APPENDIX I – SAFETY EVALUATION OF SUPPLEMENT 2 TO NEDC-33173P

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NEDC-33173P, REVISION 2 AND SUPPLEMENT 2, PARTS 1-3

"ANALYSIS OF GAMMA SCAN DATA AND REMOVAL OF SAFETY LIMIT MINIMUM CRITICAL POWER RATIO (SLMCPR) MARGIN"

GE-HITACHI NUCLEAR ENERGY AMERICAS, LLC

PROJECT NO. 710

1.0 INTRODUCTION AND BACKGROUND

The interim methods licensing topical report (NEDC-33173P-A, "Applicability of GE [General Electric] Methods to Expanded Operating Domains," hereafter "IMLTR") provides the basis for the application of the suite of GE-Hitachi (GEH) and Global Nuclear Fuel (GNF) computational methods to perform safety analyses relevant to extended power uprate (EPU) and maximum extended load line limit analysis plus (MELLLA+) licensing (Reference 1). During its review of the IMLTR, the NRC staff identified concerns regarding the power distribution uncertainties applied in the calculation of the safety and operating limits. These power distribution uncertainties include the [ ] and the pin power peaking uncertainty (σ_{peak})[1]. In its safety evaluation (SE) of the IMLTR, the NRC staff imposed penalties on the safety limit minimum critical power ratio (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+) (Reference 2).

By letter dated November 22, 2006, GE committed to provide an updated qualification of the nuclear design methods to expanded operating domains in the form of gamma scans (Reference 3). Gamma scanning is a method for characterizing the core power distribution near the end of cycle and provides a means for determining the local bundle and local pin power distribution.

Gamma scanning, in principle, works by detecting the 1.6 MeV gamma ray emission from lanthanum-140 (^{140}La) decay. The fuel inventory of ^{140}La is predominantly a function of barium-140 (^{140}Ba) beta decay. The ^{140}Ba distribution is characteristic of the recent fission density distribution. Therefore, end-of-cycle (EOC) measurements using gamma scan techniques characterize the core power distribution near the EOC (Reference 4).

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[1] Nomenclature for these uncertainty parameters is specific to the GE-Hitachi and Global Nuclear Fuel analysis methods.

Gamma scanning has been a standard means for quantifying power distribution uncertainties and has formed the basis for power distribution uncertainties in GEH methods (References 5 and 6). Gamma scanning has been utilized throughout the nuclear industry to establish power distribution uncertainties for boiling water reactors (BWRs) (Reference 4).

By letter dated August 14, 2009 (Reference 7), GEH submitted a revision to the IMLTR (Reference 8, hereafter "IMLTR Revision 2") and Supplement 2 to the IMLTR (hereafter "Supplement 2") in three parts (Parts 1 through 3 are References 9, 10, and 11, respectively). Supplement 2 is intended to fulfill the commitment made by GEH in its letter dated November 22, 2006 (Reference 3). IMLTR Revision 2 references the expanded gamma scan database and provides changes to the IMLTR that remove references to the SLMCPR penalties imposed by the NRC staff in its SE for the IMLTR. Specifically, the condition specified in Section 9.4, "SLMCPR 1," of the NRC staff's SE for the IMLTR (hereafter "Limitation 4") imposes an additive penalty of 0.02 to the SLMCPR for EPU operation. The condition specified in Section 9.5, "SLMCPR 2" (hereafter "Limitation 5") imposes an adder of 0.03 to the SLMCPR for MELLLA+ operation.

Supplement 2 provides the details of gamma scan campaigns performed at Cofrentes Nuclear Power Plant (CNC) and James A. FitzPatrick Nuclear Power Plant (JAF). These scans are consistent with the gamma scan campaigns described in the November 22, 2006, letter. The NRC has acknowledged that the proposed gamma scan campaigns formed a reasonable basis to qualify the neutronic methods uncertainties.

By its letter dated August 14, 2009, GEH requested that the NRC staff review and approve IMLTR Revision 2 and Supplement 2, and revise the SE for the original IMLTR to remove Limitations 4 and 5.

2.0 REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations* Section 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 license change request 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 4 of the IMLTR SE imposes an additive penalty of 0.02 to the cycle-specific SLMCPR for EPU operation, and Limitation 5 imposes an additive penalty of 0.03 to the cycle-specific

SLMCPR for MELLLA+ operation. Removal of these limitations requires NRC review and approval.

3.0 TECHNICAL EVALUATION

Limitations 4 and 5 were imposed to address specific uncertainties in the GEH neutronic analysis methods, particularly the assembly and pin power uncertainties. GEH has submitted Supplement 2, which provides the results of bundle gamma scan campaigns to address the bundle power uncertainty and pin-wise gamma scan campaigns to address the pin power uncertainty. The NRC staff has separately reviewed these campaigns and the qualification of the uncertainties in these parameters and documents its findings in this SE.

3.1 Bundle Gamma Scan Campaigns at CNC

3.1.1 Description of CNC

CNC is a large (624 bundle), high power density BWR/6 in Spain. Core designs for CNC are typically highly heterogeneous since it has been the practice at CNC to use different fuel vendors in its fuel reloads. The gamma scan campaign results provided by Supplement 2 were performed at the EOC for Cycles 13 and 15. The Cycle 13 (c13) CNC core was comprised of GE11, GE12, and SVEA-96 fuel, while the Cycle 15 (c15) CNC core was comprised of GE12, SVEA-96, SVEA Optima 2, and GE14 (owing in part to the reload of partial batches of GE14 and SVEA Optima 2 at the beginning of cycle (BOC) 15) (References 9 and 11).

The highly heterogeneous CNC core designs between c13 and c15 make qualification against these data particularly challenging for any vendor's nuclear design methods. Of particular interest in the current review is the prevalence of modern fuel bundle designs in the c13 and c15 core designs. The GE12, SVEA-96, SVEA Optima 2, and GE14 fuel designs include 10X10 lattice geometries with part-length fuel rods.

During c13, CNC was operating at approximately 104 percent of originally licensed thermal power (%OLTP). In the intervening period between c13 and c15, CNC was uprated to 112 %OLTP. The core power density was increased from 52 kilowatts/liter (kW/l) to 58.6 kW/l between its original commissioning and c15, (References 9 and 11). While operating only at 112 %OLTP, the CNC power density is near the very highest of the expanded GEH cycle-tracking database. Power densities for the expanded cycle-tracking database are presented in Table 25-1 in GEH's response to MELLLA+ Methods RAI 25 (Reference 12, hereafter MFN 05-029). This high power density makes the CNC c15 operation characteristic of EPU operation at 120 %OLTP for the domestic fleet of BWRs.

CNC is operated with a flow control window (FCW) at the highest licensed thermal power level. At 112 %OLTP, the FCW extends between approximately 88 percent rated core flow (%RCF) and 105 %RCF. At 104 %OLTP this FCW extends between 80 %RCF and 105 %RCF. Operation during c13 and c15 are therefore characteristic of operation using spectral control at high power density conditions through the FCW (References 9 and 11). The NRC staff finds that these data are, to a certain extent, representative of the spectral control strategies expected for operation with a MELLLA+ FCW. However, the NRC staff notes that the flow ranges do not extend as low as those proposed for domestic BWRs at MELLLA+ conditions (Reference 13). Supplement 2 Part 3 provides the power-to-flow map for CNC during c13 and c15, as well as the operating points where traversing in-core probe (TIP) measurements were performed. These operating maps demonstrate that the operating cycles have utilized the full extent of the FCW (Reference 11).

Therefore, the NRC staff finds that qualification against the c13 and c15 CNC data provides a robust means of qualifying the neutronic methods uncertainties. The NRC staff further notes that these data are representative of: (1) modern fuel designs, (2) operation under high power density conditions typical of domestic EPU cores, and (3) operation with expanded FCWs.

3.1.2 [ ]

The uncertainty in the bundle power is factored into the calculation of the cycle-specific SLMCPR. When determining the bundle power uncertainty, [

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As the individual bundle powers are not measured during normal operation, the [ ] can be determined by using techniques such as gamma scanning. The [ ] was initially determined based on a battery of gamma scan campaigns performed at Quad Cities Nuclear Power Station, Edwin I. Hatch Nuclear Plant (Hatch), and Millstone Power Station (Reference 5). More recently, the [ ] for the improved steady state methods was quantified in Reference 6 based on the Hatch gamma scan data. This uncertainty is determined by [

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3.1.3 <u>Gamma Scan Data Collection and Processing</u>

The gamma scan data are collected for each scanned bundle by averaging the measured gamma source using a collimated detector for each of the four bundle corners. This radial averaging is performed for 25 axial locations along the bundle. The averaged axial data are proportional to the bundle power.

The data must be adjusted to account for measurement corrections such as dead-time and extent of measurement. Supplement 2 states that the appropriate measurement corrections have been considered in the gamma scan data.

In addition to the measurement corrections, Supplement 2 describes the process used to account for axially varying geometry. With the advent of part-length fuel rods, the bundle gamma transport characteristics vary axially along the bundle height. This is due to variations in the geometric view factors for gamma transport from the rod gamma sources to the collimated detector. To adjust the measurement data, GEH calculated corrections to account for the geometric view factors using the Monte Carlo N-Particle transport code (MCNP). This analysis is similar to the calculational approach used to calculate gamma instrument response. The NRC staff agrees with the assessment in Supplement 2 that this approach should not be considered experimental, but rather a component of the nuclear calculational methodology, and that the corrections for geometric effects were appropriately determined and utilized.

Of the bundles that were scanned, only those bundles that were part of a full four-bundle set were considered in the qualification of the [ ]. This makes the calculation and measurement of the [ ] consistent in terms of the measurement data. This amounts to eight four-bundle sets per campaign. The NRC staff finds this approach reasonable. In its request for additional information (RAI) 1, the NRC staff requested that GEH specify the location of the TIP strings relative to the four-bundle sets. GEH responded to this RAI by providing Figure 1-1 and Figure 1-2. These figures provide the locations of the TIP strings, with each TIP instrument tube identified by the TIP string number (Reference 14).

In RAI 2 the NRC staff asked whether it was possible to evaluate the scanned bundles that were not in a four-bundle set. Per GEH's response to RAI 2, calculating [ ] for TIP string locations where not all four of the adjacent fuel assemblies have gamma scan measurements, would require substituting analytical calculated values for the missing data. This process would taint the resulting statistics and make them misleading. [ ]. However, [ ] such as the one cited in the NRC staff's RAI (bundle AA0104) is considered in the overall bundle root mean square (RMS) statistics provided in Table 4-1 of Supplement 2 Part 1 (Reference 8).

The NRC staff finds that the data collected and the processes used to account for measurement corrections and geometric view factors, are acceptable. The data was collected over the full bundle at various radial and axial locations, giving the NRC staff reasonable assurance that these measurements provide a comprehensive scan of the bundle to determine the total bundle power.

3.1.4 Gamma Scan Results

Two gamma scan campaigns were performed at CNC; the first following c13 and the second following c15. The scanned bundles were distributed throughout the core in sets of neighboring bundles. Figure 2-1 of Reference 9 and Figure 4-7 of Reference 11 provide the core maps that illustrate the relative locations of the scanned bundles for c13 and c15, respectively.

3.1.4.1 Stretch Power Uprate (c13)

The gamma scan data from c13 were used to quantify the [ ] for the bundles that were potentially minimum critical power ratio (MCPR)-limiting. Specifically, [

]. Therefore, the NRC staff finds that [ ] is reasonable for establishing the bundle power uncertainty for the potentially limiting bundles.

Table 5-1 of Supplement 2, Part 1 (Reference 9) provides the [ ] for several analysis cases. The relevant case is Case 3 from the table, which considers the [ ] and incorporates the adaptive core monitoring. This case is consistent with the core monitor accuracy in predicting the power of the potentially limiting bundles in the core. The RMS difference in the [ ]. The Table 5-1 results also consider PANAC10 results; however, PANAC10 methods have not been approved for application to EPU or MELLLA+ applications (see Limitation 1 from the NRC staff's SE for the IMLTR).

The [ ] CNC c13 gamma scan based [ ] is to be compared to the standard production uncertainty assumed in the SLMCPR analysis provided by Reference 5 ([ ]). These values are very comparable. This standard production value is based on the comparison of PANAC10 calculations to historical gamma scan data for 7X7 and 8X8 fuel. When the PANAC11-specific [ ] is calculated using the Hatch gamma scan data, the [ ] (Reference 6). The PANAC11 assessment accounts for improvements in the PANAC11 and TGBLA06 methods relative to their predecessor codes: PANAC10 and TGBLA04. Supplement 2 combines the PANAC11 [ ] assessment based on the Hatch data (50 four-bundle sets) and the assessment based on the more recent CNC c13 data (8 four-bundle sets) The statistical combination of these assessments yields a [ ].

First, the NRC staff notes that the [ ] value determined purely from the 8 four-bundle sets from CNC c13 indicates very close agreement with the value assumed in the SLCMPR analysis [ ]. The NRC staff understands that these CNC c13 gamma scan data are relatively limited compared to the historical gamma scan database that considered many more four-bundle sets. Therefore, while the CNC c13 data indicates a slightly higher uncertainty, these data are too sparse to conclude that the [ ] has increased at stretch power uprate (SPU) conditions. Further, based on the relatively limited quantity of data from the CNC c13 data alone, the NRC staff finds it reasonable to consider a subset of the historical gamma scan data (Hatch c1 and c3 data). When these data are considered as a single set, the data indicate a small decrease in the [ ] that is largely attributed to improvements in the TGBLA06 and PANAC11 physical models. However, these data remain insufficient to fully justify the continued applicability of the historically-determined [ ] on their own.

In addition to the statistical assessment of the [ ] based on the CNC c13 data, the NRC staff reviewed the trending of the gamma scan measurements with power, exposure, and axial location.

Figure 4-10 of Supplement 2 Part 1 (Reference 9) provides a plot of the error in the calculated bundle power as a function of the measured bundle power. The figure does not demonstrate any discernable bias in the calculated power with increasing bundle power levels. This provides the NRC staff with assurance that the neutronic methods are sufficiently robust over a range of bundle powers.

Figure 4-5 of Supplement 2 Part 1 (Reference 9) provides a plot of the error in the calculated bundle power as a function of the bundle exposure. The figure shows that data are scattered above and below the mean value of zero. These data do not indicate any bias. The data are presented for different fuel bundle types. As the scanned fuel types were loaded in different batches, the GE11, SVEA, and GE12 fuel data are clustered. The NRC staff observed that the relative difference in measured and calculated bundle powers for all bundles remained within the one standard deviation uncertainty in bundle power according to Reference 5 [ ] over the full range of exposure. This provides the NRC staff with reasonable assurance that the bundle power uncertainty is applicable over the full range of exposure and is not expected to change as a function of the bundle exposure.

The NRC staff reviewed any trends in the local power distribution calculations with axial elevation. As the void fraction itself is not measured, the NRC staff relied on trends along the axial elevation of the bundle to serve as a surrogate for any trend in the uncertainties or errors that is potentially sensitive to the in-channel void fraction (which increases with axial elevation). Figure 4-12 of Supplement 2 Part 1 (Reference 9) provides a plot of the adapted axial power shape against the data collected for the scanned bundles at each axial location. The comparison of the monitored power shape and the measured power shape does not indicate any bias in terms of increasing biases or uncertainties with increasing axial elevation. Therefore, these data indicate that the computational efficacy does not degrade with increasing nodal void fraction.

3.1.4.2 EPU (c15)

In the CNC c15 database, the gamma scan results for several bundles were excluded due to errors in the measurements. These errors were attributed to a missing absorber component in the gamma scan measurements. Therefore, the NRC staff agrees that these data are erroneous and should be removed from the dataset. Several comparisons between measurements were considered for this database. In particular, results were presented for bundle power calculations and measurements that included low-power, peripheral assemblies. Generally, when deriving the [ ] the non-limiting peripheral bundles are excluded from the dataset.

The NRC staff reviewed the integral performance of PANAC11 to predict the bundle powers. Table 9-2 of Supplement 2 Part 3 (Reference 11) provides the comparison of the adapted and non-adapted PANAC11 bundle power calculations to the gamma scan measurements. Three scenarios are presented where, in certain cases, low-powered bundles are removed from the qualification database. The NRC staff compared the bundle RMS errors to the bundle power uncertainty of [ ] for the TGBLA06/PANAC11 code system as reported in Reference 6.

With just four erroneous measurements removed from the data set, the bundle RMS error for the adapted cases is [ ]. This value is slightly improved when the low-powered assemblies are removed from the database, resulting in a value of [ ] when five low-powered assemblies are removed. In all three scenarios, the bundle power uncertainty compares well with the accuracy reported in Reference 6.

The NRC staff further notes that the experimental uncertainty in the gamma scan measurement itself is [ ]. Therefore, better agreement with the experimental data could not be expected. These comparisons demonstrate excellent agreement between the measurements and calculations of the bundle powers with only a small uncertainty that is associated with the calculational methods. Additionally, the SLMCPR calculational process utilizes a higher bundle power uncertainty as determined for TGBLA04/PANAC10 methods (which have been shown to be less accurate than TGBLA06/PANAC11). The PANAC10-based bundle power uncertainty is [ ][2] (Reference 5).

The [ ]. In total, eight four-bundle sets were considered. This is partially attributed to the removal of a four-bundle set due to elimination of one of the bundles within the set that was at the core periphery (see Figures 9-21 and 10-2 of Supplement 2 Part 3). Table 10-1 of Supplement 2 Part 3 provides a summary of the statistical results. The NRC staff notes that removing additional bundles from consideration does not impact the [ ] since these bundles were not part of a four-bundle set. The results show a [ ] for the eight four-bundle sets. Including the removed peripheral fuel bundle in the dataset [ ] (adapted case) (Reference 11). The NRC staff notes that the [ ] utilized in the SLMCPR determination is [ ].

The NRC staff agrees that removing the peripheral bundles from consideration is acceptable since large gradient errors in these bundles affect the accurate prediction of the bundle powers. These bundles are low in power and are not potentially limiting in terms of thermal margin. However, the NRC staff compared [ ] for both cases to the PANAC11 [ ] as reported in Reference 6. The NRC staff finds that the CNC c15 gamma scan data comparison with PANAC11 is consistent with the performance of PANAC11 when compared with the Hatch c1 and c3 gamma scan data.

When the EPU and SPU (c15 and c13, respectively) data are considered together, the average [ ] determined from these data is [ ]. This average value based on both CNC gamma scan campaigns agrees well with the PANAC11-specific [ ]. This indicates essentially no degradation in the [ ] calculations with the introduction of 10X10 fuel and higher core power-to-flow ratios relative to the original Hatch qualification data.

In addition to the statistical assessment of the [ ] based on the CNC c15 data, the NRC staff reviewed the trending of the gamma scan measurements with bundle type, power, exposure, and axial location.

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[2] This value is the [ ]

Figure 9-4 of Supplement 2 Part 3 (Reference 11) provides a plot of the adapted predicted barium concentration versus the measured lanthanum concentration. The measured concentration is a measure of the near EOC power. The data are presented for all of the scanned fuel bundles, including GE12, GE14, SVEA Optima 2 and SVEA-96. These bundles are designed by different vendors and all are based on a 10X10 lattice array. As is evident from the plot, no discernable trends in the uncertainty are apparent as a function of either the bundle power or the specific bundle design for these 10X10 fuel designs.

Figure 9-5 of Supplement 2 Part 3 indicates some [

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Figure 9-6 of Supplement 2 Part 3 provides a figure showing the power error as a function of the bundle exposure for the adapted case. [

]. The larger errors are inconsequential as these bundles are in non-limiting locations and the bundle powers are very low. Generally, the figure indicates a [

]. Overall, no discernable trends are observed as a function of exposure.

Figure 9-8 of Supplement 2 Part 3 provides plots of the measured and calculated axial power shape. The data indicate good agreement. [

]. Figure 9-20 of Supplement 2 Part 3 provides a similar data comparison with the spread in the errors depicted alongside the average.

Figures 9-14 through 9-18 of Supplement 2 Part 3 provide plots of the nodal predicted and measured powers. These plots provide another way to visualize trends with either power or bundle design. The figures indicate good agreement in the nodal power predictions over a large range of powers for all of the bundle types. As these data are nodal powers, they likewise indicate good agreement over the full range of axial location.

3.1.5 <u>Supporting TIP Data and Comparison to the Experience Base</u>

CNC is a gamma TIP plant. GEH provided comparisons of calculated and measured TIP responses. In addition to the gamma scan measurement results, the NRC staff reviewed these supporting data for consistency with the expanded EPU database.

The c15 TIP data are provided in Appendix A of Supplement 2 Part 3. The axial power shape evolves from a bottom-peaked to a top-peaked shape over the cycle. The individual and core average axial measurements are provided. The results indicate consistent agreement and bundle, axial, and nodal TIP RMS differences are within expected ranges. The NRC staff compared the CNC c15 TIP comparisons to those data provided to the NRC staff in response to MELLLA+ Methods RAI 25 (see MFN 05-029, Reference 12). The NRC staff plotted the c15 TIP differences as a function of power-to-flow ratio for direct comparison to the gamma TIP results provided in Figure 25-19 of MFN 05-029. Figure 3.1.5-1 of this SE provides the c15 TIP comparisons. The power-to-flow ratios encompass those experienced by the plants operating in the expanded database and demonstrate consistent trends in local power distribution RMS differences.

The four-bundle power differences appear to have [

] depicted in Figure 25-19 of MFN 05-029.

In RAI 3, the NRC staff requested that GEH provide a figure similar to Figure 25-19 from MFN 05-029 (Reference 12) based on the c13 TIP data. GEH provided a response to this RAI in the form of Figure 3-1 (Reference 14). GEH pointed out in this response that the CNC c13 and c15 data are quite compatible with the information in Figure 25-19. In each case, [

] as compared to Figure 25-19.

The NRC staff evaluated the applicability of the CNC gamma scan data based on comparisons of key operating parameters for c15 against those identified by the NRC staff in Section 2.1.1 of the SE for the IMLTR. Figures 2-1 through 2-4 of the NRC staff's SE for the IMLTR (Reference 1) summarize the range of key operating parameters for several EPU plants and a high power density SPU plant. The NRC staff compared these figures to those provided in Supplement 2 Part 3, Section 6.

- *Maximum Bundle Power*

Supplement 2 Part 3, Figure 6-1 is analogous to Figure 2-1 from the IMLTR SE. These figures plot the maximum bundle powers as a function of the cycle exposure. The range of maximum bundle powers is consistent between the experience base and CNC c15. The SVEA Optima 2 bundles reach slightly higher bundle powers [ ] compared to the reference experience base, but are largely consistent with the highest bundle powers for the reference plants.

- *Maximum Bundle Power-to-Flow Ratio*

Supplement 2 Part 3 Figure 6-5 is analogous to Figure 2-2 from the IMLTR SE. These figures plot the maximum ratio of bundle power-to-flow as a function of the cycle exposure. The range of power-to-flow ratios is consistent between CNC c15 and the reference plants. Both figures show maximum values of approximately [

]. The CNC c15 power-to-flow ratios decrease along with the core average power-to-flow ratio near the EOC. This is consistent with the overall operation during c15 as shown in Figure 4-8 of Supplement 2 Part 3. The NRC staff finds that the range of maximum bundle power-to-flow ratios is consistent between CNC and the IMLTR reference plants.

- *Exit Void Fraction*

Supplement 2 Part 3 Figure 6-7 is analogous to Figure 2-3 from the IMLTR SE. These figures plot the maximum exit void fraction as a function of the cycle exposure. The figures demonstrate consistent maximum void fractions of approximately [ ].

- *Peak Linear Heat Generation Rate*

Supplement 2 Part 3 Figure 6-8 is analogous to Figure 2-4 from the IMLTR SE. These figures plot the maximum bundle linear heat generation rate (LHGR) as a function of the cycle exposure. Figure 6-8 illustrates the higher peak LHGRs for the fresher fuel assemblies (GE14 and SVEA Optima 2). For these bundles, the peak LHGR reaches approximately [ ]. Figure 2-4 shows somewhat higher peak LHGR near the BOC, in certain cases exceeding [ ]. However, these results are indicative of the peak LHGR for the core while the CNC results are plotted as a function of the bundle type as well. The once-burnt fuel assemblies (GE12 and SVEA-96) illustrate this point as they achieve substantially lower peak LHGR during the cycle. Therefore, some differences between the peak LHGRs are expected. Overall, the NRC staff finds that the peak LHGRs achieved by the higher-powered fresh assemblies considered in Supplement 2 Part 3 are within the range of peak LHGRs shown in Figure 2-4 of the IMLTR SE, and therefore the evaluations for the CNC and the IMLTR reference plants are consistent.

The NRC staff reviewed the TIP data, key operating parameters, and predicted void conditions for CNC c13 and c15. These comparisons demonstrate consistency between the CNC results and the expanded EPU database. On this basis, the NRC staff finds that the overall performance of the nuclear methods is expected to also be consistent for various EPU core designs and CNC. Therefore, the NRC staff is reasonably assured that CNC gamma scan data provides a sufficient basis to justify [ ] for domestic EPU plants.

3.1.6 <u>Bundle Power Uncertainty Conclusions</u>

The NRC staff has reviewed the bundle power gamma scan data provided in Supplement 2. These data support the claim that the TGBLA06/PANAC11 computational methods remain applicable to EPU conditions and retain the capability to calculate the individual bundle powers within those uncertainty values applied in the SLMCPR calculations.

The NRC staff has reviewed gamma scan trends with power, exposure, void fraction, and geometry. In its review, the NRC staff discerned no evidence of degradation in the calculational capability of the code suite to calculate the bundle powers. Further, the NRC staff requested that GEH confirm that the differences between measurements and data were normally distributed. In response to RAI 21 (Reference 15), GEH provided the results of an Anderson-Darling normality test. The response is consistent with a similar RAI (III-3) the NRC staff issued in its review of NEDC-32694P-A (Reference 5) and likewise indicates that the data are normally distributed. The consistency of the calculational accuracy over these varying nodal conditions provides assurance that the methods are sufficiently robust in their treatment of the nuclear phenomena that extrapolation to EPU conditions is adequately treated.

The NRC staff notes that the CNC c13 and c15 core designs present a particular challenge to the nuclear methods on the basis of the highly heterogeneous nature of the core design. The analytical methods demonstrated acceptable performance in their capabilities for this core design, including the accurate prediction of the power in bundles manufactured by a different fuel vendor. The NRC staff reviewed the operational characteristics of CNC and found that the power density was near the highest power density of plants currently operating at EPU conditions. Additionally, operation during c13 and c15 at CNC utilized a limited FCW that extends to relatively low flow rates, making these data particularly relevant to qualification of the nuclear methods for the extension to MELLLA+ applications.

The NRC staff must note that the bundle power uncertainty utilized in the SLMCPR calculation is based on qualification of the TGBLA04/PANAC10 code suite, and therefore, the lower uncertainties demonstrated as part of the subject qualification are expected, given the improvements in the current standard production versions (TGBLA06/PANAC11). The NRC staff, however, based its review on demonstration that the currently approved uncertainties are sufficient to bound operation in expanded operating domains and that no change in the currently approved uncertainty values is proposed in the subject submittal.

The NRC staff's SE for the IMLTR imposed a penalty of 0.01 for the SLMCPR to account for potentially increased uncertainty in the [ ]. On the basis of the expanded qualification for CNC at SPU and EPU conditions, the NRC staff has found that the [ ] remains within the accuracy purported in Reference 5, even considering challenges to the methods including: high power density, operation along a FCW at EPU power levels, modern fuel bundle designs, and mixed core conditions.

On this basis, the NRC staff approves the reduction of the SLMCPR adder imposed by Limitations 4 and 5 by a margin of 0.01.

3.2 Pin-wise Gamma Scan Campaigns at JAF

3.2.1 Description of JAF and Scanned Bundles

JAF is a 560 bundle, D-lattice BWR/4 with a SPU to approximately 104 %OLTP. At SPU conditions, the reactor power density is 51.2 kW/l (Reference 10). This power density is at the lower power density range of the expanded GEH cycle-tracking database from MFN 05-029 (Reference 12).

Pin-wise gamma scan data were collected for GE14 fuel assemblies depleted at JAF during Cycles 16 and 17 (c16 and c17, respectively). The c16 core introduced the first reload batch of GE14 fuel and is comprised predominantly of GE12 fuel. The c17 core is approximately 70 percent GE14 fuel following another reload batch of GE14 fuel (Reference 10).

Gamma scans were performed for one once-burnt GE14 fuel bundle (designated JLM420) and for one twice-burnt GE14 fuel bundle (designated JLD505). The exposures were approximately 20 gigawatt-days per metric ton (GWD/MT) for the once-burnt and 40 GWD/MT for the twice–burnt bundles. The gamma scans were performed on a rod basis to measure the rod power distribution within these bundles. The scanned rods were selected along the symmetry axis (lattice diagonal). Some rods in symmetric lattice locations were also scanned.

3.2.2 Power Peaking Factor Uncertainty

The power peaking factor uncertainty is a [ ]. These uncertainties were generically defined in the GEH SLMCPR process in Reference 16. During its review of the IMLTR, the NRC staff determined that the infinite lattice peaking factor uncertainty was not adequately qualified for modern fuel bundle designs and expanded operating domains (Reference 1). This uncertainty is a [ ]. Overall qualification using pin-wise gamma scan data provides a direct means for qualifying the overall code system against direct measurement of the local pin power distribution. Therefore the Supplement 2 assessment did not individually consider these component uncertainties.

Table 7.1-1 of Supplement 2 Part 2 provides a summary of the component uncertainties comprising the total σ_{peak}. These component uncertainties include [ ]. The general approach outlined in Supplement 2 Part 2 is to demonstrate pin peaking uncertainties that are within the total uncertainty assumed in the safety limit analysis.

For conservatism, the NRC staff compared the gamma scan campaign comparison results to a smaller uncertainty. This smaller uncertainty was determined according to [ ]. This approach conservatively ignores [ ] on the pin power distribution uncertainty. This approach was adopted as it is inherently conservative [ ] and allows the NRC staff to limit its review of the [ ] of the scanned bundles. The NRC staff's review method is a conservative, alternate approach to the one described in Supplement 2 Part 2.

The combination of the uncertainties related to [ ]. Therefore, the NRC staff considered pin power uncertainties less than [ ] to be acceptable evidence that the uncertainties assumed in the safety analysis are conservative.

3.2.3 Gamma Scan Results

Section 5 of Supplement 2 Part 2 provides a description of the traditional basis for the comparison of gamma scan data. The traditional basis refers to the method employed by GEH to characterize the pin power distribution uncertainty using integral gamma scan results from scans performed at Duane Arnold Energy Center and reported in Reference 5. Section 5 describes the process of accounting for measurement reproducibility. In simplistic terms, the measurement uncertainty is determined by performing repeated scans for a reference fuel rod. This establishes the contribution to the total uncertainty attributed to deviations associated with measurement itself. In the traditional basis, this component is referred to as the reproducibility. Consistent with the previously approved traditional basis, reference rod measurements were performed during the JAF gamma scan campaign to quantify the measurement reproducibility. The NRC staff finds that this approach is consistent with the previously approved basis and is therefore acceptable.

Section 5 of Supplement 2 Part 2 also provides the results and statistics for each axial level. The corrected standard deviation reported in this section for each axial level is a measure of the uncertainty in the prediction of the pin power distribution. Specifically, the NRC staff considered the off-line adapted PANAC11 results as these calculations most closely approximate the performance of the 3D MONICORE core monitoring system which is used during normal operation to evaluate thermal margins.

Figure 3.2.3-1 in this SE provides a plot of the pin power corrected standard deviation as a function of the axial height for both of the scanned bundles. These plots are derived from the data presented in Tables 5.2-1 and 5.3-1 of Supplement 2 Part 2 (Reference 10). The NRC staff plotted these data to visualize any trends in the pin power distribution uncertainty as a function of the axial height. Axial height serves as a surrogate to visualize any trend in the calculation of the pin power distribution uncertainty as a function of void fraction. Figure 2.9.3 of Supplement 2 Part 2 (Reference 10) provides a plot of the void distribution in both of the scanned bundles as calculated by PANAC11 and illustrates that the void fraction varies over a wide range for both bundles. Figure 3.2.3-1 shows that there are no trends observed for the data.

In Figure 3.2.3-1, the NRC staff also plotted the linear average of the axial results. The agreement between the two scanned bundles indicates consistency in the performance of the methods. The very close agreement in the accuracy of the methods between the two scanned bundles likewise indicates that there is no strong trending with the bundle or nodal exposure.

The NRC staff compared the corrected standard deviation (which is a measure of the uncertainty associated with the methods) to the pin power distribution uncertainty figure of merit ([ ] established in Section 3.2.2 of this SE). The NRC staff found that the uncertainties in the local pin power distribution are within the uncertainty figure of merit. Therefore, these data indicate that the pin power distribution uncertainty used in the safety limit analysis is conservative.

Supplement 2 Part 2 also provides detailed figures that provide the results of the measurement and calculation comparisons on a rod-by-rod basis. These figures are provided in Section 5.4 of Supplement 2 Part 2. To assist the NRC staff, Section 8 of Supplement 2 Part 2 provides isometric figures that illustrate trends in rod-by-rod uncertainties for bundle JLM420. The NRC staff reviewed these rod-by-rod data to determine if the methods indicate any systematic biases and to examine if any observed biases are expected to be exacerbated at EPU or MELLLA+ operating conditions.

The figures provided in Section 8 appear to indicate a [ ]. This appears to the NRC staff to be a [ ]. The NRC staff requested additional information regarding this corner rod in several RAIs. In reference to Figures 2.3-1 and 2.4-1 of Supplement 2, Part 2, GEH was asked to indicate where the nearest instrument tube is located relative to the scanned bundles. GEH responded by providing Figure 5-1 (Reference 14), showing the locations of the TIP strings in JAF, with each TIP instrument tube identified by the TIP string number. The TIP string is located at the bottom, right-hand corner of the bundle with the TIP string number. GEH pointed out that the four-bundle cells highlighted in Figure 5-1 are the four-bundle cells surrounding the TIP string. However, GEH did not identify the four bundles around a control rod. GEH also pointed out that JLD505 is not adjacent to an instrument tube in either c16 or c17, while JLM420 is adjacent to an instrument tube.

3.2.4 Supporting TIP Data and Comparison to the Experience Base

Appendix A of Supplement 2 Part 2 provides non-adapted TIP comparisons for JAF c17. These data are provided as additional confirmation of the validity of the neutronic methods. The NRC staff reviewed these data for consistency with the expanded EPU database of TIP measurement comparisons. The NRC staff found that the nodal, axial, and radial TIP comparisons were generally very good. With respect to the radial TIP comparisons, the NRC staff requested additional information in RAI 18 regarding an anomalous point near the EOC exposure. GEH responded to this RAI by noting that toward the end of c17, the TIP machine was found to be in-operable. Specifically, the TIPs associated with this machine were not normalized to the same integral values as the TIP data from the other TIP machine. Consequently, the nodal RMS difference between the measured and the calculated TIPs increased significantly. The problem was corrected by the next TIP set.

The cycle average radial TIP RMS is [ ]. This is largely consistent with the four-bundle power uncertainty derived from the database in Reference 6 [ ] and the results from the expanded EPU database detailed in Table 25-14 of MFN 05-029 (Reference 12) [ ].

The NRC staff compared the key operating parameters for the gamma scanned bundles against relevant key operating parameters for high power-density plants considered in the NRC staff review of the IMLTR. These key operating parameters for various plants are plotted in Figures 2-1 through 2-4 in the SE for the IMLTR (Reference 1). These parameters include maximum bundle power, maximum power-to-flow ratio, maximum exit void fraction, and peak LHGR.

- *Maximum Bundle Power*

Figure 2.7-1 of Supplement 2 Part 2 is analogous to Figure 2-1 from the IMLTR SE. Figure 2.7-1 provides the peak bundle power as a function of cycle exposure for JAF c17. The NRC staff notes that the peak bundle power shifts from one bundle to another during normal exposure. However, Figure 2.7-1 also provides the power histories for the scanned bundles (JLM420 and JLM505). The figure shows that throughout cycle exposure, JLM420 is operated at bundle powers very near the maximum for the core. There is a short duration where bundle JLM420 is partially controlled. During c17, JLD505 is also burnt at high bundle power considering that this bundle had already been irradiated during c16. The maximum bundle powers for JAF c17 range between [ ]. This is similar to the average maximum bundle power for the EPU plants plotted in Figure 2-1 of the IMLTR SE; however, peak bundle powers for the EPU reference plants included several at powers as high as 7.5 MW. Therefore, the NRC staff would consider the high-duty bundles to be representative of EPU, but would not consider the operation of these bundles during JAF c17 to be bounding of EPU operation.

It is clear from Figure 2.7-1, however, that the bundles considered in the gamma scan campaign (JLM420 and JLD505) were high-duty bundles. These bundles may not achieve instantaneous peak bundle powers that bound the EPU operating experience, but they were selected based on aggressive power histories, such that the exposure averaged bundle powers appear to significantly exceed average bundle powers for EPU operation. From visual inference, the JLM420 exposure average bundle power appears to be approximately [ ] whereas 5.5 MW is typical for average bundle power at EPU conditions.

Considering that the bundles used in the gamma scan campaign were high-duty bundles, the NRC staff accepts these bundles as being reasonably representative of bundles operated in EPU cores.

- *Maximum Bundle Power-to-Flow Ratio*

Figure 2.7-2 of Supplement 2 Part 2 is analogous to Figure 2-2 from the IMLTR SE. This figure plots the maximum bundle power-to-flow ratio as a function of the cycle exposure. The JAF c17 maximum bundle power-to-flow ratios are consistent with the ratios plotted in Figure 2-2 of the IMLTR SE. At SPU power levels, the radial peaking factors tend to be higher than at EPU conditions. As such, flow tends to favor lower power bundles and the peak powered bundles receive relatively lower apportionments of the total core flow relative to an EPU core. Therefore, the agreement is expected. The NRC staff notes that the EPU reference plants plotted in Figure 2-2 of the IMLTR SE include some bundles operated at maximum bundle power-to-flow ratios [ ] whereas the maximum ratio for JAF c17 is [ ]. The difference is slight, however, and the NRC staff notes that JAF c17 operation is consistent with EPU operation in terms of limiting bundle power-to-flow ratio. As can be seen the JLM420 bundle operating history includes bundle power-to-flow ratios that approach the limiting conditions during c17. Likewise, JLD505 attains aggressive bundle power-to-flow ratios, particularly early and late in the cycle. Other than the period of exposure where JLM420 is controlled, this bundle operates consistently near the highest power-to-flow ratio. As stated previously, the maximum bundle power shifts from bundle to bundle during cycle operation. Therefore, Figure 2.7-1 depicts how aggressively the bundles were depleted. The NRC staff concludes that the bundles selected for the gamma scan campaign were operated at high power and were therefore depleted at power-to-flow ratios consistent with EPU operation.

- *Exit Void Fraction*

Figure 2.7-3 of Supplement 2 Part 2 is analogous to Figure 2-3 from the IMLTR SE. This figure plots the exit void fraction as a function of the cycle exposure. Figure 2.7-3 depicts the exit void fractions for bundles JLM420 and JLD505. The exit void fractions remain consistently large through the entire cycle of exposure, which is consistent with the high power operating histories for these bundles. The void fraction remains [ ] for both bundles, except for the period of control. These conditions are slightly lower than the maximum void fractions expected for EPU operation (85 to 90 percent) and less than the maximum exit void fraction expected for MELLLA+ operation (greater than 90 percent).

While the maximum void fractions are [ ] the NRC staff notes that the void fractions are consistently high for both bundles over the cycle exposure. Therefore, while the instantaneous void fractions may not encompass those for EPU operation, the void histories are relatively high. On this basis, the NRC staff finds that the gamma scans were performed on bundles that can be reasonably expected to be representative of void history conditions for EPU cores. However, at EPU conditions the void fractions, power-to-flow ratios, and the maximum bundle powers are higher. On this basis, the NRC staff does not consider the JAF comparisons to be bounding. Based on the consistency of the high power operation and void fraction, however, the NRC staff considers the exposure histories for these bundles to be aggressive for SPU operation and therefore representative of EPU operation.

- *Peak Linear Heat Generation Rate*

Figure 2.7-4 of Supplement 2 Part 2 is analogous to Figure 2-4 from the IMLTR SE. These figures plot the peak LHGR as a function of the cycle exposure. Figure 2.7-4 plots the maximum LHGR for JAF c17 as well as the individual maximum LHGRs for bundles JLM420 and JLD505. In addition, Figure 2.7-4 also plots the peak LHGR at the limiting maximum fraction of limiting power density (MFLPD) node. Figure 2.7-4 shows that the JLM420 LHGR approaches the maximum for the core early during cycle exposure. The JLD505 LHGRs are lower; however the LHGR limit for the higher exposure nodes is also lower. The plot of the peak LHGR at the limiting MFLPD node shows that lower LHGRs are allowable at higher exposures. Between the peak LHGR curve and the limiting MFLPD curve, Figure 2.7-4 shows that JLM420 and JLD505 were operated near LHGR limits. The early LHGR exposure for JLM420 was approximately [ ]. This is consistent with Figure 2-4 from the IMLTR SE. However, peak LHGR is constrained by the fuel design specific thermal-mechanical operating limits and therefore early cycle peak LHGRs are constrained to the same maximum. From about mid-cycle to the EOC, the JLD505 peak LHGR tracked closely with the limiting MFLPD peak LHGR, indicating an aggressive operating history for this once-burnt assembly.

The NRC staff requested additional information regarding the operating history for JLD505 in RAI 8. In response to this RAI, GEH provided a series of figures (Figures 8-1 through 8-4 in Reference 14). Based on the comparison of key operating parameters, the NRC staff concludes that the JAF scanned bundles are representative of EPU operation.

3.2.5 Local Power Range Monitor Calibration Interval Considerations

The NRC staff requested additional information regarding quantification for the basis of the uncertainty attributed to instrument failure. In addition, the NRC staff also pointed out that upon cursory review of NEDC-32694P-A, “Power Distribution Uncertainties for Safety Limit MCPR Evaluations,” Appendix B (Reference 5), the basis appears to be based [ ]. GEH answered all of the NRC staff’s concerns in detail in its response to RAI 20 (Reference 14).

GEH pointed out in the responses to RAI 20 that LPRM update uncertainties for currently operating BWRs with modern fuel designs and current LPRM detector types have been examined for representative population of the entire BWR fleet. To evaluate the LPRM uncertainty, GEH evaluated [ ]. Current data was obtained from 12 cycles of 7 plants, as shown in Table 20-1 of the RAI 20 response (Reference 14). Table 20-1 shows a list of plants that includes D, C, and S lattices, small plants and large plants, and both thermal (neutron) TIP monitoring systems and gamma TIP monitoring systems.

As shown in Figures 20-1, 20-2, and 20-33 of Reference 14, the LPRM update uncertainty evaluations demonstrate essentially no exposure dependency. As summarized in Table 20-3, the one sigma (standard deviation or RMS) uncertainty values are well within the currently accepted GEH licensing basis for LPRM update uncertainty. In particular, the current LPRM update uncertainty of [ ] for LHGR evaluations is quite well supported by the summary data provided in Table 3, “% Change in MFLPD” of Reference 14.

In follow-up discussions with GEH regarding the responses to RAI 20, the NRC staff questioned the combined impact on LPRM update uncertainty if simultaneous extrapolations of both LPRM calibration interval and power-to-flow ratio are considered. The NRC staff requested that GEH quantify this impact on LPRM update uncertainty and the resultant impact on LHGR uncertainty. In its response to RAI 20 Supplement 1 (Reference 15), GEH demonstrated that considering these simultaneous extrapolations would result in a bounding LPRM update uncertainty of [ ] percent. Using this value brings the total LHGR uncertainty to [ ] percent, which still allows for sufficient margin to the LHGR process limit of [ ] percent. The NRC staff finds this assessment of the combined impact on LHGR uncertainty acceptable.

3.2.6 Pin-wise Power Uncertainty Conclusions.

The NRC staff’s SE for the IMLTR imposed a penalty of 0.01 for the SLMCPR to account for potentially increased σ_{peak}. On the basis of the expanded qualification for JAF, the NRC staff has found that the σ_{peak} remains within the accuracy defined in Reference 5. On this basis, the

NRC staff approves the reduction of the SLMCPR adder imposed by Limitations 4 and 5 by a margin of 0.01.

3.3 Special Considerations for MELLLA+

In its SE for the IMLTR, the NRC staff imposed a penalty to the SLMCPR for EPU operation of 0.02 (see IMLTR SE Limitation 4). This adder is comprised of a penalty addressing increased bundle power uncertainty and another addressing increased σ_{peak}. In addition, the NRC staff increased the penalty to 0.03 for MELLLA+ operation to account for additional thermal margin (see IMLTR SE Limitation 5). The additional 0.01 value is 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 due to the higher bundle power-to-flow ratio on both pin and bundle powers (Reference 1).

In its SE for the IMLTR, the NRC staff recommends scrutinizing any gamma scan data for applicability to the MELLLA+ operating domain to ensure that the σ_{peak} is derived from spectrally hard conditions similar to those expected for MELLLA+ core conditions (Reference 1).

The NRC staff reviewed the core monitoring calculations performed for the bundles scanned as part of the JAF c17 campaign. Figure 2.9.3 of Supplement 2 Part 2 provides a plot of the PANAC11 predicted axial void distribution for the scanned GE14 bundles. While the JLM420 bundle achieves high void fraction [ ] the average void fraction for these bundles remains well below the expected range of exit void fraction for limiting bundles operating at MELLLA+ low-flow conditions. In addition, [ ] – which are expected to be significantly increased for MELLLA+ operation. Therefore, the NRC staff cannot conclude that the spectral conditions experienced by the JAF bundles during the c17 campaign were inclusive of the conditions expected for MELLLA+ operation.

The JAF c17 gamma scan campaign, however, has addressed concerns regarding the neutronic methods. First, these scans have served to provide the NRC staff with assurance that the methods remain robust for application to modern fuel bundle designs. Additionally, while not fully reaching anticipated void fractions for MELLLA+ operation, these data do provide assurance that the methods remain robust for high bundle power application where the void fraction exceeds 70 percent. Trend data for the overall rod power uncertainty statistics provides assurances that discernable trends in the methods' performance do not occur over a wide range of void fractions up to approximately 75 percent.

The NRC staff further notes that the uncertainties in the rod powers were significantly lower than those assumed in the SLMCPR analysis. This is due in part to conservatism in the uncertainty values as they were developed on the basis for the less accurate TGBLA04/PANAC10 methodology.

In RAI 14 the NRC staff requested additional information to characterize what appears to be a [ ]. GEH responded to RAI 14 by comparing the results for two bundles – one that appeared to show [

]. GEH stated that more detailed calculations could be made to [

]. Since the normal design process does not consider the effects of the [ ] this improved statistical comparison would not be representative of the accuracy of the design process, and so, has not been included. The NRC staff agrees with this assessment of [ ] and finds GEH's assessment of this issue acceptable.

In RAI 17, the NRC staff requested that GEH consider the extrapolation of any biases to MELLLA+ conditions and the subsequent ramification for TIP simulation. GEH responded to RAI 17 by referencing the RAI 14 response and stating that no additional impact for these potential biases are foreseen for MELLLA+ operating conditions. The NRC staff found the response to RAI 17 to be acceptable.

Further, GEH has committed to provide future cycle tracking information (hot and cold eigenvalue and TIP data comparisons - see the response to RAI 6 in Reference 17). The NRC staff imposed a limitation to this effect in its SE for the IMLTR (Limitation 23, Reference 1). The evaluation of the core-tracking data will provide the basis to establish if MELLLA+ operation indicates any changes in the performance of the nuclear methods or any needs to revise the uncertainties applied in the determination of the safety and operating limits. In the IMLTR SE (Reference 1) the NRC staff identified the potential for anomalies to influence the predictive capabilities of the core monitoring and simulation methods.

In the interim, the NRC staff has not reviewed operational data demonstrating the capability of the GEH nuclear methods for MELLLA+ operation. Therefore, the NRC staff cannot conclude that extrapolation of the GEH methods to MELLLA+ is possible without additional analytical thermal margin provided in the form of Limitation 5. Therefore, while the gamma scan data have provided adequate qualification to support the reduction in this SLMCPR penalty, data derived from operation at CNC and JAF is insufficient to fully bound the operational characteristics of MELLLA+ operation. Additionally, since the gamma scan data was limited to conditions with power-to-flow ratios up to 42 MWt/Mlbm/hr, the staff remains concerned with maintaining additional margin for MELLLA+ conditions with power-to-flow ratios above 42 MWt/Mlbm/hr in view of the uncertainties in extrapolating beyond the range of the available data. The NRC staff has previously noted that the CNC data provides particular relevance to qualification for MELLLA+ operation given the utilization of a FCW during c15 operation at high thermal power. This is to be contrasted with the conditions of the JAF gamma scan campaign.

The NRC staff does not have reasonable assurance that the uncertainties have been adequately justified for applicability to MELLLA+ conditions. Therefore, the NRC staff continues to impose a penalty to the SLMCPR for MELLLA+ applications. The penalty to be added to the SLMCPR will be 0.01 for MELLLA+ applications with power-to-flow ratios up to 42

MWt/Mlbm/hr. For MELLLA+ applications with power-to-flow ratios above 42 MWt/Mlbm/hr, the penalty to be added to the SLMCPR will be 0.02.

GEH's responses to the NRC staff's RAI 13 and 14 provide additional details diagnosing and quantifying the trends in pin power distribution. On the basis of these detailed evaluations, the NRC staff concludes that the trends in power distribution have been adequately explained and there is assurance that additional error or bias would not be introduced by further extrapolation to higher void conditions. However, anomalies associated with MELLLA+ operation have not been addressed. Such an anomaly, as postulated during the initial review of the IMLTR, could occur if modeling assumptions are not valid at the hard spectral conditions for MELLLA+ operation. However, such an anomaly 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.

4.0 CONCLUSION

In Reference 18, GEH committed to revise NEDC-33173P (IMLTR) with the analysis of the new gamma scan data and sufficient reanalysis of existing data currently summarized in NEDC-32694P-A (Reference 5). The purpose of the revision was to justify the use of GEH's analytical methods in expanded operating domains, up to and including MELLLA+, without the use of the additional SLMCPR margin specified in the NRC staff's SE for the IMLTR. The NRC acknowledged the acceptability of the approach committed in Reference 18 as providing a basis to finalize the neutronic methods uncertainty qualification.

With Reference 7, GEH submitted to the NRC a three-part supplement to the IMLTR documenting the analysis of bundle and pin-by-pin gamma scans, and a revision to the IMLTR removing the need for the temporary additional SLMCPR margin. GEH considers that the enclosed Supplements support the original uncertainties used in its methods. The submitted revision to the IMLTR is labeled Revision 2. Revision 1 to the IMLTR is the acceptance (-A) version of the originally approved IMLTR. No changes are being proposed in Revision 2 other than the changes supporting the removal of the additional SLMCPR margin. All other Limitations and Conditions of the Revision 1 SE remain applicable.

Limitations 4 and 5 of the NRC's SE for the Methods LTR impose a 0.02 adder to the cycle-specific SLMCPR value for EPU operation and a 0.03 adder for MELLLA+ operation. GEH requested that the NRC review and approve NEDC-33173P, Supplement 2, Parts 1-3, and Revision 2, and issue a revision to the NRC staff's SE for NEDC-33173P removing Limitations 4 and 5.

Based on the NRC staff's review of this supplement and revision to the IMLTR, the NRC staff approves GEH's request with one exception. Limitation 5 stipulates that for operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state-point, a 0.03 value shall be added to the cycle-specific SLMCPR value. The added value of 0.03 will now be reduced to 0.01 for power-to-flow ratios up to 42 MWt/Mlbm/hr, and to 0.02 for power-to-flow ratios above 42 MWt/Mlbm/hr. This adder may be removed if GEH submits MELLLA+

operation data, subject to NRC staff review and approval. Thus, for operation at MELLLA+, including operation at 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. The NRC staff will revisit the applicability of this limitation during its review of the MELLLA+ cycle-tracking data that will be provided by GEH following the first MELLLA+ implementation for a GNF-fueled reactor.

To this end, the NRC staff has revised IMLTR SE Limitations 4 and 5 as follows without further review.

Limitation 4 from the SE for the IMLTR states:

> For EPU operation, a 0.02 value shall be added to the cycle-specific SLMCPR value. This adder is applicable to SLO [single loop operation], which is derived from the dual loop SLMCPR value.

On the basis of the subject review, the NRC staff finds that Supplement 2, Parts 1-3 provide the additional data and analysis needed to finalize the neutronic methods uncertainty qualification and justify GEH's original uncertainties used in its methods for EPU operation. Therefore, the NRC staff has revised Limitation 4 in Section 9.4 of the IMLTR SE as follows:

> This Limitation has been removed according to Appendix I of this SE.

Limitation 5 from the SE for the IMLTR states:

> For operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state-point, a 0.03 value shall be added to the cycle-specific SLMCPR value.

On the basis of the subject review, the NRC staff finds that Supplement 2, Parts 1-3 provide the additional data and analyses needed to finalize the neutronic methods uncertainty qualification and justify GEH's original uncertainties used in its methods for MELLLA+ operation, except as stated above. Therefore, the NRC staff has revised Limitation 5 in Section 9.5 of the IMLTR SE as follows:

> This Limitation has been revised according to Appendix I of this SE.
>
> 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.

The NRC staff reviewed IMLTR Supplement 2, Parts 1-3, and Revision 2 only insofar as it justifies revisions to Limitations 4 and 5. The NRC staff review in this matter does not impact any other aspects of the original review of the IMLTR. Therefore, all other NRC staff guidance, limitations, and conclusions documented in the SE for the IMLTR remain applicable as originally stated.

5.0 REFERENCES

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14. Letter from GEH to NRC, MFN 10-355, "Response to Request for Additional Information Re: 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 Margin (TAC No. ME1891)," dated December 17, 2010. (ADAMS Package Accession No. ML103640071)

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18. Letter from GEH to NRC, MFN 06-434, "Updated Response to RAI 28-2 – NEDC-33173P (TAC No. MD0277)," dated November 22, 2006. (ADAMS Accession No. ML063350054)

Principal Contributors: P. Yarsky
A.C. Attard
S. Philpott

Date:

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Figure 3.1.5-1: Cofrentes Cycle 15B TIP Comparisons

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Figure 3.2.3-1: Trends in Pin Power Differences with Axial Height