June 13, 2005

Mr. Louie Quintana, Manager
Engineering & Technology
GE Nuclear Energy
175 Curtner Avenue
San Jose, CA 95125

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION – LICENSING TOPICAL REPORT NEDC-33006P, REVISION 1, "GENERAL ELECTRIC BOILING WATER REACTOR MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS (MELLLA+)" (TAC NO. MB6157)

Dear Mr. Quintana:

By letter dated August 22, 2002, GE Nuclear Energy (GENE) submitted Licensing Topical Report (LTR) NEDC-33006P, "General Electric Boiling Water Reactor Maximum Extended Load Limit Analysis Plus, Revision 1." As a result of our review of the LTR, the NRC staff has prepared the enclosed request for additional information (RAI) related to the review of the adequacy of GENE's neutronic and thermal-hydraulic methods in simulating the core conditions for boiling water reactors operating in the proposed MELLLA+ domain.

Pursuant to 2.390 of Title 10 of the *Code of Federal Regulations*, we had determined that the enclosed RAI did not contain proprietary information. However, we provided you with the opportunity to comment on the proprietary aspects. By letter dated April 21, 2005, you provided us your comments. We have reviewed your comments and concluded that proprietary and non-proprietary versions of the RAI need to be issued. As such we have enclosed both proprietary and non-proprietary versions.

If you have any questions regarding this RAI, please contact me at (301) 415-1445.

Sincerely,

/RA/
Alan Wang, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 710

Enclosures: As stated

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REQUEST FOR ADDITIONAL INFORMATION

LICENSING TOPICAL REPORT NEDC-33006P, REVISION 1, "GENERAL ELECTRIC BOILING WATER REACTOR MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS"

GE NUCLEAR ENERGY

PROJECT NO. 710

As a result of the Nuclear Regulatory Commission’s (NRC's) review of the maximum extended load line limit analysis plus (MELLLA+), the staff identified issues in the methods used in various General Electric Nuclear Energy (GENE) topical reports used to support the MELLLA+ topical. The staff objective for review of these methods is described below:

- To determine the accuracy of GENE’s analytical method for the current core and fuel designs (GE14) and operating strategies.
- To confirm that the biases and uncertainties (e.g., power distribution, void coefficient) currently used in the GENE analytical methods remain valid and applicable for depletion at high in-channel void conditions.
- To determine if the biases and uncertainties established through code-to-code comparisons remain valid and applicable for operation at high in-channel void condition expected for extended power uprate (EPU)/MELLLA+ conditions.

Related to the discussions above, the staff position is that the uncertainties and biases associated with operation at the current high void operating strategies and core designs need to be established through actual benchmarking as opposed to TGBLA/MCNP code-to-code comparisons for benchmarking with exposure. The following request for additional information (RAI) is intended to clarify technical issues that have emerged in discussions with GENE.

PART I: Benchmarking the Accuracy of GENE’s Analytical Method for the Current Operating Strategies and Fuel Designs

In accordance with the standard industry practice and GENE’s safety limit minimum critical power ratio (SLMCPR) methodology (NEDC-32601P-A and NEDC-32694P-A), core tracking and gamma scan data are used to establish the uncertainties and biases of key calculational parameters (e.g., bundle power, σ P4B, power allocation factor, [[ ]]and pin power peaking) that are used in your safety analyses. Tests and measurements are also done to validate the analytical models that simulate physical phenomena such as void fraction,

ENCLOSURE 1

dryout, and pressure drops. Since it is not possible to measure all the key parameters that affect the fuel and core response and that are used in the safety analyses (e.g., void coefficient, SLMCPR, delta maximum critical power ratio (MCPR), peak-clad temperature, peak pressure response), code-to-code comparisons and propagation of error analysis provide the additional means to establish the biases and uncertainties errors in the prediction of the analytical methods.

The methods enclosure relied solely on code-to-code comparisons to define the uncertainties and biases associated with GENE's lattice physics/core simulator method (fit/extrapolation). As stated above, the staff position is that the uncertainties and biases associated for operation at the current operating strategies and core designs need to be established through actual benchmarking as oppose to code-to-code (TGBLA/MCNP) benchmarking for exposed fuel. The TGBLA lattice physics data has been compared with MCNP. GENE previously submitted some core follow data for GE14 fuel. However, GENE has not submitted an amendment with comprehensive core follow and gamma scan data to benchmark the lattice physics and core simulator codes for high in-channel void conditions.

Methods RAI 5 asked GENE to provide plant data on conditions as close to the EPU/MELLLA+ conditions as possible. In followup RAIs 25 through 28, the staff asks GENE to evaluate the benchmarking data and provide supporting discussions.

25. Core Follow Data: The objective of this review is to determine the accuracy of TGBLA and PANAC for the current operating strategies. The staff understands that GENE receives operating data from plants and performs offline PANAC calculations to monitor the plants' performance (i.e., eigenvalue tracking).

25-1. Select plants with challenging core designs (e.g., uprated plants and high-density plants with extended cycles) to benchmark the TGBLA and PANAC codes system for operation with high in-channel exit void conditions. The data from the plants should be statistically significant to current boiling water reactor (BWR) operating strategies and fuel designs (GE14). The core tracking cycle exposure should extend to the number of cycles a fuel bundle may remain loaded in a core.

25-2. Provide plant-specific information for each set of core follow data (the plant type, whether the power level has been uprated, power density, operating domain, fuel type, cycle length, etc.). For each TIP reading, give the cycle state point, the operating power/flow state point, and the corresponding calculated thermal margin available. Evaluate the plant-specific data, including whether the core follow data indicates that the code is less accurate for higher in-channel void conditions. Explain any trends in the data in terms of operation at higher operating domain, cycle length, uprate and high-density plants. Demonstrate that the current uncertainties and biases used in the NRC-approved analytical method (e.g., bundle power, σ P4B, power allocation factor, [[ ]], and pin power peaking, etc.) remain valid and applicable.

26. Low-Flow and Off-rated Conditions: BWRs currently operate with lower core flow ranges at rated power. However, the general practice is to benchmark the codes for plant operation at rated conditions on the assumption that plants do not routinely operate at the lower flow conditions. The low-flow conditions can be limiting in terms of the thermal-hydraulic conditions (e.g., higher void conditions, axial and radial power peaking, and distribution) that adversely affect the performance of the core and the fuel (critical power ratio response). As far as the available data allows, include core follow data for nonrated conditions. If core follow data during plant maneuvers (i.e., during startup, off-rated, and lower core flow at rated power operation) is not available, provide a commitment to benchmark the fidelity of your lattice physics and core simulator codes at these conditions for the EPU/MELLLA+ operation. State what actions you will take to fulfill this commitment.

27. Hot Channels: The high-powered bundles are the most limiting. The core follow data is based on statistically averaged values that may not reflect how well the codes predict the conditions in the high-powered bundles. The code-to-code benchmarking using MCNP (MCNP not benchmarked with exposure and not a depletion code) may not be suitable for establishing the uncertainties and biases with depletion. In addition, the core follow TIP readings average out the four-bundle TIP readings axially within the bundle, along with all the TIP readings for a given cycle state point. In some cases, the TIP readings for different cycle points and different sets of core follow data are statistically averaged to determine the uncertainties of the core simulator codes. This approach tends to mask the accuracy of the codes in predicting hot bundle radial and axial power distribution.

    Using limiting control cell loading pattern (two or three hot bundles in a control cell), benchmark the accuracy of TGBLA and PANAC in predicting the four-bundle radial and axial power distribution. Include the EPU/MELLLA+ data for the pilot plants (Brunswick Units 1 and 2 and Clinton) in your hot channel data. Provide the corresponding calculated void distribution for the hot channels.

28. Gamma Scan Benchmarking: The standard industry practice is to do bundlewise and pinwise gamma scans for new fuel designs to benchmark the analytical methods used to predict the bundle and pin power peaking and distribution. GENE's SLMCPR methodologies [e.g., Sections 3.1.1, 3.1.4, (page 3 -4) and 4.0 (page 4-2) of NEDC-32601P-A and Section 3.1 (pages 3-1 and 3-2) of NEDC-32694P-A)] require that the [[ ]] and pin power peaking for each bundle in a four-bundle core cell and the pin power peaking be determined through gamma scans.

28-1. Provide statistically significant gamma scan data to benchmark the bundle and pin power distribution for the current fuel designs (GE-14). The objective is to evaluate the accuracy of TGBLA and PANAC codes in predicting the bundle and pin peaking and power distribution for depletion at high-void conditions. Select bundles that are once-burned, twice-burned, and, if necessary, thrice-burned. Gamma scans should also be used to benchmark the codes' accuracy in predicting the axial power distribution and to determine whether GENE's code systems need any changes for depletion at high-void conditions. Your gamma scan data should therefore include high-powered bundles that have high gigawatt-days (GWd) loadings and operate at high-void conditions. Most important, the gamma scan data and the corresponding calculational analysis should provide additional validation for the statement in Section 2.1.4 of the methods enclosure (see RAI 3-1).

28-2. If GE14 gamma scan data is not available, make a commitment to do the gamma scans. Your commitment should include an action plan and a timetable for doing the gamma scans for the GE14 fuel design. Also, describe your proposed future approach that would ensure new fuel designs are benchmarked through gamma scans consistent with your licensing methodology. Interim actions are covered in RAIs 30-7, 30-8, and 35 below.

29. Calculation of Nodal, Bundle, and Axial TIP Responses: RAI 29 follows up on methods RAI 21-2. The objective is to determine whether the statistical combination and normalization of the measured and the calculated TIP data comparisons show the axial and nodal differences between the calculated and the measured data for a four-bundle TIP cell.

29-1. Using a limiting four-bundle TIP cell (limiting number of hot bundles in a control cell, limiting enrichment, limiting cycle exposure point), tabulate the TIP calculated and measured data. Show how the axial, bundle, and nodal TIP RMS is calculated from the TIP readings.

29-2. For the same four-bundle TIP data, compare the absolute calculated and measured values for each TIP element reading and provide a tabulation of the corresponding bundle axial void profiles and the absolute difference in TIP data.

29-3. Evaluate the absolute difference in TIP readings and determine whether the fidelity of the TIP readings varies axially with void. Compare the four-bundle TIP data with core follow TIP readings for less challenging core and lattice designs and determine whether the four-bundle power uncertainties should be increased.

29-4. Since the four-bundle control cell can contain bundles at different exposures, explain how the accuracy of the GENE methods can be benchmarked for depletion under high-void conditions by using the core follow data. This issue is important because MCNP is not well-suited for benchmarking the historical effects. Use gamma scan data, if available, for bundles and peak pin at different exposures (e.g., fresh, once-burned, twice-burned). As an interim measure, select four-bundle TIP readings and cycle state points to assess the fidelity of TGBLA and PANAC for depletion at high-void conditions. State whether the accuracy of the code for the hot bundle changes with exposure at core conditions as close to EPU/MELLLA+ conditions as possible.

PART II Evaluation and Presentation of the Lattice Physics Data and Uncertainties

As part of the methods review, GENE evaluated the fidelity of the TGBLA lattice physics code in Enclosure 3 (MFN 04-026). In addition, GENE provided some lattice physics data for selected lattices. GENE stated that it would resubmit the enclosure to the staff as a stand-alone methods topical report. The staff reviewed the enclosure and issued a set of methods RAIs. The followup RAIs below identify recommended changes in the presentation of the data in Enclosure 4, provide insights from the staff's evaluation of the lattice physics data, and propose additional topics that should have been covered in the methods' enclosure.

30. Presentation of Data: In performing the code-to-code benchmarking, Enclosure 4 provides root mean square of data from different lattices. For void and exposure trending purposes, the staff proposes that GENE supplement the plots in the enclosure by plotting void and/or exposure data for each lattice.

30-1. Section 2.1.1 (Figures 2-1 to 2-11) and Section 2.1.2 (Figures 2-12 to 2-21): Section 2.1.2 provides a TGBLA/MCNP instantaneous cross-section comparison [[ ]]. For different lattices, supplement the current plots with absolute cross-section comparisons between TGBLA and MCNP with exposure. Use the lattice physics data calculated and extrapolated to 90 percent void conditions. Some of the lattices may not experience high-void conditions (>90 percent) during steady-state operation. However, during transients (anticipated operational occurrences) and accidents, the lower part of the bundles may experience high-void conditions. Therefore, it is reasonable to evaluate the performance of TGBLA-generated data at high-void conditions for all lattices. For the lattices that represent the upper part of the bundle, use the 90 percent void fraction for the TGBLA history calculations and use 90 percent void fraction isotopic concentrations instead of 40 percent void fraction isotopic concentrations in the MCNP calculation. The objective of these plots is to evaluate the exposure dependence of the cross-sections for lattices representing different zones of the bundle.

30-2. Section 2.1.2 (Figures 2-22 to Figures 2-27): [[

]]. Provide plots of the changes in error with voids and exposure for the various different lattices.

30-3. Section 2.1.2 (Figure 2-28) and Section 2.1.3 (Figure 2-29): [[

]]. However, the data provided is averaged for all lattices, making trending difficult. Plot the pin power differences between TGBLA and MCNP at the 90 percent calculated or an extrapolated void fraction for various lattices at various different exposures. Evaluate these results.

30-4. Section 2.1.4, "Historical Water Density Cross-Section Fit Adequacy" (Figures 2-30 to 2-38): [[ ]]. To account for the dependency of the isotopic chains on spectral differences due to depletion at different void conditions, GENE used a developmental lattice physics transport code (LANCER). The staff understands that the data presented in Section 2.1.4, "Historical Water Density Cross-section Adequacy," is [[

]], the staff finds that using a developmental code (LANCER) as sensitivity evaluation acceptable for assessing TGBLA's depletion capability (provided GENE's response to RAI 3-2 is acceptable). Provide plots of TGBLA/LANCER cross-section data versus void for various exposures for different lattices. Provide similar plots using the LANCER/TGBLA RMS pin power difference for each void condition for all of the exposure points. Evaluate the plots and explain the trends.

30-5. Section 2.1.2 benchmarks the accuracy of TGBLA's instantaneous water density cross-sections against MCNP. [[ ]]. Identify the key parameters in which MCNP/TGBLA code-to-code benchmarking is used to determine the uncertainties and biases (e.g., void coefficient, pin powers). Explain how exposure dependency and historical effects are taken into account in establishing the uncertainties when the standard MCNP/GENE code-to-code benchmarking is used.

30-6. Pin Power Uncertainty: Based on the individual TIP core follow data performance and any applicable available gamma scan data propose an interim pin power uncertainty that ensures that the instantaneous and historical effects will be accounted for in the uncertainty calculations. The proposed pin power uncertainty should offset the lack of statistically adequate gamma scan data.

30-7. Bundle Power Uncertainty: Similarly, there is no core follow data for EPU/MELLLA+ conditions or hot channel core follow data for operation at the high-power, low-flow conditions. Therefore, evaluate the available data and the limitations of TGBLA and PANAC for depletion at high-void conditions and propose a bundle power uncertainty that will ensure that the bundle power for the hot bundle is not underestimated.

30-8a. Assessing TGBLA Accuracy With Exposure: Using LANCER and TGBLA, plot the isotopic concentrations and fission fractions of U-235, U-236, U-238, Pu-239, Pu-240, Pu-241 as functions of burnup. Use lattice 5168 and any other lattice used to perform LANCER calculations. Present the isotopic concentration vs. exposure plots for depletion at 40 percent, 70 percent, and 90 percent void conditions. The objectives are to baseline potential changes due to spectral hardening for operation at different void conditions and to determine both the accuracy of TGBLA and how TGBLA's accuracy changes with void fraction. Provide plots similar to the plots in Figures 3-8 and 3-9 of NEDE-20944-P for depletion at different void conditions and for the two lattice physics codes (LANCER and TGBLA). Evaluate and discuss the plots generated above.

31. R-Factor: The R-factor methodology is described in NEDC-32505P, "An R-Factor Calculation Method for GE11, GE12, and GE13 Fuel," dated July 1999. Evaluate the R-factor methodology to ensure that the key assumptions in the R-factor methodology remain applicable to the EPU/MELLLA+ conditions. Also, evaluate the pin peaking factors used in the R-factor calculation for operation at high-void conditions. Amend the topical report accordingly, and amend the RAI responses for operation at the EPU/MELLLA+ conditions. RAIs 31-1 through 31-4 pertain to several features of the R-factor calculation, [[ ]].

31-1. RAI 5 (Attachment B) and RAI 4 (Attachment D) of NEDC-32505P-A address the methods used to calculate the R-factor [[ ]].

31-2. [[ ]].

32. Section 2.9, "Utilization of Lattice Average (Active + Bypass) Relative Water Density for Parameterization": This section evaluates the adequacy of correlating the lattice cross-sections and pin powers with the lattice-averaged water density for combining active and bypass voiding. Methods RAI 15 addresses the impact of bypass voiding on the cross-sections and pin powers. The following RAIs concern the data provided in Section 2.9. Figures 2-52 to 2-55 show the cross-section errors (K-infinity, thermal absorption cross-section, diffusion coefficient, and flux ratios) as functions of relative water density. The error benchmarking was done with MCNP at BOL. Using the errors seen in the cross-sections at BOL, state whether these errors are expected to remain the same with exposure and explain why.

33. Section 2.6, "Spectral History Impacts of Extended High-Void Operation": This section discusses how PANAC11 accounts for the spectral history reactivity, using the "effective void history model."

33-1. Are any plants using PANAC10 in their core simulator or their safety analyses? Since PANAC10 does not correct for the spectral history reactivity, justify any continued use of this code version for depletion under high-void conditions.

33-2. Has the adequacy of PANAC11 correction been benchmarked or qualified? How does the method used in the developmental core simulator code compare with the method used in the PANAC11 correction model to account for the spectral history reactivity?

34. Progression-of-Error Analysis (TGBLA/PANAC11): This RAI clarifies what the staff is looking for in Methods RAI 2-7. The progression-of-error analysis is intended to determine the propagation of errors in the lattice physics code (TGBLA06) and the core simulator code (PANAC) for the high-void conditions characteristic of EPU/MELLLA+ operation operating with the current fuel designs (GE14). The sources of error in the [[

]]. GENE methods, Enclosure 4, provides analyses of each kind of error. However, Enclosure 3 did not address the impact of these errors on core behavior predictions.

The progression-of-error analysis has the following objectives:

- Identify the key safety analysis parameters that would be significantly affected by the cross-section errors (e.g., void coefficient, core reactivity at different exposures, the pin power distribution, bundle-wise and core-wide power distribution, void fraction calculations). RAI 2-6 asked for GENE's criteria for accepting errors in the cross-sections. Without specific acceptance criteria, it is necessary to establish the impact of the cross-section errors on the safety analyses.

- Identify (through sensitivity analyses) which cross-section errors would have significant impact on key safety analysis parameters, and quantify the impact.

- Quantify the impact of these cross-sections errors on the steady-state and transient response and the thermal limits.

- Qualify/benchmark the core simulator code (PANAC11) for operation at high-void conditions. In the most recent PANAC assessment (MFN# 098-96), GNF-A compared TGBLA04/PANAC11 to TGBLA04/DIF3D for the three standard void conditions. The submittal included an evaluation of the differences in the dynamic responses between TGBLA/PANAC10 and TGBLA/PANAC11. A similar assessment of the core simulator code performance is necessary to account for inaccuracies associated with the application of the 1.5 group method and the diffusion theory and to correct the spectral history corrections for the EPU/MELLLA+ operation.

- Develop interim actions for the EPU/MELLLA+ operation (see RAI 28-2).

34-1. Propose a progression-of-error method that achieves the objectives discussed above. and provide an additional assessment of the impact of the cross-section errors due to lattice physics modeling deficiencies at high-void conditions. Alternatively, establish uncertainties in the key parameters as proposed in Part I, based on individual TIP measured/calculated data and the available gamma scan data.

34-2. Based on the results of 35-1, discuss the potential impacts on the core safety analysis, including the core thermal margins and the safety and operating limits.

34-3. Propose a method to benchmark TGBLA and PANAC for the current high-void conditions and associated core and fuel designs. Explain why the previously proposed developmental codes (LANCER and AETNA) are not viable for code-to-code benchmarking, considering MCNP's depletion limitation as applied.

36. Void Coefficient Calculations and Benchmarking: Section 5.0, "Modeling Uncertainties and Biases," of NEDE-32906P-A: This section discusses how the void coefficient uncertainties and biases were determined. [[

]]. The following questions pertain to applicability of the current void coefficient uncertainties and biases for the EPU/MELLLA+ operation.

36-1. Justify how code-to-code benchmarking using MCNP/TGBLA would account for uncertainties and biases associated with the historical effects due to depletion at high void conditions. Similarly evaluate if ODYN void coefficient biases and uncertainties would be within the NRC-approved applicability ranges.

36-2. What fuel designs did the [[ ]] lattices used to establish the generic uncertainties and biases represent? State if the lattices representing the current fuel designs (GE14) would be bounded by the [[ ]] lattices.

36-3. Any increases in the biases in the kinf with depletion would affect the void coefficient uncertainties. Update the void coefficient biases and uncertainties based on the current operating strategies and fuel designs (GE14). Justify why the current biases and uncertainties are acceptable for EPU and MELLLA+ operation.

37. Code Upgrades: The staff finds that the current operating strategies (including EPU/MELLLA+) result in reduced safety margins for all design bases analyses. Therefore, the fidelity of the lattice physics and core simulator codes is important. The EPU/MELLLA+ review is hampered by the use of lattice physics/simulator vintage code systems that have not been comprehensively benchmarked with core follow and gamma scan for the current challenging plant operating strategies and fuel designs. The use of MCNP (using isotopics from TGBLA) in benchmarking lattices depleted at high void conditions limits the staff confidence in the code-to-code benchmarking provided.

    Considering that for EPU/MELLLA+ operation, BWRs would be operating outside the current operating experience, the staff highly recommends (1) that GENE adopt more accurate lattice physics and core simulator code systems and (2) that GENE validate its methods with additional, detailed operational and testing data for the full operational regimes of the BWR fleet.

38. Current Licensing Topical Reports: During the EPU/MELLLA+ review, the staff has also determined that the current licensing topical reports need to be updated for current applications. For example, fuel design updates for NRC-approved methodology topical reports are customarily submitted to the Commission by letter (e.g., NEDC 32505P-A, NEDC-32601P-A, and NEDC-32694P-A), but licensing topical reports are not systematically updated for new fuel designs and/or for proposed operating strategies. The staff highly recommends that GENE review its suit of codes and licensing topical reports and amend any generic analyses or evaluations that are no longer applicable. Since many of the technical topics are covered in responses to the staff's RAIs, the updated evaluation should include the RAIs and the corresponding response. In addition, Part 21 reporting and associated changes implemented through plant-specific changes should be included in GENE's licensing methodology. Therefore, for any Part 21 report that requires changes in the analytical methods or code systems, GENE should amend their licensing documents, implementing the changes.