ENCLOSURE 2

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NEDC-33173P Supplement 6 –SLMCPR Penalty Removal

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NEDO-33173 Supplement 6
Revision 0
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Non-Proprietary Information – Class I (Public)

Licensing Topical Report

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

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TABLE OF CONTENTS

LIST OF FIGURES

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 3D-Monicore 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 [[ ]]

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 [[ ]]

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.
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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.
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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.