UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

ACRSR-2189

April 21, 2006

Mr. Luis A. Reyes
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: APPLICATION OF THE TRACG COMPUTER CODE TO EVALUATE THE STABILITY OF THE ECONOMIC SIMPLIFIED BOILING WATER REACTOR

Dear Mr. Reyes:

During the 531st meeting of the Advisory Committee on Reactor Safeguards, April 5-7, 2006, we reviewed the staff's draft Safety Evaluation Report related to the use of the TRACG computer code to evaluate the stability of the Economic Simplified Boiling Water Reactor (ESBWR). This issue was reviewed by our Thermal-Hydraulic Phenomena Subcommittee on January 19 and March 14, 2006. During our reviews, we had the benefit of presentations by and discussions with representatives of the NRC staff and General Electric (GE). We also had the benefit of the documents referenced.

RECOMMENDATIONS

The staff should approve the use of TRACG to analyze the stability of the ESBWR during normal operation, anticipated operational occurrences, and the low-power phase of reactor startup.

DISCUSSION

TRACG has been validated for the analysis of anticipated operation occurrences in boiling water reactors (BWRs) and for loss-of-coolant accident analyses of the ESBWR. It has also been used as a basic computational tool for predicting the performance of BWRs in commercial service. It is currently under review for use in addressing stability-related issues for operating BWRs.

The question we addressed was whether TRACG can adequately model those ESBWR features that affect stability. The main difference between the ESBWR and current operating BWRs is the use of natural circulation, rather than forced circulation, to provide flow to the core during full-power operation. This leads to a number of design changes, including the use of a subdivided "chimney" section above the core.

Our evaluation was limited to the capabilities of TRACG to represent the major physical phenomena and was not a detailed assessment of the performance of an ESBWR.

Our review focused on several questions:

- How well does TRACG model the phenomena that have an important influence on ESBWR stability?

- Do the data from operating reactors and the test facilities accurately represent the phenomena that will exist in the ESBWR?

- Does TRACG adequately model two-phase flow in the chimney?

- Are the nodalization of the chimney and the associated computational scheme adequate to represent unsteady flow in the chimney?

- Does TRACG adequately model natural circulation oscillations?

- Are the predictions of pressure drop fluctuations in the core, the chimney, and other parts of the natural circulation loop reasonable?

- Is the interaction between criticality conditions and the void fraction, flow rate, and heat transfer fluctuations reasonably represented?

- Are the predicted transient responses and decay ratios credible?

In response, GE and the staff presented detailed calculations. There are several sources of data from operating BWRs that have experienced oscillatory behavior. Limited experimental data relevant to the ESBWR are also available. These data include void fraction measurements by Ontario Hydro in large-diameter pipes and transient tests at SIRIUS/CRIEPI which were specifically designed to model some features of the ESBWR.

GE presented several comparisons between TRACG predictions and data recorded at operating BWRs (Peach Bottom, La Salle, Leibstadt, and Dodewaard). These comparisons included scenarios during which the plants were operating at or close to natural circulation conditions. The comparisons indicated that the code has the ability to model the phenomena that are relevant to the ESBWR, and that it represents these oscillations with reasonable accuracy.

Based on comparisons with the Ontario Hydro tests, TRACG appears to provide a reasonable representation of the average void fraction in a large duct, such as the ESBWR chimney, as a function of flow rate and steam quality. At a meeting with our Thermal-Hydraulic Phenomena Subcommittee, GE also presented predictions for the ESBWR response to random void fraction fluctuations that were observed in some tests.

GE explored various nodalizations of the chimney. GE demonstrated that the computational scheme can describe void propagation without significant distortion, numerical diffusion, or artificial mixing. However, they presented other results which indicated that there could be significant numerical diffusion, leading to artificial attenuation of void waves, if the Courant number was not close to 1. GE was able to argue that the effects of this distortion were not significant for the particular case of the ESBWR response that they presented. However, GE and the staff will need to evaluate these effects carefully when more complete analyses are performed in support of the ESBWR design certification.

GE showed that TRACG modeled the main features of low-pressure (startup) oscillations observed in the CRIEPI/SIRIUS tests. These results were consistent with qualitative descriptions of the governing physical processes. High-pressure oscillations in CRIEPI/SIRIUS were also successfully modeled by TRACG. Natural circulation instability in the FRIGG tests, which used electrical heating and lacked the damping introduced by neutronic feedback in the ESBWR, was also successfully modeled by TRACG.

TRACG simulations of ESBWR transients displayed the usual density-wave oscillations that are familiar from BWR experience, but did not reveal significant natural circulation oscillations. GE and the staff provided detailed calculations and physical arguments to explain the absence of these oscillations to our satisfaction. This included presentation of the interaction between components of pressure drop and buoyancy fluctuations in components of the system. They also explained why criticality feedback tended to induce density-wave oscillations but suppress natural circulation oscillations.

The staff performed several useful confirmatory analyses. These included runs of the LAPUR and RELAP5 codes, and the use of a drift-flux void propagation model. In addition, the staff performed several sensitivity studies using TRACG to confirm the code's robustness. They also confirmed that the use of a low Courant number could lead to numerical diffusion.

On the basis of these detailed explanations we found the predicted transient responses to be credible and concluded that TRACG was able to model them adequately. We expect to consider them further during our review of the ESBWR design certification application.

Sincerely,

/RA/

Graham B. Wallis
Chairman

References:
1. Memorandum from David B. Matthews, Director, Division of New Reactor Licensing, Office of Nuclear Reactor Regulation, to John T. Larkins, Executive Director, Advisory Committee on Reactor Safeguards, “Draft Safety Evaluation for the Application of TRACG for ESBWR Stability,” January 12, 2006.
2. Memorandum from Frank M. Akstulewicz to Laura A. Dudes, Safety Evaluation by the Office of Nuclear Reactor Regulation, “Application of the TRACG Computer Code to Stability Analysis for the ESBWR Design — NEDE-33083P, Supplement 1,” March 28, 2006.
3. NEDE-33083P, Supplement 1, “TRACG Application for ESBWR Stability Analysis,” General Electric Nuclear Energy, December 2004.
4. NEDE-32176P, Rev. 2, “TRACG Model Description,” December 1999.
5. NEDE-33083P-A, “TRACG Application for ESBWR,” March 2005.

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