August 29, 2006

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

SUBJECT: FINAL SAFETY EVALUATION FOR GENERAL ELECTRIC NUCLEAR ENERGY (GENE) TOPICAL REPORT (TR) NEDE-32906P, REVISION 2, "TRACG APPLICATION FOR ANTICIPATED OPERATIONAL OCCURRENCES (AOO) TRANSIENT ANALYSES" (TAC NO. MD0249)

Dear Mr. Brown:

By letter dated February 14, 2006, GENE submitted TR NEDE-32906P, Revision 2, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," to the U.S. Nuclear Regulatory Commission (NRC) staff. By letter dated July 12, 2006, an NRC draft safety evaluation (SE) regarding our approval of TR NEDE-32906P was provided for your review and comments. By letter dated July 26, 2006, GENE commented on the draft SE. The NRC staff's disposition of GENE's comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter.

The NRC staff has found that TR NEDE-32906P is acceptable for referencing in licensing applications for boiling water reactor (BWR)/2, BWR/3, BWR/4, BWR/5, and BWR/6 designs to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

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

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

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, GENE and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

**/RA/**

Ho K. Nieh, Acting Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosure: Final SE

cc w/encl: See next page

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Sincerely,

**/RA/**

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cc w/encl: See next page

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**ADAMS ACCESSION NO.: ML062210315 *No major changes to SE input. NRR-106**

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# FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

# TOPICAL REPORT NEDE-32906P, REVISION 2

# "TRACG APPLICATION FOR ANTICIPATED OPERATIONAL

# OCCURRENCES (AOO) TRANSIENT ANALYSES"

# GENERAL ELECTRIC NUCLEAR ENERGY (GENE)

# PROJECT NO. 710

## 1.0 INTRODUCTION AND BACKGROUND

GENE and its subsidiary Global Nuclear Fuel (GNF) submitted TRACG02A (referred to hereafter as TRACG) for U.S. Nuclear Regulatory Commission (NRC) review for application to anticipated operational occurrence (AOO) transient events on January 25, 2000 (Reference 1). The submittal included the code model documents related to the TRACG code (References 2(a), 2(b), and 2(c)). The TRACG code is a thermal-hydraulic analysis code intended to be used as a realistic analysis model. The NRC staff approved TRACG for AOO transient events on October 22, 2001 (Reference 3). The approved topical report, NEDE-32906P-A, Revision 1, was provided by GENE on February 6, 2006 (Reference 4).

The TRAC family of codes began as a pressurized water reactor analysis code developed for the NRC at Los Alamos National Laboratory. A boiling water reactor (BWR) version of the code was developed jointly by the NRC and GENE at the Idaho National Engineering Laboratory as TRAC-BD1/MOD1 (Reference 5). GENE developed a proprietary version of the code designated as TRACG. The objective of the proprietary code development was to have a code capable of realistic analyses of transients, stability, and anticipated transients without scram events. The code was modified to include a three-dimensional kinetic model in addition to the multi-dimensional, two-fluid thermal-hydraulics models.

The plant types for which the TRACG code is to be applied include the BWR/2, BWR/3, BWR/4, BWR/5, and BWR/6 designs. This version of the code has not been submitted for review for application to any other plant design.

GENE submitted a proposed revision to TRACG, in a letter dated February 14, 2006 (Reference 6). GENE has corrected a small error in the quantification of the accuracy of the void coefficient, an element of the NRC-approved methodology used in TRACG licensing basis AOO analyses. GENE revised the discussion of item "C1AX Void Coefficient, H" in Subsection 5.1, "Model Parameters and Uncertainties" of NEDE-32906P-A, Revision 1. The responses to related NRC staff requests for additional information (RAIs) during the initial review, particularly RAI 13, were also revised to document the void coefficient correction. In addition, other non-technical changes were made to address typographical errors and provide additional clarifications. Because the error did not involve the model description or qualification

studies, there were no changes to the TRACG model and qualification reports (References 2(a) and 2(b)).

GENE supplemented the submittal in response to the May 31, 2006, NRC staff RAI (Reference 7) on June 7, 2006 (Reference 8).

## 2.0 REGULATORY AND TECHNICAL EVALUATION

TRACG uses a 3-dimensional neutron kinetics model to compute the needed neutronics parameters. The contribution of the change in the water density to the reactivity in a node is computed in terms of the infinite multiplication factor as a function of the void fraction and fuel exposure in the node (modeled volume).

The overall analysis approach to AOOs in NEDE-32906P followed the Code Scaling Applicability and Uncertainty (CSAU) analysis methodology (Reference 9). In the CSAU process, model uncertainty is derived from the propagation of individual model uncertainties through code calculations and experimental comparisons. The total uncertainty for a figure of merit is characterized by a bias and a standard deviation which allows for the computation of a "best-estimate" value with its uncertainty. This permits a more realistic comparison to regulatory acceptance criteria as opposed to the use of computed conservative values. One such individual model uncertainty of high significance is the void coefficient. The biases and uncertainties in the estimate of the void coefficient are predominantly due to biases and uncertainties in the infinite lattice eigenvalues ($k_4$) calculated with GESTAR II (Reference 10).

The TGBLA code is used to generate the cross section fits that are evaluated in TRACG. The biases and uncertainties associated with the TGBLA computed infinite multiplication factors were estimated by comparing the TGBLA results to those computed with the continuous energy Monte Carlo code MCNP (Reference 11). The accuracy of MCNP in predicting $k_4$ has been well established through numerous comparisons to critical experiments. While it is reasonable to assume that the MCNP computed void coefficient is the "true" value, the TRACG transient calculation uses TGBLA generated cross sections. Therefore, the approach used in TRACG required a correction factor based on the comparison of the TGBLA and the MCNP calculations of $k_4$.

The revised approach to the computation of the correction factor removes an artificially introduced void-fraction dependent variation in the bias and the variance of the correction factor to the TGBLA computed value. The NRC staff reviewed the revised void coefficient description in "C1AX Void Coefficient, H" of Subsection 5.1, "Model Parameters and Uncertainties" in TR NEDE-32906P, Revision 2, and the revised development of the bias and variance correction to the TGBLA computer void coefficient presented in the responses to RAI 13. The NRC staff finds the revised approach consistent with the standard methodology used for incorporating data from critical experiments (the "true" value) into core design calculations where the Monte Carlo computed values of $k_4$ are used to replace measured data from critical experiments.

GENE has revised Table 5-1, "Normality Test P-Values for the Void Coefficient Residual Errors," of NEDE-32906P, Revision 2, in response to the NRC staff's RAI. Table 5-1 was updated using the revised void coefficient correction factor to confirm the NRC staff's previous conclusion in Reference 3 that the "p-values for the Andersen-Darling statistic demonstrates the normality at the 5 percent level at each exposure-in-channel void fraction point."

GENE has revised Section 7.5.1, "Conformance with Design Limits," of TR NEDE-32906P, Revision 2, in response to the NRC staff's RAI. The revision clarifies the process by which the statistical results are used to compare key output values to design limits. Cases are defined where (1) the key output should be greater than the design limit and (2) where the key output should be less than the design limit.

GENE updated Section 7.6, "Statistical Analysis for Qualification Events," and Section 8.4.1, "Uncertainty Screening," of TR NEDE-32906P, Revision 2, as appropriate to evaluate the proposed revision to the calculation of the void coefficient correction factor. The comparisons of the TRACG results to typical licensing analysis data and the deviation from nominal at a ±1 sigma uncertainty were updated using the revised void coefficient correction factor. The correction in the void coefficient accuracy typically results in more conservative responses in the licensing analyses, and the TRACG results fall within the 2 sigma band. The NRC staff finds these results acceptable for licensing analyses.

## 3.0 CONCLUSION

GENE has documented the quantification of uncertainties as applied to realistic nominal results from TRACG analyses such that less than 0.1 percent of the fuel rods are expected to experience a boiling transition for the most severe AOO. The approach follows the accepted CSAU analysis methodology. GENE has quantified the uncertainties and biases in models associated with those identified and highly ranked phenomena based on experimental data and computation with validated codes. GENE's proposal to revise the computation of the void coefficient, a high ranked phenomenon, correction factor is acceptable. The revised approach to the computation of the correction factor removes an artificially introduced void-fraction dependent variation in the bias and the variance of the correction factor to the TGBLA computed value. The NRC staff finds the revised approach consistent with the standard methodology used for incorporating data from critical experiments (the "true" value) into core design calculations where the Monte Carlo computed values of $k_4$ are used to replace measured data from critical experiments. The process is acceptable and the quantities are reasonable. These together with the computed sensitivity estimates of the change in the critical power ratio with respect to variation in the model parameters indicate smoothness and stability in the solution to TRACG transient computations within the uncertainties in the models.

The conditions and limitations identified in Section 6.0 of the NRC staff's previous safety evaluation (Reference 3) are unchanged as a result of the proposed revision to the calculation of the void coefficient correction factor.

## 4.0 REFERENCES

1. Letter MFN 00-001 from J. F. Klapproth, Manager, Engineering and Technology, GE Nuclear Energy, to USNRC, "TRANSMITTAL OF GE PROPRIETARY LICENSING TOPICAL REPORT NEDE-32906P, ‘TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses,’ Revision 0, dated January 2000," January 25, 2000 (ADAMS Package Accession No. ML003681270).

2. (a) Letter MFN 99-40 from J. F. Klapproth, Manager, Engineering and Technology, GE Nuclear Energy, to USNRC, "TRANSMITTAL OF GE PROPRIETARY LICENSING TOPICAL REPORT NEDE-32176P, 'TRACG Model Description,' Revision 2, dated December 1999," December 15, 1999 (ADAMS Package Accession No. ML993630286).

(b) Letter MFN 00-002 from J. F. Klapproth, Manager, Engineering and Technology, GE Nuclear Energy, to USNRC, "TRANSMITTAL OF GE PROPRIETARY LICENSING TOPICAL REPORT NEDE-32177P/R2, 'TRACG Qualification,' Revision 2, dated January 2000," January 31, 2000 (ADAMS Accession Package No. ML003682927).

(c) Letter MFN 00-007 from J. F. Klapproth, Manager, Engineering and Technology, GE Nuclear Energy, to USNRC, "TRANSMITTAL OF GE PROPRIETARY REPORT NEDC-32956P, 'TRACG02A User's Manual,' Revision 0, dated February 2000," February 28, 2000 (ADAMS Package Accession No. ML003688295).

3. Letter from S.A. Richards, USNRC, to J.F. Klapproth, Manager, Engineering & Technology, GE Nuclear Energy, "Safety Evaluation Report on General Electric Nuclear Energy Topical Report NEDE-32906P, Revision 0, 'TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses'' (TAC NO. MA7779)," October 22, 2001 (ADAMS Accession No. ML012740161).

4. Letter MFN 06-042 from L.M. Quintana, Manager, Licensing, GE Nuclear Energy, to USNRC, "GE Licensing Topical Report NEDE-32906P-A, Revision 1, 'TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses'," February 6, 2006 (ADAMS Package Accession No. ML060390557).

5. NUREG/CR-3633, "TRAC-BD1/MOD1: An Advanced Best Estimate Program for Boiling Water Reactor Transient Analysis, Volumes 1-4," Idaho National Engineering Laboratory, April 1984.

6. Letter MFN 06-046 from L.M. Quintana, Manager, Licensing, GE Nuclear Energy, to USNRC, "GE Licensing Topical Report NEDE-32906P, Revision 2, 'TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses'," February 14, 2006 (ADAMS Package Accession No. ML060530560).

7. Letter from M.C. Honcharik, Project Manager, USNRC, to L.M. Quintana, Manager, Licensing, GE Nuclear Energy, "Request for Additional Information (RAI) Regarding General Electric Nuclear Energy (GENE) Topical Report (TR) NEDE-32906P, Revision 2, 'TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses' (TAC NO. MD0249)," May 31, 2006 (ADAMS Accession No. ML061450405).

8. Letter MFN 06-169 from L.M. Quintana, Manager, Licensing, GE Nuclear Energy, to USNRC, "Response to Request For Additional Information (RAI) Regarding General Electric Nuclear Energy (GENE) Topical Report (TR) NEDE-32906P, Revision 2, ‘TRACG Application For Anticipated Operational Occurrences (AOO) Transient Analyses' (TAC No. MD0249)," June 7, 2006 (ADAMS Package Accession No. ML061600297).

9. NUREG/CR-5249, "Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large-Break, Loss-of-Coolant Accident," December 1989 (ADAMS Package Accession No. ML030380503).

10. Letter from S.A. Richards, USNRC, to G.A. Watford, Manager, Nuclear Fuel Engineering, GE Nuclear Energy, “Amendment 26 to GE Licensing Topical Report NEDE-24011-P-A, “GESTAR II” Implementing Improved GE Steady-State Methods (TAC NO. MA6481), November 10, 1999.

11. Briemeister, J. G., Ed., "MCNP - A General Monte Carlo Code for Neutron, Photon and Electron Transport, Version 3A/3B/4," LA-7396-M, Los Alamos National Laboratory, 1986/Revisions 1988 and 1991.

Attachment: Resolution of Comments

Principle Contributor: E. Throm

Date: August 29, 2006

RESOLUTION OF COMMENTS

ON DRAFT SAFETY EVALUATION

FOR TOPICAL REPORT (TR) NEDE-32906P, REVISION 2,

"TRACG APPLICATION FOR ANTICIPATED OPERATIONAL OCCURRENCES (AOO)

TRANSIENT ANALYSES"

By letter dated July 26, 2006, General Electric Nuclear Energy (GENE) provided three comments on the draft SE for TR NEDE-32960P, Revision 2, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses." The following are the NRC staff's resolution of these comments:

GENE Comment:

In the third paragraph of Section 1.0 (lines 21-23), the statements regarding the TRACG code require some clarification. While not included in the scope of TR NEDE-32906P, the TRACG code has been submitted for review for several applications to the ESBWR design and already approved for certain applications to ESBWR.

NRC Resolution:

On page 1, line 22, the words at the beginning of the second sentence of the third paragraph of Section 1.0 have been changed from "This code..." to "This version of the code..."

GENE Comment:

The phrase, "The total uncertainty for a figure of merit is characterized by a bias and a standard error..." which begins the third sentence in the second paragraph of Section 2.0 (lines 17 & 18), is more correctly, "The total uncertainty for a figure of merit is characterized by a bias and a standard deviation...."

NRC Resolution:

On page 2, line 18, the phrase "standard error" has been replaced with the phrase "standard deviation."

GENE Comment:

The reference cited in the last sentence (lines 21-24) of the second paragraph of Section 2.0 and listed in Section 4.0, as Reference 10 was not included in the TR NEDE-32906P, Revision 2, submittal and is of a type not typically cited in safety evaluations. The use of TGBLA Version 06 and Panacea Version 11 was initiated following approval of Amendment 26 of GESTAR II. This reference or perhaps reference to the appropriate NRC staff techical audit

ATTACHMENT

report which documented staff review of the noted Reference 10 is suggested as an alternative citation.

NRC Resolution:

On page 2, lines 23 & 24, the words "the TGBLA lattice physics code" have been replaced with the words "GESTAR II." On page 5, lines 12 & 13, Reference 10 has been changed to replace reference to TGBLA with reference to Amendment 26 of GESTAR II.