March 5, 2007

Mr. Bob E. Brown
General Manager, Regulatory Affairs
GE Nuclear Energy
P. O. Box 780, M/C A-30
Wilmington, NC 28401

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: GENERAL ELECTRIC NUCLEAR ENERGY (GENE) TOPICAL REPORT (TR) NEDE-32906P, SUPPLEMENT 3, "MIGRATION TO TRACG04/PANAC11 FROM TRACG02/PANAC10 FOR TRACG AOO AND ATWS OVERPRESSURE TRANSIENTS" (TAC NO. MD2569)

Dear Mr. Brown:

By letter dated May 25, 2006 (Agencywide Documents Access and Management System Accession No. ML061500182), GENE submitted for U.S. Nuclear Regulatory Commission (NRC) staff review TR NEDE-32906P, Supplement 3. Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. On February 13, 2005, Jim Harrison of your staff and I agreed that the NRC staff will receive your response to the enclosed Request for Additional Information (RAI) questions by May 18, 2007. If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-1774.

Sincerely,

/RA/

Michelle C. Honcharik, Project Manager
Special Projects Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosure: RAI questions

cc w/encl: See next page

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ADAMS ACCESSION NO.: ML070540310 NRR-106

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DATE	3/2/07	2/27/07	1/24/07	3/5/07

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REQUEST FOR ADDITIONAL INFORMATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NEDE-32906P, SUPPLEMENT 3

"MIGRATION TO TRACG04/PANAC11 FROM TRACG02/PANAC10 FOR

TRACG AOO AND ATWS OVERPRESSURE TRANSIENTS"

GENERAL ELECTRIC NUCLEAR ENERGY (GENE)

PROJECT NO. 710

1. Do you intend to use TGBLA06-Modified as part of this application?

2. Provide a qualitative discussion on the differences seen in the transient analysis time traces between TRACG02/PANAC10 and TRACG04/PANAC11 in the thermal hydraulic parameters such as pressure, core flow, inlet subcooling, etc.

3. **(RAI 21.6-78 on the Economic Simplified Boiling Water Reactor (ESBWR) Docket)** On Page 7-47 of NEDE-32176P, Revision 3 (Reference 1), you state: "Two options exist for the calculation of the CPR [critical power ratio] for transient conditions." Why do you have two options for calculation of transient CPR? Is one method more conservative than the other? What are your guidelines for when to use which method for transient CPR calculations? Which method is used during an anticipated operational occurrence (AOO) calculation and during an anticipated transient without scram (ATWS) calculation? On Page 7-48 of the same document you state: "The assessment of the critical power calculation can be found in Section 3.6 of the *TRACG Qualification LTR*." The NRC staff has not received Revision 3 of the *TRACG Qualification LTR* which you state was to be published in June 2006. Provide the information from this document that may answer the above questions on the CPR calculation options for transient conditions.

4. **(RAI 21.6-80 on the ESBWR Docket)** The variable f in Equation 9.3-2 in NEDE-32176P, Revision 3, is described as the sum of the five decay heat group fractions, f_k. However, in the preceding paragraph you state that TRACG04 allows for a variable number (N_d) of decay heat groups. Please update your documentation to reflect this change.

5. **(RAI 21.6-81 on the ESBWR Docket)** Please address the following questions related to distribution of channel power:

   a. Equation 9.4-11 in NEDE-32176P, Revision 3, includes Fco, which is the fraction of direct moderator heating that appears in the coolant in the bypass, water rod, and bundle coolant. In TRACG, the water rod coolant, the core bypass coolant,

ENCLOSURE

and the bundle coolant are simulated as separate flow paths. How is the direct moderator heating associated with Fco split up for these three different coolant regions within the boiling water reactor core? Please describe the basis of the model.

b. Page 62 of NEDC-32965P, Revision 0 (Reference 2) describes the user input fractions for fission power and decay heat for direct moderator heating, fuel clad gamma heating and water rod(s) clad gamma heating as described in Reference 1, Page 9-35. The description for FDMN2 (direct moderator heating fraction for decay heat power) states: "The prior practice of setting FDMH2=FDMH1 is discouraged since it is non-conservative with respect to post-scram evaluations of peak clad temperature." Where FDMH1 is the direct moderator heating fraction for fission power. Please explain why you have set FDMH1=FDMH2 for all of the CHANs in the ESBWR TRACG decks for loss-of-coolant accident (LOCA), AOO, ATWS, and Stability given this statement in the user's guide.

c. You state that c_0 in Equation 9.4-14 of Reference 1 is calculated based on the Monte Carlo N Particle (MCNP) analysis. Page 63 of Reference 2 provides the default value of this parameter (DMHZERO in TRACG) for GE11 fuel design. TRACG models for LOCA, AOO, ATWS, and Stability use a given value for GE14 fuel. Is this number based on MCNP calculations for GE14 fuel? If not, provide the basis for assuming that c_0 does not change for the GE14 fuel design.

d. How does the direct moderator heating model change based on the control fraction for a given CHAN component? How specifically is the user input for bypass area per channel (BPAPC) used in the direct moderator heating model?

e. The fission power distribution model presented in Section 9.4 in Reference 1 appears to assume no gamma heat of the pressure vessel walls. Explain how gamma heating of the pressure vessel walls is considered.

f. In Equation 9.4-13 of Reference 1 a and b are assumed constant for calculating the fractional deposition of fission power in the fuel clad, water rod clad, control blades, and channel wall. For the case of direct moderator heating you make the correction in Equation 9.4-14 in Reference 1. Please provide justification that a and b are independent of the moderator density for fuel clad, water rod clad, control blades, and channel wall deposition, or that the correction made by Equation 9.4-14 in Reference 1 adequately characterizes the moderator density dependence of a and b for the above.

g. What is the normalization formula used to normalize Equation 9.4-11 in Reference 1? If the energy distribution fraction Fco is decreasing, because the moderator density is decreasing, how are the other fractions in Equation 9.4-11 in Reference 1 adjusted to ensure that they sum to one?

h. Does the TRACG uncertainty analysis include uncertainty associated with a and b for c, f, w, bl, ch, and co?

6. **(RAI 21.6-82 on the ESBWR Docket)** Section 9.1.3 in Reference 1 indicates that at the beginning of the calculation with the PANCEA Wrap up, that the TRACG cross sections include the presence of xenon. However, the transient calculation procedure does not indicate that the xenon concentration is updated. The NRC staff is aware that TRACG is capable of simulating transients with transient xenon conditions but is unable to locate any details about your models and calculation procedures. Please provide these details. Are transient xenon conditions used in the simulation of any AOO and ATWS events? Include information on how the treatment of xenon is conservative for these events.

7. **(RAI 21.6-84 on the ESBWR Docket)** In discussing the biases and uncertainties for the void coefficient in NEDE-32906P, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," in response to NRC staff RAI 12 you state: "When the PANAC11 model is implemented in TRACG it will be necessary to make a similar assessment TGBLA06 and MCNP and change the TRACG void coefficient model accordingly." Please state if this has been done and provide the NRC staff with the documentation that includes the details of the new evaluation.

8. **(RAI 21.6-85 on the ESBWR Docket)** Describe the computational procedure used to generate a PANACEA Wrap up file for use with TRACG. Specifically explain what calculations are performed with PANAC11 and how these results are captured numerically in the PANACEA Wrap up file.

9. **(RAI 21.6-86 on the ESBWR Docket)** The isotopic tracking in the PANAC11 code is discussed in NEDC-33239P (Reference 4). Please provide a protypical calculational model (e.g., the differential equations) for the determination of plutonium content based on the nodal power, exposure, and moderator density history.

10. **(RAI 21.6-87 on the ESBWR Docket)** PANAC11 uses the GEXL correlation to determine critical quality for the purpose of calculating the minimum CPR. Describe how PANAC11 calculates the bundle power where boiling transition occurs.

11. DELETED

12. **(RAI 21.6-68 on the ESBWR Docket)** On Page 6-135 of Reference 1, should the reference to Figure 6-34 actually be to Figure 6-37?

13. **(RAI 21.6-75 on the ESBWR Docket)** Please submit Reference 5.

14. **(RAI 4.3-3 on the ESBWR Docket)** In DCD Tier 2, Page 4.3-3, reference is made to the lattice code TGBLA06, which has recently been modified to accommodate a minor correction in the programming of analytical formulation in the code. Please submit the modification(s) to TGBLA06. The submittal should include the changes made to the code and validation of the code as it pertains to recent application(s) since the modification of the code, and any natural circulation database, as it pertains to the analysis of the ESBWR steady-state neutronic performance. The contents of the submittal should include before and after calculational results with technical justification(s) in support of the changed results. Also provide a comparison between

the modified TGBLA and MCNP results in Section 1.3 of NEDC-33239P, “GE14 for ESBWR Nuclear Design Report” (Reference 4).

15. **(RAI 4.3-4 on the ESBWR Docket)** Discuss any recent changes made to PANACEA since the NRC staff’s last approval. Provide similar information to that requested in RAI 4.3-3. It is presumed that this version of the code is the NRC-approved version of record.

16. **(RAI 6.3-54 on the ESBWR Docket)** Section C.1.4.1 of Reference 1, states that the correlation for thermal conductivity used in TRACG04 for UO2 with and without gadolinia has been updated to be compatible with the model used in PRIME03. PRIME03 has not been reviewed and approved by the NRC staff. Provide justification for using this model.

17. **(RAI 6.3-55 on the ESBWR Docket)** Provide justification for using gas gap conductivity and fuel thermal conductivity from two different analysis codes (GSTRM for gap conductivity and PRIME03 for fuel thermal conductivity).

18. DELETED

19. DELETED

20. DELETED

21. Provide additional information demonstrating that the uncertainty in the Doppler coefficient and in scram reactivity (phenomena identification ranking table (PIRT) items C1BX and C1CX, respectively) cited in Table 5-5 in the TRACG AOO analysis for BWR/2-6 (Reference 3) is still applicable or bounding when applying the new PANAC11 physics methods.

22. Regarding the decay heat model, provide additional information on how you determine fission fractions of U-238 and Pu-239 as a function of exposure and the MeV/fission values by submitting the following reference (Reference 203 in Reference 1): C. L. Martin, *Nuclear Basis for ECCS (Appendix K) Calculations*, NEDO-23729, Class 1 GE Report, November 1977. In addition, clarify if the MeV/fission value cited on Page 9-24 of Reference 1 (TRACG04 Model Description) is used in the nodal power calculation (ε_i in Equation 9.1-59 in Reference 1).

23. Provide additional information on the specific implementation and/or guidelines for using the American Nuclear Society (ANS) decay heat curves for use in BWR/2-6 AOO analyses. Include user input details such as number of irradiation periods selected and number of decay heat groups.

24. In the TRACG04 application for ESBWR AOO’s (Reference 6), you increased the uncertainty in interfacial shear based upon comparisons to the Toshiba data (PIRT Item C2AX in Table 4.4-1, Reference 6, PIRT22 in TRACG04). This value was increased from the value for BWR/2-6 AOO’s cited in Table 5-5 as PIRT item C2AX in Reference 3, which was based upon comparisons to FRIGG data. In addition, in the ESBWR application (Reference 6) you included an uncertainty for the entrainment

multiplier to account for the data in the transition and annular flow regimes (included with PIRT Item C2AX in Table 4.4-1, Reference 6, PIRT52 in TRACG04). Explain why you do not increase/include these uncertainties in the TRACG04 application for BWR/2-6 AOO events.

25. Provide the implementation details of the optional 6-cell jet pump model. Please update the TRACG04 User's Manual (Reference 2) and the TRACG Model Description (Reference 1) with these details.

26. Provide additional information demonstrating that the bias and standard deviation in the jet pump N-ratio (PIRT parameters G1 and G3) cited on Pages 5-35 and 5-36 of Reference 3 are applicable or bounding when using the 6-cell jet pump model in BWR/2-6 AOO analysis.

27. **(Similar to RAI 21.6-93 on the ESBWR Docket)** The TRACG Model Description (Reference 1) states that "The default correlation for thermal conductivity (k) for unmolten UO2 has been updated to be compatible with the model used in PRIME03." For the demonstration calculations presented in your submittal (Reference 7), please state if you used the GSTRM or PRIME03 model for fuel thermal conductivity. In addition, how does a TRACG04 user specify the use of either model in a TRACG04 input deck? Provide the NRC staff the location in the TRACG04 User's Manual (Reference 2) that provides this guidance.

28. Provide additional information on the procedures for selecting the pump homologous curve input into TRACG.

29. The void reactivity coefficient bias and uncertainties in TRACG must be representative of the lattice designs of the fuel loaded in the core. State the lattices used to generate the void reactivity coefficient response for TRACG04/PANAC11. Include the restriction that Reference 7 is only applicable for these lattice designs.

30. TRACG internally models the response surface for the void coefficient biases and uncertainties for known dependencies due to the relative moderator density and exposure on a nodal basis. Section 2.8.7 of the Vermont Yankee extended power uprate (EPU) safety evaluation report (Reference 8) reviewed the impact of the void history bias on the safety analyses. RAI SRXB-A-68 response (Reference 9) quantified the void history bias and discussed its impact. Section 2.2.2.2, "Treatment of Fuel Parameter Uncertainties," of Reference 10 also addressed the void history bias. Based on the quantified void history bias typical for the fuel designs typical of the EPU and the maximum extended load line limit analysis plus (MELLLA+) operating domain, modify the TRACG methodology to account for void history bias. The void history bias can be incorporated into the response surface "known" bias or through changes in lattice physics/core simulator methods for establishing the instantaneous cross-sections. Including the void history bias in the methodology negates the need for ensuring that each plant-specific application has sufficient margin available to account for the impact of the void history bias. Revise the nodal void reactivity coefficient biases and uncertainties and incorporate the void history biases. Provide sufficient technical details for the NRC staff to assess that the void history bias applied on a nodal level will

conservatively bound the non-conservatisms in the current assumptions for nodes depleting at high void conditions.

31. Section 3.1 of NEDE-32177P, “Licensing Topical Report, TRACG Qualification” (Reference 5), discusses the qualification of the TRACG void fraction predictions. FRIGG OF–64 tests simulate a full-scale 64-rod BWR fuel bundle. The test was designed as a full-scale simulation of an Oskarshamn-I fuel assembly, consisting of 64 heated rods placed in a 8x8 array. The test simulated a realistic and somewhat conservative (outlet peaked) BWR heat flux and the TRACG interfacial shear model void fraction prediction is compared against FRIGG OF-64 void fraction data.

    Table 3.1-1 of NEDE-32177 (Reference 5) shows the ranges of the FRIGG OF-64 test parameter ranges as follows:

Test Parameter	**Range**
Pressure (MPA)	4.8 and 6.8 MPa
Inlet Subcooling	9-38 K
Void Fraction	0-90%
Mass Flux	500 – 250 Kg/m2-s

    Table 3.1-4 of NEDE-32177 (Reference 5) provides the mean and standard deviation for TRACG Model based on the FRIGG OF-64 tests as follows:

Pressure (MPA)	**Mean**	**Standard Deviation**
4.8	2.1%	2.6%
6.8	0.6%	2.4%

    The following questions relate to the applicability of the TRACG qualification ranges for operation at EPU and MELLLA+ conditions.

    1. Tabulate the key thermal-hydraulic parameters (e.g., mass flux, pressure, void fractions, inlet subcooling) for the 10X10 GE14 within bundle conditions for operation at the EPU / MELLLA+ conditions, during steady state, transient, and accident conditions.

    2. Provide the qualification range and tests used to qualify the TRACG interfacial shear and model, if different than the above data.

Demonstrate that the qualification data supporting the TRACG interfacial shear model is applicable and acceptable for operation at EPU/MELLLA+ condition, during steady state, transient and accident conditions. Justify the accuracy of the void fraction predictions for the ranges in which qualification data is not available.

32. TRACG04 is coupled with PANAC11 for neutronic feedback. Specifically, the TRACG04 steady state power distribution is initialized using the PANAC11 predicted power distribution. PANACEA uses the Findlay-Dix void fraction correlation, while the TRACG thermal-hydraulic analysis relies on the interfacial shear model to predict the void

fraction. The NRC staff evaluated the Findlay-Dix correlation and determined that the database supporting the Findlay-Dix correlation is not well supported.

a. The NRC staff is concerned that the uncertainties associated with the correlation will result in additional uncertainty in the void coefficient model. Explain how the uncertainty in this correlation is accounted for in the TRACG04 analyses performed in the methodology described in Reference 3.

b. Propose a means of calculating the initial TRACG04 power and void distribution using the interfacial shear model (i.e., using PANAC11 cross sections but void and power distribution not initialized to the PANAC11 solution) and provide a code to code comparison of the "independent" TRACG04 solution to the TRACG04 solution initialized to the PANAC11 conditions (i.e., using Findlay-Dix void correlation).

c. Provide the data range used to develop the Findlay-Dix correlation and demonstrate that the experimental data covers the range of steady state, transient, EPU and expanded operating domains for which Reference 7 applies.

33. Section 7.5.2.7, "High Worth Scram Rods for Pressurization event OLMCPR," of NEDC-32906P (Reference 3) describes the initial conditions used to minimize the worth of the scram reactivity. Section 8.0 in Reference 3, "Demonstration Analysis," covers the bases for application of TRACG for AOO, using sensitivity analyses to establish the initial conditions and assumptions that will be applied on plant-specific bases. Section 8.2 in Reference 3, "Initial Conditions and Plant Parameter Review," defines the initial conditions that are demonstrated to have an impact the AOO response.

    Table 8-9 in Reference 3, "Allowable Operating Range Characterization Basis," list the key parameters that influence the AOO response. For the axial power shape, the table states that the cases are analyzed at nominal (top-peaked) end-of-cycle (EOC) conditions and at EOC bottom peaked conditions. For the control rod pattern, Table 8-9 of Reference 3 states that cases are analyzed at middle-of-cycle (MOC) with a nominal rod pattern and with a conservative black and white rod pattern.

    From this discussion, it is not apparent that for EPU and MELLLA+ operation, the assumed axial power shapes with exposure will be conservative relative to the nominal or planned operating control rod and core flow strategies. Specifically, considering the impact of TVAP, Reference 3 did not discuss why bottom and middle peaked or double hump power profile early in the cycle will not result in higher transient response. The following RAIs relate to the use of TRACG for EPU/MELLLA+ applications.

    1. For the plant-specific EPU/MELLLA+ application of TRACG04 to AOOs (References 3 and 5), demonstrate that the limiting control rod patterns assumed in the power history envelops and bounds the axial power peaking the plant will experience at different exposure ranges.

    2. Discuss how the limiting control rod patterns assumed as the core depletes minimizes the scram reactivity worth.

3. Provide an assessment of TVAP that would result from the scram during power profiles other than top-peaked.

REFERENCES:

1. NEDE-32176P, Revision 3, “TRACG Model Description,” April 2006.

2. NEDC-32596P, Revision 0, “TRACG04A,P User’s Manual,” eECPER-0000-0009-7162-00, UM-0136, Rev 0 Class 3, July 2005.

3. NEDE-32906P, Revision 2, “TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses,” February 2006.

4. NEDC-33239P, “GE14 for ESBWR Nuclear Design Report,” February 2006.

5. NEDE-32177P, Revision 2, “TRACG Qualification,” January 2000.

6. NEDC-33083P-A, “TRACG Application for ESBWR,” March 2005.

7. NEDE-32906P, Supplement 3, “Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients,” May 2006.

8. Vermont Yankee Nuclear Power Station - Draft Safety Evaluation for the Proposed Extended Power Uprate (TAC No. MC0761), October 21, 2005.

9. BVY 05-088 Letter, J. Thayer (Vermont Yankee) to NRC, “Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263, Supplement No. 35, Extended Power Uprate - Response to Request for Additional Information,” September 28, 2005. ADAMS Accession No. ML052770039.

10. NEDC-33173P, “Applicability of GE Methods to Expanded Operating Domains,” February 2006.

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