ENCLOSURE 2

M190068

NEDO-33173 Supplement 6-A, Revision 1

Non-Proprietary Information

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GE Hitachi Nuclear Energy

HITACHI

NEDO-33173 Supplement 6-A
Revision 1
August 2019

Non-Proprietary Information

Licensing Topical Report

Applicability of GE Methods to Expanded Operating Domains - Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty

INFORMATION NOTICE

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of obtaining Nuclear Regulatory Commission (NRC) approval of the Applicability of GE Methods to Expanded Operating Domains – Removal of the SLMCPR Penalty. The only undertakings of GEH with respect to information in this document are contained in the contracts between GEH and its customers or participating utilities, and nothing contained in this document will be construed as changing that contract. The use of this information by anyone for any purpose other than that for which it is intended is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 8, 2019

Ms. Michelle P. Catts
Senior Vice President, Regulatory Affairs
GE-Hitachi Nuclear Energy Americas, LLC
P.O. Box 780 M/C A-10
Wilmington, NC 28401

SUBJECT: FINAL 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 (EPID: L-2017-TOP-0040)

Dear Ms. Catts:

By letter dated September 15, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17261A068), GE Hitachi Nuclear Energy (GEH) submitted Licensing Topical Report (LTR) NEDC-33173P Supplement 6 – Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty to the US Nuclear Regulatory Commission (NRC) staff for review.

By letter dated March 26, 2019, an NRC draft safety evaluation (SE) regarding our approval of NEDC-33173P Supplement 6 was provided for your review and comment (ADAMS Accession No. ML19071A101). By letter dated April 18, 2019, you provided comments on the draft SE (ADAMS Accession No. ML19108A018). The NRC staff's disposition of the GEH comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter.

The NRC staff has found that LTR NEDC-33173P Supplement 6 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the LTR and in the enclosed final SE. The enclosed final SE has been redacted for viewing by the public. The final SE defines the basis for our acceptance of the LTR.

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

In accordance with the guidance provided on the NRC website, we request that GEH publish approved proprietary and non-proprietary versions of LTR NEDC-33173P Supplement 6, within three months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information (RAIs) and your responses. The approved versions shall include a "-A" (designating approved) following the LTR identification symbol.

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

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.

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

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

Sincerely,

/RA/

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

Project No. 99902024

Enclosure: Final SE (Non-Proprietary)

SUBJECT: FINAL SAFETY EVALUATION FOR NEDC-33173P SUPPLEMENT 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) DATE: AUGUST 8, 2019

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GE Hitachi Nuclear Energy

Project No. 710
Docket No. 99902024

cc:

Ms. Michelle P. Catts
Senior Vice President, Regulatory Affairs
GE-Hitachi Nuclear Energy Americas, LLC
P.O. Box 780 M/C A-10
Wilmington, NC 28401
Michelle.Catts@ge.com

Mr. Kent E. Halac
Senior Project Manager, Regulatory Affairs
GE-Hitachi Nuclear Energy Americas, LLC
P.O. Box 780, M/C A-70
Wilmington, NC 28401-0780
Kent.Halac@ge.com

Dr. Brian R. Moore
General Manager, Core & Fuel Engineering
Global Nuclear Fuel–Americas, LLC
P.O. Box 780, M/C A-75
Wilmington, NC 28401-0780
Brian.Moore@ge.com

FINAL 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"
GE-HITACHI NUCLEAR ENERGY AMERICAS LLC.
EPID: L-2017-TOP-0040/DOCKET NO. 99902024

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. The power distribution uncertainties with which the NRC staff had concerns are the bundle **[ ]** and the overall pin power peaking uncertainty (σ_{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, 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 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. 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 ability of every bundle 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 σ_{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., σ_{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 σ_{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 σ_{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 σ_{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 σ_{peak} increased from [ ][1]. GEH propagated the higher overall pin

[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 [ ]

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 onsidered 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.

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

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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.

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 σ_{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 σ_{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 ~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. **[**

]

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 σ_{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 0, 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 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 σ_{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 0.

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 the 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.

[

]

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 0 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 σ_{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 σ_{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 σ_{P4B} value of **[ ]**. This is greater than the accepted value and is inconsistent with the expected reduction in σ_{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 σ_{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 σ_{P4B}. While the calculated Supplement 6 σ_{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 σ_{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 σ_{P4B} 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 σ_{P4B} makes use of comparisons to measured TIP data, suggesting the σ_{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 σ_{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 0 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 σ_{P4B} using only the radial gamma TIP RMS percent data from the Peach Bottom Units 2 and 3 datasets. The updated value for σ_{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 σ_{P4B} using only the radial thermal TIP RMS percent data from the Monticello and Nine Mile Point, Unit 2 datasets. The updated value for σ_{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 0 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 σ_{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 0, 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 0, σ_{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 0 and Section 0 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 0 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.

3.3 Assessment of Grand Gulf Data

Section 4 of Supplement 6 discusses how additional TIP data and comparisons of TIP data will be handled when collected in the future. This discussion specifically considers Grand Gulf Nuclear Station (Grand Gulf), which was in the process of a TIP data collection campaign at the time Supplement 6 was submitted to the NRC for review. As per Section 4 of Supplement 6, on May 3, 2019, GEH voluntarily submitted to the NRC for consideration a letter with the additional TIP data and comparisons from Grand Gulf (Reference 12).

The figures included in the Grand Gulf data letter are the same as the figures presented in Supplement 6 but updated to include the Grand Gulf TIP data. The letter also presented the Grand Gulf TIP data in a tabulated form, consistent with the request made by the NRC in RAI-5 of Supplement 6. The NRC staff assessed the updated aggregate of the radial TIP RMS percent data as well as the Grand Gulf radial TIP RMS percent data independently and made several observations.

First, regarding the aggregate of radial TIP RMS percent data, the trends between and across the non-MELLLA+ and MELLLA+ operating domains remain largely consistent with those identified and discussed in Section 3.1.1 of this SE. There is a slight reduction in **[** **]**, which is readily attributable to the higher power-to-flow ratios of the Grand Gulf data, but otherwise there are no changes. Second, Grand Gulf is a thermal TIP plant. As such, the Grand Gulf radial TIP RMS percent data exhibit a larger uncertainty than the data obtained from gamma TIP plants. The Grand Gulf thermal radial TIP RMS percent data has a mean of **[** **]**, which is consistent with that of the **[** **]** datasets of **[** **]**. Third, the Grand Gulf radial TIP RMS percent data is extremely well-behaved, showing no **[** **]**. These consistent behaviors continue to support GEH's assertion that the neutronic methods performance is comparable regardless of the operating domain and the power-to-flow ratio.

GEH's intent with Supplement 6 and the Grand Gulf data letter was to provide TIP RMS percent data that, ideally, covered the entire power-to-flow ratio range available to all plants approved for MELLLA+ operation. Grand Gulf in particular has the highest power-to-flow ratio of any MELLLA+ plant at 57.4 MWt/(Mlbm/hr), and the data collected here would itself be bounding. However, the range of data supplied in the Grand Gulf data letter only covers power-to-flow ratios up to 51 MWt/(Mlbm/hr). According to GEH, the reason for this is testing at the edge of the allowable MELLLA+ operating domain, especially at the corners, can be difficult because the plants collecting TIP data could not maneuver to higher power-to-flow ratios without violating administrative thermal limits on core monitoring or administrative limits on allowable operational space. To help illustrate this, GEH provided power-to-flow maps for several plants that identify the locations at which TIP data had been collected. These maps show that TIP data was collected from deep within the MELLLA+ operating domain (nearly to the lower "cliff edge" of the MELLLA+ operating domain), well beyond the 100 percent power line of nominal operation and bounding for most MELLLA+ plants.

Acknowledging that there is some unsampled operational space that is theoretically possible to enter, GEH performed a series of PANAC11 cases to assess the possible differences in core characteristics expected in the unsampled region versus what has been tested. The results are provided in a table in the Grand Gulf data letter.

Of primary importance in the assessment are the core average void fraction and core average exit void fraction; the power-to-flow ratio primarily serves as a surrogate figure-of-merit for void fraction, and the higher void fractions expected for MELLLA+ operation are the underlying phenomenological contributor to concerns over increasing uncertainties. The NRC staff examined the predicted core average and core average exit void fractions provided in the assessment table and identified that, for each of the plants investigated, the void fractions are expected to only change by **[ ]** between the greatest power-to-flow ratios where TIP data has been collected and the maximum possible power-to-flow ratios. For Grand Gulf, the core average void fraction and the core average exit void fraction at the maximum bounding power-to-flow ratio are expected to be **[ ]**.

The small change **[ ]** in predicted void fractions across the Grand Gulf power-to-flow ratio range of 51 MWt/(Mlbm/hr) to 57 MWt/(Mlbm/hr) is not unexpected. While power-to-flow ratio serves as a surrogate figure-of-merit for void fraction, the magnitude of the void fraction does not change linearly with power-to-flow ratio across the entire MELLLA+ operating domain. The change in void fraction with change in power-to-flow ratio is much greater in regions where power is held constant and flow changes than in regions where both power and flow are changing together. This is evident if the void fraction data provided in Supplement 6 are plotted versus power-to-flow ratio. In Figure 3-3, below, NRC staff plotted the core average exit void fraction data from Peach Bottom Units 2 and 3. The data are broken into sequences where power was held constant, but flow was changing and when both power and flow were changing.

[

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Figure 3-3: Sequences of Subsequent Core Average Exit Void Fraction Data Versus Core Power-To-Flow-Ratio for Peach Bottom Units 2 and 3

The void fraction assessment data provided by GEH in the Grand Gulf data letter and Figure 3-3 above demonstrate that the increase in void fraction with increasing power-to-flow ratio is small for the higher power-to-flow ratios found deep within the MELLLA+ operating domain, where both power and flow are changing. A small change in void fraction of **[ ]** between the largest power-to-flow ratio where TIP data has been collected and the maximum bounding power-to-flow ratio for Grand Gulf is not expected to create conditions that challenge GEH's neutronic methods and introduce increasing uncertainties.

On the basis of the consistent behavior of the Grand Gulf radial RMS percent TIP data provided for power-to-flow ratios up to 51 MWt/(Mlbm/hr), the continued applicability of the NRC staff's assessments from Section 3.1.2 of this SE, and the assessment that the change in core average and core average exit void fractions at the higher power-to-flow ratios deep within the MELLLA+ operating domain are small, the NRC staff finds there is reasonable assurance the historically established values for the **[ ]** and overall pin power peaking uncertainty remain applicable for MELLLA+ applications within the range of power-to-flow ratios assessed (i.e., 57 MWt/(Mlbm/hr)). Limitation 5 has been updated to reflect this.

Because of the manner in which the higher power-to-flow ratios found deep within the MELLLA+ domain have been assessed (i.e., a small change in void fraction due to both power and flow changing together), plants approved for MELLLA+ operation that will operate at 100 percent power at power-to-flow ratios exceeding the supplied TIP data range of 51 MWt/(Mlbm/hr) should collect additional TIP data at the higher operating core power-to-flow state point and analyze the data to ensure they are consistent with results presented within this SE.

4.0 CONDITIONS AND LIMITATIONS

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. 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 plants operating at MELLLA+ at 100 percent power at power-to-flow ratios exceeding 51 MWt/(Mlbm/hr), additional TIP data at the higher operating core power-to-flow state point should be collected and analyzed to ensure the data are consistent with the results presented within this SE. If any adverse trending or inconsistencies are

identified, appropriate measures must be put in place to protect appropriate limits and a report with the results should be submitted to the NRC for review.

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.

However, because of the manner in which the higher power-to-flow ratios found deep within the MELLLA+ domain have been assessed (Section 3.3 of this SE), plants approved for MELLLA+ operation that will operate at 100 percent power at power-to-flow ratios exceeding 51 MWt/(Mlbm/hr) should collect additional TIP data at the higher operating core power-to-flow state point and analyze the data to ensure they are consistent with the results presented within this SE. If any adverse trending or inconsistencies are identified, appropriate measures must be put in place to protect appropriate limits and a report with the results should be submitted to the NRC for review.

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)).

3. NEDC-33173P-A, Revision 4, “Applicability of GE Methods to Expanded Operating Domains,” November 2012 (ADAMS Accession No. ML12313A107/ML12313A106 (Publically Available/Non-Publically Available)).

4. NEDC-33173P-A, Supplement 2, Parts 1-3P-A, “Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Confrentes,” April 2012 (ADAMS Package Accession No. ML121150469 (Publically Available)).

5. NUREG-800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light Water Reactor Edition” (ADAMS Accession No. ML070810350 (Publically Available)).

6. NEDE-30130-P-A, “Steady State Nuclear Methods,” April 1985 (ADAMS Accession No. ML070400570 (Non-Publically Available)) and NEDE-24011-P-A (GESTAR II), Amendment 26, “Implementing Improved GE Steady-State Methods,” August 1999 (MFN-033-99) (ADAMS Package Accession No. ML993230387/ML993220237 (Publically Available/Non-Publically Available)).

7. NEDC-32601P-A, Revision 0 “Method and Uncertainties for Safety Limit MCPR Evaluation,” August 1999 (ADAMS Accession No. ML003740145 (Non-Publically Available)).

8. NEDC-32694P-A, Revision 0, “Power Distribution Uncertainties for Safety Limit MCPR Evaluation,” August 1999 (ADAMS Accession No. ML003740151 (Non-Publically Available)).

9. NEDC-33173 Supplement 2 Part 1P-A, Revision 1, “Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Confretes Cycle 13,” April 2012 (ADAMS Accession No. ML12115A227/ML12115A234 (Publically Available/Non-Publically Available)).

10. GE-Hitachi Nuclear Energy Letter (M190017) to NRC Dated February 13, 2019, “Response to Request for Additional Information for NEDC-33173, Supplement 6, Revision 0, ‘Applicability of GE Methods to Expanded Operating Domains – Removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) Penalty’ (EPID No. L-2017-TOP-0040)” (ADAMS Package Accession No. ML19053A424/ML19053A425 (Publically Available/Non-Publically Available)).

11. Entergy Letter (BVY 05-072) to NRC dated August 1, 2005, “Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263, Supplement No. 30, Extended Power Uprate – Response to Request for Additional Information” (ADAMS Accession No. ML052170310 (Non-Publically Available)).

12. GEH Letter (M190085) to NRC dated May 3, 2019, “Supplemental Grand Gulf Nuclear Station Information for NEDC-33173P Supplement 6 and Additional Information to Support the Removal of the SLMCPR Penalty in the MELLLA+ Operating Domain,” (ADAMS Package Accession No. ML19123A183 (Publically Available)).

Principal Contributor: A. Kevin Heller

Date: August 8, 2019

NRC Staff Response to General Electric Hitachi Nuclear Energy (GEH) 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 GEH's original draft safety evaluation (SE) markup enclosure. Due to suggested changes in the 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	NRC Response
Section 1.1 Background	Page 4: 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. GEH suggests the following change (Line 35): "…**[** **]** <u>the four-bundle power uncertainty (σ_{P4B})</u>, and the…" *Suggested change shown in the markup.*	The intention of Page 4, Lines 34-36 is to indicate which of the power distribution uncertainties the NRC staff historically had concerns with. This intention can be seen if Lines 34-36 are taken within the context of Lines 32-33. Additionally, Lines 36-39 discuss how the power distribution uncertainties are the source of the SLMCPR adders; per the discussion of the SE for the original IMLTR, the four-bundle power uncertainty σ_{P4B} is not a direct source of these adders. Rereading lines 34-36, the NRC staff understands how they could be interpreted to be more of a general statement and, thus, it would seem unusual to not also mention the four-bundle power. Therefore, the NRC staff will incorporate the following edits to Lines 34-36: "The~~se~~ power distribution uncertainties <u>with which the NRC staff had concerns are</u> ~~include~~ the bundle **[** **]** and the overall pin power peaking uncertainty (σ_{peak})."

Location	Comment	NRC Response
Section 1.1.1 Interim Methods Licensing Topical Report NEDC-33173P-A	Page 5: 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. GEH suggests the following change (Line 6): "…the average bundle power can increase~~s~~, leading…" *Suggested change shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.
Section 1.1.1 Interim Methods Licensing Topical Report NEDC-33173P-A	Page 5: 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. 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. GEH suggests the following change (Lines 9-10): "Since the maximum powered bundles can set the thermal limits, EPU operation can reduce~~s~~ the margins to the thermal limits." *Suggested changes shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.

Location	Comment	NRC Response
Section 1.1.1 Interim Methods Licensing Topical Report NEDC-33173P-A	Page 5: Would be more accurate to state “all bundles” GEH suggests the following change (Line 16): “~~The maximum powered~~All bundles must meet the thermal limits…” *Suggested change shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.
Section 1.1.1 Interim Methods Licensing Topical Report NEDC-33173P-A	Page 5: Would be more accurate to state “all bundles” GEH suggests the following change (Lines 18-19): “Since the ~~high-powered bundle’s~~ ability to operate within the thermal limits of all bundles is…” *Suggested changes shown in the markup.*	The NRC staff agrees with this statement but will incorporate the following edits to maintain the context of the paragraph: “Since the ability of every bundle ~~high-powered bundle’s~~ to operate within thermal limits is analytically determined, it is…”
Section 1.1.2 Supplement 2 to NEDC-33173P-A	Page 10: This value can be higher for some plants, up to ~57 MWt/(lbm/hr) at the limiting point on the curve. GEH suggests the following change (Line 32): “…for MELLLA+ operation is up to ~~50~~~57 MWt/(Mlbm/hr)” *Suggested change shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.

Location	Comment	NRC Response
Section 3.1 Bundle Power Uncertainty	Page 14: Recommend ending the sentence with "if a statistically significant trend exists". GEH suggests the following change (Line 10): "…historically established value and if a statistically significant trend exists." *Suggested change shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.
Section 3.1.1 Assessment of Core TIP Data	Page 14: Correct the power density for Peach Bottom Units 2 and 3. GEH suggests the following change (Line 24): "…BWR/4 with power densities of ~~58.4~~59.43 kW/L,…" *Suggested change shown in the markup.*	The NRC staff agrees with this comment and finds the change acceptable.

Additional Comments by NRC staff:

Location	NRC Comment
Section 3.1.1.4 Comparison of TIP RMS Data to Experience Base	Page 19: On Line 40, the formatting on the symbol for the four-bundle power uncertainty is incorrect. The letters "P4B," which identify the uncertainty, should be subscripts of the Greek lowercase sigma. The NRC staff made the following change (Line 40): "This difference drives the calculated ~~σP4B~~σ_{P4B} for aggregate…"

Location	NRC Comment
Section 3.1.2 Conclusions for TIP Core Data	Page 22: On Line 20, the subscript letters on the Greek lowercase sigma that identify the uncertainty are incorrect. NRC staff made the following change (Line 20): "…therefore neither is the **[** **]**. The historically established…"
Section 3.3 Assessment of Grand Gulf Data	This section was added after receipt of comments from GEH on the Draft SE. Its content was agreed upon with GEH.
Section 4.0 Conditions and Limitations	Following are changes made to Section 4.0 after receipt of comments from GEH on the Draft SE. These changes were agreed upon with GEH: Page 27: Lines 15, 16: applicable to MELLLA+ operation ~~within the range of P/F ratios examined (i.e., 50MWt/(Mlbm/hr)~~. Page 27: lines 21-23 are deleted and replaced with the verbiage: 5. SLMCPR 2 For plants operating at MELLLA+ at 100 percent power at power-to-flow ratios exceeding 51 MWt(Mlbm/hr), additional TIP data at the higher operating core power-to-flow state point should be collected and analyzed to ensure the data are consistent with the results presented within this SE. If any adverse trending or inconsistencies are identified, appropriate measures must be put in place to protect appropriate limits and a report with the results should be submitted to the NRC for review.

Location	NRC Comment
Section 5.0 Conclusions	Following are changes made to Section 5.0 after receipt of comments from GEH on the Draft SE. These changes were agreed upon with GEH. Page 27: Starting at line 49 the following deletions and additions were made: 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.~~ However, because of the manner in which the higher power-to-flow ratios found deep within the MELLLA+ domain have been assessed (Section 3.3 of this SE), plants approved for MELLLA+ operation that will operate at 100 percent power at power-to-flow ratios exceeding 51 MWt/(Mlbm/hr) should collect additional TIP data at the higher operating core power-to-flow state point and analyze the data to ensure they are consistent with the results presented within this SE. If any adverse trending or inconsistencies are identified, appropriate measures must be put in place to protect appropriate limits and a report with the results should be submitted to the NRC for review.
Section 6.0 References	Reference 12 was added after receipt of comments from GEH on the Draft SE.

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REVISION SUMMARY

Revision Number	Description of Change
0	Initial Issue
1	Created the "-A" version by adding the NRC's Final Safety Evaluation (Reference 9) and GEH's responses to the NRC's Requests for Additional Information (RAIs) (Reference 10). Revised Section 1.1 to use a more general term for the core monitoring system. Added References 9 and 10.

Acronyms and Abbreviations

Term	Definition
3D	Three-Dimensional
BT	Boiling Transition
EPU	Extended Power Uprate
GEH	GE Hitachi Nuclear Energy
IMLTR	Interim Methods Licensing Topical Report
LHGR	Linear Heat Generation Rate
MAPLHGR	Maximum Average Planar Linear Heat Generation Rate
MCPR	Minimum Critical Power Ratio
MELLLA+	Maximum Extended Load Line Limit Analysis Plus
NRC	Nuclear Regulatory Commission
OLMCPR	Operating Limit Minimum Critical Power Ratio
OLTP	Original Licensed Thermal Power
P/F	Power-to-Flow
RAI	Request for Additional Information
RMS	Root Mean Square
SE	Safety Evaluation
SLMCPR	Safety Limit Minimum Critical Power Ratio
TIP	Traversing In-Core Probes

1. Purpose and Background

The purpose of this supplement is to seek removal of the Safety Limit Minimum Critical Power Ratio (SLMCPR) penalty imposed on MELLLA+ plants. GEH requests that the NRC review Supplement 6 and upon concurrence with the information presented herein, eliminate the SLMCPR penalty applied to MELLLA+ plants. The following paragraphs describe the history of the SLMCPR methodology and the penalty that was imposed and subsequently modified.

The SLMCPR is determined as a MCPR at which 99.9% of the fuel rods in the core are expected to avoid Boiling Transition (BT). The methods and uncertainties used to evaluate the SLMCPR have been approved by the Nuclear Regulatory Commission (NRC) and are documented in NEDC-32601P-A and NEDC-32694P-A (References 1 and 2, respectively). NEDC-32601P-A contains the SLMCPR methodology and uncertainties related to the thermal-hydraulic, pin power peaking and plant instrumentation. NEDC-32694P-A contains uncertainties related to the plant process computer's evaluation of the bundle power distribution.

In Section 9 of the NRC final Safety Evaluation (SE) for Interim Methods Licensing Topical Report (IMLTR) NEDC-33173P Revision 0 (Reference 3), the NRC imposed Limitations 4 and 5 on the SLMCPR for Extended Power Uprate (EPU) (above 100% and up to 120% of the Original Licensed Thermal Power (OLTP)) and the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain.

GEH subsequently submitted pin and bundle power gamma scan benchmarks for review by the NRC to address these two limitations (References 4 and 5).

In the March 15, 2012 NRC SE for NEDC-33173P Revision 2 and Supplement 2 Parts 1-3 (Reference 6), the NRC eliminated Limitation 4 and revised Limitation 5. GEH has gathered significant operational data since Limitation 5 was imposed within the MELLLA+ extended operating domain.

1.1 Bundle Power Uncertainties

The description of the calculation of bundle power uncertainty contained in NEDC-32694P-A (Reference 2) is summarized here for convenience.

The core monitoring power distribution uncertainties are required for determining the SLMCPR, Linear Heat Generation Rate (LHGR) and Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) limits. The (axially integrated) bundle power uncertainty is required for the SLMCPR' and the nodal power uncertainty is required for determining MAPLHGR and LHGR. The radial bundle power uncertainty is a statistical combination of: (1) the uncertainty in the four-bundle power associated with the Traversing In-Core Probe (TIP) location, and (2) the uncertainty in the allocation of the four-bundle power to the individual bundles.

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In the original NEDC-32694P-A evaluation, [[ ]]. Additional support for this modeling uncertainty was provided in NEDC-33173 (Reference 5) using gamma scans which included 10x10 fuels.

Several cores containing recent fuel designs have been tracked, and calculated TIP signals have been compared with measured data. These TIP data can be used to validate the bundle power model uncertainties for recent applications, including operation in MELLLA+.

[[ ]] This value was validated to be appropriate for application to more recent fuels in the response to NRC Request for Additional Information (RAI) 25 in Reference 7 as documented in Table 3-1 in Section 3.1.5 of the NRC SE for IMLTR NEDC-33173P Revision 0 (Reference 3) and in Table 3.2.1.3.1 in the NRC SE for NEDC-33173P Supplement 3 (Reference 8).

Bundle power uncertainties are examined in this report for the plants in the MELLLA+ region of interest, both below and above Power-to-Flow (P/F) ratios of 42.0 MWt/(Mlbm/hr). To provide a reference point for the typical scatter of the data observed, the bundle power uncertainties, in the form of Root Mean Square (RMS) values, include the plants of interest for all available TIP measurements for a number of cycles preceding entry into the MELLLA+ region.

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. These include, but are not limited to, TIP type ("thermal" vs. "gamma" detector), TIP alignment, failed TIPs, heat balance discrepancies, plant operation, and flow miscalibration. To properly reflect the bundle power predictability across the fleet on a consistent basis, the RMS results are typically [[

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1.2 Plant Descriptions

Plants with histories of MELLLA+ operation contributing to the subject analysis are described in this section. Grand Gulf Nuclear Station is excluded from this section due to the absence of testing data; however, it may be included later as described in Section 4.

1.2.1 Monticello Background Information

Monticello is a 484 bundle BWR/3 operated by Northern States Power Company in Cycle 28. The rated power is 2,004.0 MWt, and the rated flow is 57.6 Mlbm/hr. The original rated power was 1,670.0 MWt, so the plant is currently operating at 120.0% of the original rated power. This corresponds to a power density of 48.3 kW/L. The fuel is 100% GE14. The Monticello plant has a thermal TIP system with 24 TIP strings.

1.2.2 Peach Bottom Unit 2 Background Information

Peach Bottom Unit 2 is a 764 bundle BWR/4 operated by Exelon Generation Company, LLC in Cycle 22. The rated power is 3,951.0 MWt, and the rated flow is 102.5 Mlbm/hr. The original rated power was 3,293.0 MWt, so the plant is currently operating at 120.0% of the original rated power. This corresponds to a power density of 58.4 kW/L. The fuel is 100% GNF2. The Peach Bottom Unit 2 plant has a gamma TIP system with 43 TIP strings.

1.2.3 Peach Bottom Unit 3 Background Information

Peach Bottom Unit 3 is a 764 bundle BWR/4 operated by Exelon Generation Company, LLC in Cycle 21. The rated power is 3,951.0 MWt, and the rated flow is 102.5 Mlbm/hr. The original rated power was 3,293.0 MWt, so the plant is currently operating at 120.0% of the original rated power. This corresponds to a power density of 58.4 kW/L. The fuel is 100% GNF2. The Peach Bottom Unit 3 plant has a gamma TIP system with 43 TIP strings.

1.2.4 Nine Mile Point Unit 2 Background Information

Nine Mile Point Unit 2 is a 764 bundle BWR/5 operated by Exelon Generation Company, LLC in Cycle 16. The rated power is 3,988.0 MWt, and the rated flow is 108.5 Mlbm/hr. The original rated power was 3,323.0 MWt, so the plant is currently operating at 120.0% of the original rated power. This corresponds to a power density of 59.0 kW/L. The majority of the fuel is GE14 (58.1% of the core loading) with the remaining 41.9% composed of GNF2 fuel. The Nine Mile Point Unit 2 plant has a thermal TIP system with 43 TIP strings.

2. Power Uncertainty Evaluation

The radial TIP RMS is a direct measurement of the [[ ]]. The trending of this uncertainty with respect to P/F ratio is presented in Figure 2-1. In Figures 2-1 through 2-12, comparisons are circled when corresponding measurements were taken while the reactor was in the MELLLA+ domain. It is observed in the comparison against P/F ratio that the RMS power uncertainties in the MELLLA+ domain do not lie outside the typical range that is expected, whether with respect to P/F ratio or with respect to operating domain.

Figure 2-2 presents the same results with respect to cycle exposure. [[ ]] with respect to exposure is expected and is observed regardless of the extended P/F characteristics of the MELLLA+ regime.

The radial RMS with respect to average void fraction is presented in Figure 2-3. There appears to be no unique trend in error with respect to exit void fraction, regardless of the extended MELLLA+ domain.

The radial RMS with respect to average exit void fraction is presented in Figure 2-4. There appears to be no unique trend in error with respect to exit void fraction, regardless of the extended MELLLA+ domain.

The nodal TIP RMS is a combination of the radial and axial uncertainties. The trending of nodal and axial uncertainties with respect to P/F ratio, average core void fraction, and average exit void fraction is presented in Figures 2-5 through 2-12. There appear to be no unique trends with respect to P/F, void fraction, or exit void fraction, regardless of MELLLA+ operating domain.

Thermal limits, including the MCPR, are computed using the shape adapted core thermal power distribution. Shape adaption causes the axial RMS to approach zero, which reduces the nodal RMS to the radial RMS. Hence, the radial RMS is of most significance with respect to the SLMCPR calculation.

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Figure 2-1. Radial TIP Measured-to-Predicted RMS Comparison versus P/F Ratio

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Figure 2-2. Radial TIP Measured-to-Predicted RMS Comparison versus Exposure

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Figure 2-3. Radial TIP Measured-to-Predicted RMS Comparison versus Average Void Fraction

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Figure 2-4. Radial TIP Measured-to-Predicted RMS Comparison versus Exit Void Fraction

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Figure 2-5. Axial TIP Measured-to-Predicted RMS Comparison versus P/F Ratio

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Figure 2-6. Axial TIP Measured-to-Predicted RMS Comparison versus Exposure

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Figure 2-7. Axial TIP Measured-to-Predicted RMS Comparison versus Average Void Fraction

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Figure 2-8. Axial TIP Measured-to-Predicted RMS Comparison versus Exit Void Fraction

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Figure 2-9. Nodal TIP Measured-to-Predicted RMS Comparison versus P/F Ratio

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Figure 2-10. Nodal TIP Measured-to-Predicted RMS Comparison versus Exposure

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Figure 2-11. Nodal TIP Measured-to-Predicted RMS Comparison versus Average Void Fraction

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Figure 2-12. Nodal TIP Measured-to-Predicted RMS Comparison versus Exit Void Fraction

The variability of the TIP RMS under MELLLA+ conditions and high P/F ratios appears to be well within the typical range observed under non-MELLLA+ conditions and lower P/F ratios. It is useful to scrutinize separately those TIP measurements performed specifically to assess the power modeling uncertainty in the MELLLA+ domain and high P/F region. The TIP measurements taken in the MELLLA+ domain and at high P/F ratios were part of specially prescribed tests, and therefore were typically taken in close succession (in time and exposure), with only those plant maneuvers performed that were required to vary the P/F ratio and achieve necessary test conditions. This has the effect of minimizing variance introduced from confounding factors, allowing a direct assessment of the effect, if any, of the P/F ratio on power modeling uncertainty. Plant and cycle-specific confounding factor contributions to the uncertainty are approximately constant when measurements are taken in close succession.

TIP measurement RMS uncertainties taken in close succession are shown in Figures 2-13 through 2-15. Lines are drawn between points to indicate chronological proximity. [[

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Figure 2-13. Radial TIP RMS Uncertainties for Specific Tests

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Figure 2-14. Nodal TIP RMS Uncertainties for Specific Tests

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Figure 2-15. Axial TIP RMS Uncertainties for Specific Tests

The largest change in P/F ratio, of [[ ]]. The variability of sequential

measurements is very minor relative to the variability that would be detected over the domain of interest if chronological proximity were not considered.

These results [[

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The uncertainty observed in TIP RMS values across the domain of interest is effectively reduced when variation introduced by plant and cycle-specific confounding factors is removed, indicating that [[

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3. Conclusions

NRC concerns leading to the imposition of SLMCPR penalties for operation in the MELLLA+ operating domain were rooted in an inability to fully bound the operational characteristics of MELLLA+ operation with measurement data formerly provided. These concerns are directly addressed in this report by assessing new data in the MELLLA+ region for any trending in power uncertainty.

The power uncertainty is reflected in comparisons between predicted TIP readings to TIP measurements, with measurements that were performed during plant operation spanning both non-MELLLA+ and MELLLA+ domains, as well as low to high P/F ratios in the MELLLA+ operating domain. The evaluation includes TIP comparisons with respect to the physical parameters of core void fraction and exit void fraction.

No unfavorable trending is apparent in either the power uncertainty with MELLLA+ operation, or with high P/F ratios within the MELLLA+ domain. Removal of SLMCPR penalties for formerly unknown trending is therefore justified, including the 0.01 penalty for MELLLA+ operation below and including 42 MWt/(Mlbm/hr), and the 0.02 penalty for MELLLA+ operation above 42 MWt/(Mlbm/hr).

4. Process for Handling Future Data

As discussed in Section 1.2, there are five plants which have been licensed for operation in the MELLLA+ domain and four of those plants have performed TIP comparisons in the MELLLA+ domain. The four plants that have completed the committed testing do not plan to perform additional TIP comparisons in the MELLLA+ domain unless normal operations would cause them to do so. When additional TIP data and comparisons are available for Grand Gulf Nuclear Station, that data will be evaluated in the same manner as the data included in this report. These data comparisons are not expected to affect the conclusions based on the current data from the four plants included herein. GEH will document any new data acquired and TIP comparison evaluations from Grand Gulf Nuclear Station in a letter report to the NRC. Should the additional data adversely affect the conclusions of this report, GEH will enter the 10 CFR 21 process and inform the NRC as required.

5. References

1. GE Nuclear Energy, "Methodology and Uncertainties for Safety Limit MCPR Evaluations," NEDC-32601P-A, Revision 0, August 1999.
2. GE Nuclear Energy, "Power Distribution Uncertainties for Safety Limit MCPR Evaluations," NEDC-32694P-A, Revision 0, August 1999.
3. Letter, Thomas B. Blount (NRC) to Jerald G. Head (GEH), "Final Safety Evaluation for GE Hitachi Nuclear Energy Americas, LLC Licensing Topical Report NEDC-33173P, "Applicability of GE Methods to Expanded Operating Domains" (TAC No. MD0277)," MFN-09-808, July 21, 2009.
4. GE Hitachi Nuclear Energy, "Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Cofrentes Cycle 13," NEDC-33173 Supplement 2 Part 1P-A, Revision 1, April 2012.
5. GE Hitachi Nuclear Energy, "Applicability of GE Methods to Expanded Operating Domains – Pin-by-Pin Gamma Scan at FitzPatrick," NEDC-33173 Supplement 2 Part 2P-A, Revision 1, April 2012.
6. Letter, Robert A. Nelson (NRC) to Jerald G. Head (GEH), "Final Safety Evaluation for GE Hitachi Nuclear Energy Americas Topical Report NEDC-33173P, Revision 2 and Supplement 2, Parts 1-3, "Analysis of Gamma Scan Data and Removal of Safety Limit Critical Power Ratio (SLMCPR) Margin" (TAC No. ME1891)," MFN-12-025, March 15, 2012.
7. Letter, Louis M. Quintana (GE) to Herbert Berkow (NRC), "Responses to RAIs – Methods Interim Process (TAC No. MC5780)," MFN 05-029, April 8, 2005.
8. Letter, John R. Jolicoeur (NRC) to Jerald G. Head (GEH), "Final Safety Evaluation for GE Hitachi Nuclear Energy Americas Topical Report NEDC-33173P, Supplement 3, "Applicability of GE Methods to Expanded Operating Domains – Supplement for GNF2 Fuel" (TAC No. ME1815)," December 28, 2010.
9. Letter from Dennis C. Morey (NRC) to Michelle P. Catts (GEH), "Final 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 (EPID: L-2017-TOP-0040)," June 19, 2019.
10. Letter, Lisa K. Schichlein (GEH) to NRC Document Control Desk, "Response to Request for Additional Information for 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" (EPID No. L-2017-TOP-0040)," M190017, February 13, 2019.

APPENDIX A – GEH RESPONSES TO NRC RAIS ON NEDC-33173P SUPPLEMENT 6 REVISION 0

RAI-1

(High) In Limitation 5 of the SE for the interim methods licensing topical report (IMLTR) NEDC-33173P-A (Reference 1), the NRC staff imposed a penalty to the SLMCPR for MELLLA+ operation of 0.03. This adder was comprised of a 0.02 value to account for increased uncertainties in pin peaking and bundle powers at EPU operation and a 0.01 value to account for: (1) the fact that operation at lower core flow conditions at rated or EPU power levels are generally more limiting, and (2) potential changes in the uncertainties on both pin peaking and bundle power due to the higher power-to-flow ratios present in the MELLLA+ operating domain. In the SE for Supplement 2 of the IMLTR (Reference 2), the NRC staff removed the 0.02 value from Limitation 5 but retained the 0.01 value that is meant to capture potential changes in uncertainties for both pin peaking and bundle power. However, the discussion presented in Supplement 6 of the IMLTR (Reference 3) for removal of the remaining SLMCPR penalty focuses on bundle power uncertainty and does not address pin peaking uncertainty. Therefore, the justification for removal of the remaining penalty is incomplete. Provide justification that the uncertainty in pin peaking does not change with the higher power-to-flow ratios present in the MELLLA+ operating domain.

References

1. NEDC-33173P-A, Revision 4, “Applicability of GE Methods to Expanded Operating Domains,” November 2012, (Agency-wide Documents Access and Management System (ADAMS) Accession No. ML12313A107 / ML12313A106 (Publically Available / Non-Publically Available)).
2. NEDC-33173P-A, Supplement 2, Parts 1-3P-A, “Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Confrentes,” April 2012, (ADAMS Package Accession No. ML121150469 (Publically Available)).
3. 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)).

GNF Response

The Nuclear Regulatory Commission (NRC) staff is correct in noting that the data presented in Supplement 6 focuses on bundle power uncertainty derived from cycle-tracking data and does not directly address pin peaking uncertainty. This is due to expectations established with the NRC regarding what type of information would be necessary to revisit the removal of the penalty. In particular, Global Nuclear Fuel (GNF) agrees with the NRC’s Safety Evaluation of Supplement 2 which states that “...[postulated] anomalies associated with MELLLA+ operation ... would affect the overall transport solution methodology and would be observable in detailed TIP comparisons.

Therefore, the NRC staff will revisit Limitation 5 during its review of the MELLLA+ cycle-tracking evaluation that will be provided by GEH."

Further confidence in the use of current pin power peaking uncertainties in the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain can be obtained by investigating the performance of GNF methods in MCNP to TGBLA infinite lattice peaking comparisons. One good historical example to consider can be found in Figure 2-1 and Figure 2-2 of Supplement 3 of the IMLTR, which are shown below. In these figures, data is provided on pin power uncertainty at both Beginning of Cycle (BOC) and 65 GWD/STU lattice average exposures. The data is plotted as a function of relative water density, and discrete lattice designs for GNF2 are called out explicitly in the figures.

Of particular interest from a MELLLA+ performance perspective are [[ ]] data points at high void conditions ([[ ]]). These data points correspond to the lattice design at the very top of the assembly. This portion of the assembly will experience the highest void fraction and would be most affected by any trend in void with high core-wide Power-to-Flow (P/F) ratios.

The TGBLA to MCNP benchmarking results provided indicate that pin power peaking uncertainty is actually at or near its lowest reported value for these conditions. While some upward trending as a function of relative water density is observed in Figure 2-2, the absolute value of the comparisons at these late exposures is considerably lower than the corresponding BOC points for all void fractions.

In summary, the fact that (1) any potential anomalies in the overall transport solution method (including pin power peaking) would be observable in the detailed Traversing In-Core Probe (TIP) comparisons provided, and (2) TGBLA to MCNP pin power benchmarking results, showing excellent performance near the top of the assembly that would actually experience the highest voids, provides justification that the uncertainty in pin peaking does not change with the higher P/F ratios present in the MELLLA+ operating domain.

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

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

RAI-2

(Low) During examination of supporting documentation for Supplement 6 of the IMLTR, the NRC staff observed discrepancies in terminology and uncertainty values, and the staff is seeking clarification. Five different requests for clarification are presented within this RAI. For purposes of fully understanding the source of the NRC staff's requests for clarification on pin power uncertainty terminology and the values associated with the uncertainties, it is beneficial to begin with the IMLTR, Revision 1 (Reference 0) and proceed "backward" into the historical supportive documentation. This discussion is presented below with the request for clarification identified throughout. Additionally, the requests for clarification are compiled in a summary at the end of this RAI for ease of reference.

NEDC-33173P-A, Revision 1:

Page 2-4 of Revision 1 of the IMLTR (Reference 0) describes uncertainty associated with what is referred to as "*local pin peaking factor*" and states it is primarily associated with the lattice code TGBLA. Page 2-5 of the IMLTR goes on to state that the 1σ uncertainty was evaluated to be [[ ]] in NEDE-32601P-A based on comparisons with MCNP Monte Carlo evaluations. At this point, no symbol has been defined for the parameter, but one may see that "local pin peaking factor uncertainty = [[ ]]".

Page 2-5 of the IMLTR, Revision 1, also discusses an "*overall pin peaking uncertainty*", indicating it is comprised of [[ ]], and that it was confirmed via comparison to [[ ]] measurements. However, the discussion on page 2-5 subsequently discusses how the standard deviation between TGBLA and MCNP pin powers for GE11, GE14, and several Non-GE fuel designs are all similar (Table 2-4 of the IMLTR). As a result, the NRC staff's understanding is that, because reference is being made to TGBLA and MCNP comparisons and the results are consistent with [[ ]], the discussion within the IMLTR at this point has shifted back to "*local pin peaking factor uncertainty*."

At the top of Page 2-6 of the IMLTR, Revision 1, the discussion of additional pin power uncertainty on the determination of SLMCPR begins. It indicates that a review of [[ ]]. The NRC staff infers from this that the discussion is now in reference to "*overall pin peaking uncertainty*" as this is the uncertainty associated with comparisons to [[ ]]. However, the IMLTR, Revision 1, does not explicitly state whether it is the "*local pin peaking factor uncertainty*" or the "*overall pin peaking uncertainty*" that is [[ ]]. The IMLTR simply states that the resultant effects on the SLMCPR due to [[ ]].

Safety Evaluation for NEDC-33173P-A, Revision 1:

The IMLTR, Revision 1, did not explicitly state which of the uncertainties [[ ]]. The NRC staff therefore examined the SE (Reference 0) associated with the IMLTR, Revision 1.

Section 3.2.2.2, page 27, 4th full paragraph of the SE for the IMLTR, Revision 1, discusses a "*peak pin uncertainty*" and associates with it the symbol "σ_{Ppeak}". Since the discussion in the SE mentions how this was [[ ]], the NRC staff infers "σ_{Ppeak}" to be the "*overall pin peaking uncertainty*" discussed in the IMLTR, Revision 1.

In the following paragraph (5th full paragraph on page 27) of the SE, the discussion of [[ ]] begins. Again, making reference to [[ ]] suggests, just as in the IMLTR, that the uncertainty [[ ]] is the "*overall pin peaking uncertainty,*" or "σ_{Ppeak}". The SE goes on to state that the uncertainty [[ ]].

This is the first of the NRC staff's requests for clarification regarding terminology. Based on the IMLTR and associated SE, it is σ_{Ppeak}, otherwise known as the "*overall pin peaking uncertainty,*" that is [[ ]]. However, it would seem that [[ ]], is that of the "*local pin peaking factor uncertainty*" as identified on Page 2-5 of the IMLTR. This appears to be a discrepancy in the documentation.

The NRC staff considered that σ_{Ppeak} and the "*local pin peaking factor*" may possess the same values, but based on examination of NEDC-32694P-A (discussed below), σ_{Ppeak} has a nominal value of [[ ]].

<u>NEDC-32601P–A, Revision 0:</u>

Page 2-5 of the IMLTR, Revision 1, indicates the "*local pin peaking factor uncertainty*" is assessed in NEDC-32601P-A (Reference 0). This document was examined to further inform the NRC staff's understanding.

Page 3-1 of NEDC-32601P-A discusses the uncertainty in pin power peaking factor. Section 3.1 identifies that "*total uncertainty in fuel pin power peaking factor*" is defined as:

[[

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If correct, this would mean σ_{peak} is consistent with the definition of "*overall pin peaking uncertainty*" as identified on Page 2-5 of the IMLTR. This would then suggest σ_{peak} as defined above and σ_{Ppeak} from the SE for the IMLTR are the same parameter and possess a value of [[ ]]. The above equation also suggests that "*local pin power peaking uncertainty*" as discussed on page 2-5 of the IMLTR is [[ ]].

This is the second of the NRC staff's requests for clarification concerning terminology. Are σ_{peak} and σ_{Ppeak} the same parameter, and is [[ ]] the "*local pin power peaking uncertainty*" whose value is [[ ]]?

NEDC-32694P-A, Revision 0:

NEDC-32694P-A (Reference 0) is also referenced by the IMLTR, Revision 1, and was examined to further the NRC staff's understanding of uncertainties associated with pin peaking.

Page A-9 of NEDC-32694P-A provides a discussion on "*pin power peaking uncertainty*". This discussion indicates the uncertainty can be determined from the factors summarized in Section 3 of NEDC-32601P (discussed above). Specifically, [[

]]

This is consistent with the discussion presented in NEDC-32601P-A for "*total uncertainty in fuel pin power peaking factor*". This suggests that the "*pin power peaking uncertainty*" discussed in NEDC-32694P-A and the "*total uncertainty in fuel pin power peaking factor*" discussed in NEDC-32601P-A are the same parameter and are given the symbol σ_{peak}. Additionally, this suggests [[ ]]. However, the values of σ_{peak} and [[ ]] vary from one document to the other.

This is the third of the NRC staff's requests for clarification. [[

]]

The Fourth of the NRC Staff's Requests for Clarification:

Based the discussion presented above, it appears to the NRC staff that the IMLTR, Revision 1, is [[ ]]. However, based on the IMLTR, Revision 1, not specifically identifying [[ ]] and the SE associated with the IMLTR, Revision 1, it is the NRC staff's understanding that [[ ]]. Examination of both NEDC-32601P-A and NEDC-32694P-A suggests that the value of [[

]].

If the NRC staff's understanding is correct that the IMLTR, Revision 1, is [[ ]], then the NRC staff acknowledges that [[

]]. However, the NRC staff is not aware of a discussion justifying this position and is seeking such a discussion.

The Fifth of the NRC Staff's Requests for Clarification:

Section 3 of NEDC-32601P-A discusses the uncertainty associated with R-Factor. NEDC-32601P-A indicates it is [[

]] Given the clarification requested above regarding [[
]], clarify whether the R-factor uncertainty discussed in Section 3 of NEDC-32601P-A is [[
]].

Summary:

Below is a table summarizing the various terminology within the examined documents, its source, and the NRC staff's understanding of what the terms are. Short descriptions of the NRC staff's requests for clarification are also provided after the table.

Table 2-1: NRC Staff's Understanding of Various Uncertainty Terminology

Terminology	Source	Symbol	NRC Staff's Understanding
Local pin peaking factor uncertainty	NEDC-33173P-A, Revision 1, Page 2-4	None Provided	[[
Overall pin peaking uncertainty	NEDC-33173P-A, Revision 1, Page 2-5	None Provided	
Peak pin uncertainty	SE for NEDC-33173P-A, Revision 1, Page 27	σ_{Ppeak}	

Terminology	Source	Symbol	NRC Staff's Understanding
Total uncertainty in fuel pin power peaking factor	NEDC-32601P-A, Revision 0, Page 3-1	σ_{peak}	
Infinite Lattice Peaking Uncertainty	NEDC-32601P-A, Revision 0, Page 3-2	[[ ]]	
Pin power peaking uncertainty	NEDC-32694P-A, Revision 0, Page A-9	σ_{peak}	
Pin peaking uncertainty determined from Monte Carlo comparisons	NEDC-32694P-A, Revision 0, Page A-9	[[ ]]	]]

NRC Staff's requests for clarification:

1) Is the NRC staff's understanding of the various terminology presented in Table 2-1 correct?
2) Are σ_{peak} and σ_{Ppeak} the same parameter?
3) [[

]]
4) If the discussion provided in the IMLTR, Revision 1, [[

]] If it is only necessary [[
]], what is the justification for [[
]]
5) Is the R-factor uncertainty that is discussed in Section 3 of NEDC-32601P-A [[

]]

References

4. NEDC-32601P-A, "Methodology and Uncertainties for Safety Limit MCPR Evaluations," August 1999 (ADAMS Accession No. ML003740145 (Non-Publically Available)).
5. NEDC-33173P-A, Revision 1, "Applicability of GE Methods to Expanded Operating Domains," November 2012, (ADAMS Accession No. ML102920140 (Non-Publically Available)).
6. NEDC-32694, Revision 0, "Power Distribution Uncertainties for Safety Limit MCPR Evaluations," August 1999, (ADAMS Accession No. ML003740151 (Non-Publically Available)).

GNF Response

GNF response to requests for clarification (1) and (2):

The Nuclear Regulatory Commission (NRC) staff's interpretation of the terminology presented in Table 2-1 appears to be correct. In those cases where the NRC was the author of the terminology used (in the referenced Safety Evaluation (SE)), Global Nuclear Fuel (GNF) infers the same meaning inferred by the NRC staff. In particular, GNF agrees that the NRC staff's use of the symbol σ_{Ppeak} (in the SE of NEDC-33173P-A Revision 1) agrees with GNF's use of the symbol σ_{peak} (in NEDC-32601P-A Revision 0). The most precise terminology with respect to power uncertainty components can be found in Table 2-14 of NEDC-33173P-A Revision 1, or the most recent revision NEDC-33173P-A Revision 4, while the meaning of less precise terminology, when used, must be inferred based on full context.

GNF response to request for clarification (3):

The correct value of the [[ ]], as reported in Revision 0 of NEDC-33173P, and in the most recent revision, NEDC-33173P-A Revision 4. The value of [[ ]] is the correct original value reported in NEDC-32601P-A and is associated with the original [[ ]] overall peak pin uncertainty value. The value of [[ ]] for this uncertainty component was incorrect and appears to have been originally reported in NEDC-32694P-A Revision 0 RAI II.5 (Reference 2-1). Subsequent references to this [[ ]] value and the [[ ]] were incorrect. The correct value for the overall peak pin power uncertainty, σ_{peak}, for current plant-specific Safety Limit Minimum Critical Power Ratio (SLMCPR) calculations is the value of [[ ]].

GNF response to request for clarification (4):

The application of the postulated increased uncertainty in NEDC-33173P-A Revision 1, from [[ ]] was the subject of a former SE which approved the application and is not the subject of the current submittal. The increase to the component uncertainty was removed with the addition of data in the subsequently approved Supplement 2 of NEDC-33173P-A (See Table 3-14 of NEDC-33173P-A Revision 4), and the

discussion of the referenced interim approach was therefore removed from the most recently approved NEDC-33173P-A Revision 4.

The following discussion is provided to assist the NRC in consolidating historical context. The NRC's SE for NEDC-33173P Revision 0 (February 10, 2006) identifies the interim measure used by General Electric (GE), in the approved NEDC-33173P-A Revision 1 of that document, to account for a possible increase in pin power uncertainty. The reason for this interim approach was to account for potential additional uncertainties in pin power uncertainty as modern fuel types were not represented in the original gamma scan data. This approach led to additional safety limit margin by means of treating the existing data with a more conservative statistical treatment than approved in the SLMCPR methodology.

Table 2-14 of NEDC-33173P-A Revision 4 shows that the [[ ]] value was decreased to its original value of [[ ]] in what is referred to as NEDC-33173P Revision 2, which is described in the text as reflecting changes motivated by additional confirmatory data of Supplement 2 of the IMLTR. Supplement 2 provided the basis for removing the artificially introduced increased pin power uncertainty [[ ]], which is captured in the referenced table.

The following is a discussion of [[

]]

The above information was provided for clarification of historical context, by reference to historical documents.

GNF response to request for clarification (5):

The [[ ]] uncertainty that is discussed in Section 3 of NEDC-32601P-A is solely dependent upon the uncertainty [[ ]].

References

2-1 GE Nuclear Energy, "Power Distribution Uncertainties for Safety Limit MCPR Evaluations," NEDC-32694P-A, August 1999.

2-2 Letter, J. S. Charnley (GE Nuclear Energy) to NRC Document Control Desk, "Fuel Channel Bow Assessment," MFN086-89, November 15, 1989.

2-3 Letter, Ashok C. Thadani (NRC) to J. S. Charnley (GE Nuclear Energy), "Acceptance for Referencing of Topical Report Titled "GE-Nuclear Energy Report MFN086-89"," MFN 014-91, January 11, 1991.

2-4 Letter, J. S. Charnley (GE Nuclear Energy) to NRC Document Control Desk, "Responses to Channel Bow Questions," MFN-041-90, May 3, 1990.

2-5 Letter, Robert J. Wanczyk (Entergy) to NRC Document Control Desk, "Vermont Yankee Nuclear Power Station Technical Specification Proposed Change No. 263 - Supplement No. 30 Extended Power Uprate - Response to Request for Additional Information," BVY 05-072, August 1, 2005.

RAI-3

(Moderate) Section 2.0 of Supplement 6 of the IMLTR states, [[ ]] with respect to exposure is expected”. However, no explanation is provided to qualify this statement. The [[ ]] with respect to exposure is also exhibited in [[ ]]. An [[ ]] with respect to exposure could be indicative of difficulty in accurately predicting plutonium accrual and removal. This 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 higher power-to-flow ratios exhibit increasingly harder neutron spectrums, a possible [[ ]] with power-to-flow ratio could manifest. This would be in opposition to the approach presented in Supplement 6 for justifying removal of the SLMCPR penalty: [[ ]]. Provide an explanation for [[ ]] with exposure, and provide justification that the phenomena underlying [[ ]] will not ultimately manifest as [[ ]] with increasing power-to-flow ratio.

GNF Response

NEDC-32694P-A RAI II.3 (Reference 3-1) provides historical context for this expectation of [[ ]] with respect to exposure. The focus on [[ ]] with respect to the Safety Limit Minimum Critical Power Ratio (SLMCPR) calculation is justified in Section 2 of the Supplement 6 submittal. Namely, thermal margins to limits, including the Minimum Critical Power Ratio (MCPR), are computed using the [[ ]]. Thus, the [[ ]] is the sole component of the [[ ]] that affects the SLMCPR calculation.

[[ ]] are shown on the following pages. With respect to exposure, no discernible exacerbation of the [[ ]] in the MELLLA+ domain (RMS_MP) compared to the non-MELLLA+ domain (RMS_nMP) is observed.

This consistent behavior with respect to exposure, in combination with TIP measurements in the Supplement 6 submittal showing [[ ]] with respect to the Power-to-Flow (P/F) ratio, justifies that the phenomena underlying the [[ ]] will not ultimately manifest as a [[ ]] with increasing P/F ratio.

Reference

3-1 GE Nuclear Energy, “Power Distribution Uncertainties for Safety Limit MCPR Evaluations,” NEDC-32694P-A, August 1999.

[[

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RAI-4

(Moderate) Of the data plotted in each of Figures 2-1 through Figure 2-12 in Supplement 6 of the IMLTR, approximately [[ ]] are associated with operation in the MELLLA+ domain. Of these data points, [[ ]] are associated with power-to-flow ratios greater than 42 MWt/(Mlbm/hr). The approach presented in Supplement 6 to justify removal of the SLMCPR penalty is [[ ]]. Provide justification that [[ ]] are statistically sufficient for demonstrating no adverse trends exist at power-to-flow ratios greater than 42 MWt/(Mlbm/hr).

GNF Response

As discussed in the pre-submittal meeting, the [[ ]] above the 42 MWt/(Mlbm/hr) were all collected as part of Maximum Extended Load Line Limit Analysis Plus (MELLLA+) startup testing. It is not typical for currently operating MELLLA+ plants to operate significantly above this Power-to-Flow (P/F) ratio, and therefore, the ability to collect additional data in this area of the P/F map is limited.

The [[ ]] above 42 MWt-hr/Mlbm are a subset of the overall population of Traversing In-Core Probe (TIP) Root Mean Square (RMS) data used to assess trends. The cutoff of 42 MWt-hr/Mlbm was identified as an upper bound of the previously submitted TIP RMS measurement data, not reflecting or implying any expected discontinuity in trending of physical data. Truncating the data population by removing points below 42 MWt-hr/Mlbm artificially neglects the majority of the basis for assessing trending; therefore, the entire data population is used to assess trends.

However, it is important to emphasize that [[ ]] can therefore be considered statistically reliable for the corresponding core state and time of measurement. As discussed in Supplement 6 and as shown in Figure 2-13 through 2-15 in Supplement 6, these implementation tests provide outstanding data to look for trending as a function of P/F ratio in the MELLLA+ domain because they represent TIP comparisons where little is changing except for this ratio.

RAI-5

(Low) The plots of data in each of Figure 2-1 through Figure 2-12 in Supplement 6 of the IMLTR are too condensed for the NRC staff to thoroughly assess applicability of the data to MELLLA+ operating conditions and potential trends with power-to-flow ratio and void fraction. For the data points labeled as MELLLA+ in these figures, tabulate the RMS data with power, flow, exposure, core average void fraction, exit void fraction, and the average RMS used for normalization.

GNF Response

The requested data table is provided in the Excel file in Enclosure 4.

RAI-6

(High) The response to RAI SRXB-A-27 of letter BVY 05-072 for the review of the Vermont Yankee extended power uprate (Reference 1) discusses power distribution acceptance criteria. These acceptance criteria are listed as [[ ]] for radial TIP RMS%, [[ ]] for axial TIP RMS%, and [[ ]] for nodal TIP RMS%. Analysis of the tabulated data supplied in the response to RAI-5 of the initial round of RAIs indicates the average weighted axial and nodal TIP RMS% for all these data are [[ ]], respectively. If the data are broken down by thermal TIP and gamma TIP, then weighted axial and nodal TIP RMS% are respectively [[ ]] for the gamma TIP and [[ ]] for the thermal TIP. In each of these cases, the average weighted axial and nodal TIP RMS% exceed the referenced acceptance criteria. Additionally, when comparing the tabulated data to the historical database as presented in the interim methods topical report (IMLTR, Reference 2) and Supplement 2 of the IMLTR (Reference 3), the historical data meet the acceptance criteria. The NRC staff acknowledges that, as discussed in the response to RAI SRXB-A-27, the nodal TIP RMS% are not reflected in any licensing analysis. Nevertheless, the response also indicates any nodal RMS values greater than the [[ ]] "criterion" observed consistently require further explanation and review of the nuclear methods accuracy, and the NRC staff has observed that approximately [[ ]] supplied in the tabulated data for Supplement 6 exceed the criterion. This suggests the data provided in Supplement 6 do not fully support the continued adequacy of the nuclear methods, and the data are therefore inappropriate to justify the complete removal of the remaining SLMCPR penalty. Provide justification that the average weighted axial and nodal TIP RMS% of the Supplement 6 data demonstrate continued adequacy of the nuclear methods (and are acceptable for justifying the complete removal of the remaining SLMCPR penalty) despite exceeding the referenced acceptance criteria and their inconsistency with the performance of the historical database.

References

1. Entergy Letter (BVY 05-072) to NRC dated August 1, 2005, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263, Supplement No. 30, Extended Power Uprate – Response to Request for Additional Information," (ADAMS Accession No. ML052170310 (Non-Publically Available))

2. NEDC-33173P-A, Revision 4, "Applicability of GE Methods to Expanded Operating Domains," November 2012, (Agency-wide Documents Access and Management System (ADAMS) Accession No. ML12313A107 / ML12313A106 (Publically Available / Non-Publically Available)).

3. NEDC-33173P-A, Supplement 2, Parts 1-3P-A, "Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Confrentes," April 2012, (ADAMS Package Accession No. ML121150469 (Publically Available)).

GNF Response

GNF's response is broken into three main components:

(1) Clarification on Threshold Value Used to Define "High" Axial and Nodal TIP RMS

(2) Justification for Acceptability of High Average Weighted Nodal TIPs in Supplement 6

(3) Demonstration of Continued Adequacy of Nuclear Methods

Clarification on Threshold Value Used to Define "High" Axial and Nodal TIP RMS

The values cited by the Nuclear Regulatory Commission (NRC) staff of [[ ]] for axial Traversing In-Core Probe (TIP) Root Mean Square (RMS) %, and [[ ]] for nodal TIP RMS% were not intended to be applied as acceptance criteria on a plant specific basis, and exceeding these values consistently in a subset of nuclear plants does not signify inadequacy of the nuclear methods for the purpose of Safety Limit Minimum Critical Power Ratio (SLMCPR) evaluations.

To support this statement, it is first important to note that the value of [[ ]] is cited incorrectly as a criteria related to axial TIP RMS in RAI-6; instead, it was originally observed in the response to Request for Additional Information (RAI) SRXB-A-27 of BVY 05-072 (Reference 6-1) that the average RMS difference (nodal implied) of all predicted to measured TIP responses is less than [[ ]] for the reference Boiling Water Reactors (BWRs). Thus, the [[ ]] value was never meant to be compared against either axial or nodal TIP RMS, but was merely a statement of observation.

Secondly, it is noted that the response to SRXB-A-25 of BVY 05-072 (Reference 6-1) provides a discussion on the topic of how methods uncertainty quantification has historically been developed and approved for use. In this response, it is emphasized that the use of an average RMS over a number of plants is the appropriate approach for quantifying overall methods performance and associated uncertainty. This is the case because of plant-to-plant variability that is observed in TIP comparisons, the causes of which are discussed in detail in Section 1.1 of Supplement 6. This point is reemphasized here because it is important to consider when trying to draw conclusions about overall methods adequacy over a subset of plants. These subsets are useful to help understand if trends exist in methods performance as a function of independent variables (e.g., power/flow as is done in Section 2, and particularly in Figure 2-13 through Figure 2-15, of Supplement 6); however, 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.

Finally, and as noted in the RAI itself, [[

]].

As stated in the General Electric (GE) response to SRXB-28 of BVY 05-072 (Reference 6-1), [[

]]. The discussion of [[

]] is therefore not relevant to the current analysis supporting removal of the entire SLMCPR penalty.

<u>Justification for Acceptability of High Average Weighted Nodal TIPs in Supplement 6</u>

It is clear from RAI-6 that the additional data provided in RAI-5 has been processed by the NRC and has led to a desire for additional quantitative evidence for the appropriateness of the removal of the remaining SLMCPR penalties in the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain. This section provides an expanded quantitative basis in the form of a relative comparison of TIP RMS values for non-MELLLA+ data points to MELLLA+ points to identify any deviation that might characterize the extended domain.

Table 6-1 provides a comparison of the total TIP RMS in non-MELLLA+ operational domain versus TIP RMS for the MELLLA+ operational domain. It includes up-to-date exposure accounting information beyond that which was included in Supplement 6, with a total of [[ ]] MELLLA+ TIP points presented at the most recent NRC Technology Update (August 2018) out of a total of [[ ]] data points.

Table 6-1. Quantification of Methods Performance – MELLLA+ vs. Non-MELLLA+

	Include	TIP Type	TIP RMS	Non-MELLLA+	# Non-MELLLA+	MELLLA+	# MELLLA+	MELLLA+ - Non-MELLLA+ (%)
Radial	[[	n	[[					
		n						
		g						
	]]	g						
	All							
	Gamma							
	Thermal							
Axial	[[	n						
		n						
		g						
	]]	g						
	All							
	Gamma							
	Thermal							
Nodal	[[	n						
		n						
		g						
	]]	g						
	All							
	Gamma							

	Include	TIP Type	TIP RMS	Non-MELLLA+	# Non-MELLLA+	MELLLA+	# MELLLA+	MELLLA+ - Non-MELLLA+ (%)
	Thermal							]]

The following SLMCPR-related points are noted from a review of this table:

1) Radial RMS values are generally consistent with the small population of historically reported values for thermal TIPs in MFN 05-029 (Reference 6-2) RAI-25 in both the MELLLA+ and non-MELLLA+ domain.
2) Radial RMS values for gamma TIPs are always within the expected [[ ]] value, and are generally consistent ([[ ]]) in the MELLLA+ domain compared to the non-MELLLA+ domain.

The consistent behavior of radial RMS comparisons in the MELLLA+ domain, and no evidence to suggest any adverse trending of radial RMS as a function of power/flow, justifies the complete removal of the remaining SLMCPR penalty for MELLLA+ operation.

In addition, the following non-SLMCPR-related points are noted:

3) Axial and nodal RMS values are generally consistent with the small population of historically reported values for thermal TIPs in MFN 05-029 (Reference 6-2) RAI-25 in both the MELLLA+ and non-MELLLA+ domain.
4) Axial and nodal RMS values are larger than historically reported values for gamma TIP reactors. The axial RMS in the MELLLA+ domain is slightly higher than the nominal RMS for Peach Bottom Unit 2 and significantly lower for Peach Bottom Unit 3 data. On average, the axial RMS is [[ ]] lower in the MELLLA+ domain.

It is important to emphasize that the [[ ]] gamma TIP plants from which the Supplement 6 TIP RMS data originated are unique in that their nodal TIP RMS statistics are consistently higher than the fleet average both before and after implementation of extended operating domains. In fact, no other plants in the fleet with gamma TIP instrumentation have exceeded the [[ ]] cycle average nodal TIP RMS level of concern in the last five available cycles. If a degradation of nuclear methods accuracy had occurred at any point, whether within extended operating domains or not, high TIP RMS statistics would be observed more generally across the nuclear fleet, especially in reactors with similar characteristics and similar fuel design loadings. This is further investigated in the final portion of this response.

Demonstration of Continued Adequacy of Nuclear Methods

The expanded comparisons suggested above are provided in the following evaluations.

First, TIP RMS statistics for Plants A, B, and C described in MFN 05-029 (Reference 6-2) RAI-25 were updated as provided in Table 6-2. These values provide an updated look at methods performance on a basis consistent with the historical database. No consistent degradation in TIP RMS statistics of these gamma TIP instrumented plants is observed in the time since those submittals, demonstrating consistency with the performance of the historical database.

Table 6-2. Nodal TIP RMS Statistics Update for Select Gamma TIP Plants

Plant	BWR Type	# of Bundles	Power Density	Legacy Nodal Average % RMS	Cycle Range	N	New Nodal Average % RMS	Cycle Range	N
A	BWR/4	368	58.7	[[	18-19	15	[[	19-24	86
B	BWR/6	748	56.8		9-10	44		13-17	90
C	BWR/4	240	51.7	]]	30	24	]]	41-45	70

Second, a similar plant to the [[ ]] has also been evaluated to understand if there is some plant-type specific behavior that [[ ]] data is demonstrating. This similar plant is hereafter named Plant G. Plant G is considered extremely similar to the [[ ]] because, like the [[ ]], it is a [[ ]] bundle core and has [[ ]] TIP instrumentation.

The rated power density of the Plant G cycles evaluated is 56.8 kW/L, which is higher than the pre-Extended Power Uprate (EPU) and pre-MELLLA+ power density of [[ ]] (pre-EPU and pre-MELLLA+ TIP statistics comprise 7 of 10 cycles evaluated below for the [[ ]]).

TIP RMS statistics are generated for Plant G for the last four completed cycles and are shown in Figure 6-1 as compared to the [[ ]] last five completed cycles. [[ ]] are the first cycles in which both EPU and MELLLA+ were implemented.

Visual examination of Figures 6-2 and 6-3 shows that no trending over cycles in TIP statistics is observed for Plant G or for the [[ ]]. This further illustrates that the high TIP RMS statistics seen in the [[ ]] are unique to [[ ]], does not reflect degraded nuclear methods accuracy, and demonstrates consistent performance with the historical database.

References

6-1 Letter, Robert J. Wanczyk (Entergy) to NRC Document Control Desk, "Vermont Yankee Nuclear Power Station Technical Specification Proposed Change No. 263 - Supplement No. 30 Extended Power Uprate - Response to Request for Additional Information," BVY 05-072, August 1, 2005.

6-2 Letter, Louis M. Quintana (GE Energy) to NRC Document Control Desk, "Responses to RAIs – Methods Interim Process (TAC No. MC5780)," MFN 05-029, April 8, 2005.

[[

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Figure 6-1. Nodal TIP RMS Comparison of Similar Plants

[[

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Figure 6-2. Nodal TIP RMS for Plant G

[[

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Figure 6-3. Nodal TIP RMS for Peach Bottom Units 2 and 3

RAI-7

(Moderate) Analysis of variance tests performed on the tabulated data supplied in the response to RAI-5 of the initial round of RAIs indicates the subsets of data belonging to thermal TIP plants constitute significantly different uncertainty distributions compared to that of the gamma TIP data subsets. The thermal radial TIP RMS% data subsets exhibit [[ ]] than that of the gamma radial TIP RMS% data subsets, [[ ]], suggesting thermal TIP plants may possess [[ ]] in comparison to gamma TIP plants. However, an assessment of the bundle power uncertainty evaluation described in NEDC-32694P-A (Reference 4) indicates the [[ ]] is a calculational uncertainty. That is, 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 would not contain a measurement uncertainty component, and after examining the NEDC-32694P-A evaluation, it is the NRC staff's understanding that [[ ]]. Therefore, the disparity between the thermal and gamma radial Tip RMS% weighted means in the Supplement 6 data is due in part to the increased instrumentation (measurement) uncertainty that thermal TIP detectors have compared to gamma TIP detectors. This increased instrumentation uncertainty must be properly accounted for in GE's methods to accurately determine the margin to thermal limits.

NRC staff examined the SLMCPR method presented in NEDC-32601P-A (Reference 5) and identified TIP integral instrument uncertainty is [[ ]] and TIP random reading uncertainty is [[ ]]. These values are tabulated in Table 2.1 of NEDC-32601P-A. Figure 4.1 of NEDC-32601P-A indicates [[ ]]. However, to the best of the NRC staff's knowledge, the TIP values tabulated in Table 2.1 and [[ ]] have been determined for gamma TIP detectors. For plants operating in the MELLLA+ domain, it is necessary the correct TIP instrumentation uncertainties be applied. Quantify the instrumentation uncertainties associated with thermal TIP detectors. Conversely, provide justification that the existing TIP instrumentation uncertainties are applicable to thermal TIP detectors and justify that the disparity observed between thermal and gamma radial TIP RMS% does not constitute increased uncertainty in the determination of margin to thermal limits for thermal TIP plants.

References

4. NEDC-32694P-A, Revision 0, "Power Distribution Uncertainties for Safety Limit MCPR Evaluation," August 1999 (ADAMS Accession No. ML003740151 (Non-Publically Available)).

5. NEDC-32601P-A, "Methodology and Uncertainties for Safety Limit MCPR Evaluations," August 1999 (ADAMS Accession No. ML003740145 (Non-Publically Available)).

GNF Response

NEDO-20340 (Reference 7-1) discusses the relevant Traversing In-Core Probe (TIP) signal uncertainty (Section 3.1.2.1) instrument measurement uncertainty of 2.6%, which is a statistical superposition of the TIP geometrical (2.3%) and random noise uncertainties (1.2%). In the General Electric (GE) response to Request No. 7 of NEDO-20340 Amendment 1 (Reference 7-2), Oyster Creek is identified as the source of both the random and geometrical TIP signal uncertainties. The Oyster Creek reactor has a thermal TIP system. Therefore, the random noise and geometric mislocation TIP uncertainties of concern are conservative when applied to gamma detectors and representative of thermal TIP detectors.

References

7-1 General Electric Company, "Process Computer Performance Evaluation Accuracy," NEDO-20340, June 1974.

7-2 General Electric Company, "Process Computer Performance Evaluation Accuracy Amendment 1," NEDO-20340-1, December 1974.