provide a basis for the removal of the SLMCPR penalty that was introduced in the IMLTR review.

The trending analyses performed by the NRC staff on the radial, axial, and nodal TIP RMS percent data supplied by GEH for the present review showed no statistically significant adverse trending with core P/F ratio or core average exit void fraction. Therefore, for the P/F ratios examined, it is unlikely that a four-bundle power uncertainty exceeding the acceptance criterion of [[ ]] as determined in NEDC-32694P-A will be encountered at MELLLA+ conditions. Hence, the established value for the [[ ]] remains applicable. Similarly, it is unlikely that an overall pin power peaking uncertainty exceeding the acceptance criterion of [[ ]] will be encountered, and therefore the established value remains applicable. As a result, the NRC staff finds there is reasonable assurance that the imposition of a SLMCPR adder for MELLLA+ conditions is unnecessary within the range of power-to-flow ratios examined in this SE. This conclusion is contingent upon the use of TGBLA06/PANAC11-based methods by the plant core monitoring system, and plant operation within the existing P/F database. For MELLLA+ operation at P/F ratios greater than the range examined in this SE, a cycle-specific SLMCPR adder of 0.01 is applied. This value has its basis in the original 0.01 SLMCPR adder for MELLLA+ operation imposed in the IMLTR to account for potential changes in both the pin and bundle power uncertainties due to higher bundle P/F ratios.

## 6.0 REFERENCES

1. Request for Review and Approval of NEDC-33173P, Supplement 6, Revision 0, “Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty,” September 15, 2017 (ADAMS Accession No. ML17261A068 (Publically Available)).

2. NEDC-33173P Supplement 6, Revision 0, “Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty,” September 2017 (ADAMS Package Accession No. ML17261A067 (Publically Available)).

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Principal Contributor: A. Kevin Heller

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