October 6, 2009

Dr. Mario V. Bonaca, Chairman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: RESPONSE TO THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS LETTER, DATED JULY 29, 2009, ON THE "APPLICABILITY OF TRACE THERMAL-HYDRAULIC SYSTEM ANALYSIS CODE TO EVALUATE THE ESBWR DESIGN AND RELATED MATTERS"

Dear Dr. Bonaca:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I would like to thank you for your July 29, 2009, letter that provided the Advisory Committee on Reactor Safeguards (ACRS or Committee) views on the staff's presentation of the applicability of the TRACE thermal-hydraulic system analysis code to the evaluation of the Economic Simplified Boiling-Water Reactor (ESBWR) design. Your letter was in response to discussions with the staff during the 564th meeting of the ACRS held on July 8-10, 2009. In this letter, we will address the ACRS conclusions and recommendations (listed here in bold) in the order they were presented:

1a. TRACE is applicable for confirmatory analyses of the blowdown and gravity-driven cooling system (GDCS) injection phases of ESBWR loss-of-coolant accidents (LOCAs). Its applicability to cases in which noncondensables may be trapped in the GDCS lines, as well as long term cooling, has not been demonstrated.

The NRC staff agrees that the applicability to cases with noncondensables has not been demonstrated. TRACE is currently intended for analyses based on expected design conditions, where it is assumed that noncondensables are not present. Assuming conditions that may result from beyond design basis operating conditions is not within the scope of the intended use of TRACE at this time.

In addition, the qualification of TRACE for those calculations would require assessment against test data that covers the range of geometries and flow conditions where trapping of noncondensables could occur in the plant. We are not aware of any available test data that simulates these conditions. If prediction of plant behavior with trapped noncondensable gases is found necessary, an applicant will be required to provide all necessary data.

Finally, there are a number of factors that should reduce the likelihood of operations with trapped non-condensables. During the review of the Design Certification Application for the ESBWR, the staff specifically discussed the potential for noncondensables to become trapped in the GDCS lines with the applicant. The applicant has stated that design features and procedural measures, or high point vents will be installed and monitored by plant procedure to preclude this condition from occurring. Because the potential for

trapping noncondensable gases is dependent on the “as built” configuration, NRC staff is developing Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) to further ensure that noncondensable gases cannot be trapped.

For all of these reasons, the staff does not believe it is necessary to assess TRACE for noncondensables in GDCS lines as part of the ESBWR review.

1b. [The applicability of TRACE] to cases of long-term cooling has not been demonstrated.

The purpose of the TRACE calculations presented at the July 8th meeting was to demonstrate that during the blowdown and recovery periods of a design-basis LOCA, the water level remains well above the top of the core. Although TRACE could be used to analyze long-term cooling, the calculations do not extend into this period because the safety injection flow exceeds the break flow. Therefore, at this time, demonstration of this behavior with the TRACE code is not considered necessary.

2. The capability of TRACE to predict the effect of trapped noncondensables in the GDCS and the resulting collapsed liquid level in the reactor pressure vessel should be assessed.

The staff agrees that the capability to predict the effect of trapped noncondensables in the GDCS and the resulting collapsed liquid level in the reactor pressure vessel is desirable for better understanding beyond design basis behavior, and may be pursued by the staff in its future development efforts. However, for the same reasons as described in our response to question 1a, the staff does not believe it is necessary to assess TRACE for noncondensables in GDCS lines as part of the ESBWR review.

3. The adequacy of TRACE and other analysis methods, such as MELCOR, used for confirmatory analyses of long-term cooling phase of ESBWR LOCAs should be evaluated.

With regard to TRACE adequacy, see the response to question 1b. The staff does not currently plan to use TRACE for confirmatory analyses of long term cooling for the ESBWR LOCAs.

MELCOR currently is used to evaluate containment phenomena (in particular, the peak containment pressure during the long-term cooling phase). The staff has performed assessments of MELCOR against containment tests to assure that MELCOR is suitable for this purpose and the ACRS is separately reviewing the MELCOR results and modeling approach. Some results were presented to the ESBWR Subcommittee last June, and more results are expected to be presented in an upcoming subcommittee meeting.

4. TRACE should be assessed for applicability to analyses of coupled neutronic and thermal-hydraulic phenomena important to safety, such as instabilities and anticipated transient without scram (ATWS), in the ESBWR design.

We agree with the ACRS that TRACE should be assessed for these accident scenarios, and the staff has been making progress toward achieving this goal. While applicability of

TRACE to coupled neutronics and thermal-hydraulic phenomena important to safety (such as instabilities and ATWS) was not within the scope of the July 8 meeting, the staff will be happy to discuss this subject at a mutually agreeable date in the future.

5. Ongoing work to demonstrate that TRACE is adequate for confirmatory analyses of LOCAs and other safety-significant thermal-hydraulic phenomena in the new pressurized-water reactor (PWR) designs should be completed in a timely fashion to allow application in the design certification process.

The staff maintains an active research program to ensure that tools are available for analysis of the phenomena of importance to safety in new and advanced LWR designs. We have completed a TRACE applicability report for the U.S. EPR and are nearing completion of applicability reports for the US-APWR. TRACE analyses of these designs will be discussed with the appropriate ACRS subcommittee consistent with the staff review schedules for these designs.

6. Uncertainties must be estimated in the prediction of primary figures of merit for regulatory decisionmaking for new reactor designs. A similar recommendation was made by the TRACE peer review group on the adequacy of TRACE for confirmatory analyses of LOCAs in current light water reactors (LWRs).

While the staff agrees that quantification of uncertainties in the prediction of primary figures of merit is desirable, we do not believe it is required in order for the staff to approve new reactor designs. The staff is currently in the initial stages of developing an uncertainty methodology for TRACE. Such a methodology, when completed, will assist the staff in better understanding TRACE predictions and will help in assessing the sensitivity of results to parameters of interest.

Demonstration of design safety is the responsibility of an applicant or licensee and to that end the applicant or licensee performs extensive analysis and predictions of primary figures of merit. The staff performs confirmatory calculations to gain insights into system behavior, to help guide the staff's review of applicants' analysis methods and design proposals or modifications, and to confirm that licensee analyses are reasonable. The staff also uses codes such as TRACE to perform confirmatory calculations so that meaningful questions can be asked regarding the performance of applicants' codes.

7. TRACE should be improved to properly formulate and solve the momentum equation when the flow changes direction and merges.

We do not agree with the ACRS' characterization of the momentum equations in TRACE when flow changes direction and merges. The problem is not that the momentum equations are solved improperly but rather that assumptions made during their derivation—and the numerical approximations that are used—lead to situations where irreversible pressure losses in certain mesh-related configurations are overpredicted. The staff has made great strides in either reducing or altogether eliminating these overpredictions depending upon the scenario of interest.

The staff is aware of the modeling limitations imposed by the current approach to solving the momentum equations. Such limitations are why TRACE is thoroughly assessed for

each application against relevant experiments while giving special consideration to aspects of any new application that may take the code outside of its normal range of applicability (e.g., natural circulation flows in ESBWR). We also provide specific user guidance to reduce possible modeling-induced errors resulting from these code limitations.

In addition, the staff routinely performs sensitivity calculations to assess the impact of any code limitation on safety-related figures of merit. The staff has assessed the impact of the overprediction of pressure drop at turns in the lower plenum and tees and found that the impact on safety-significant figures of merit is minimal.

We understand that the ACRS is concerned about the ability of TRACE to model flows in a vessel and appears to attribute the problem to the use of 1-D modeling. The staff notes that TRACE uses a 3-D approach in the vessel component, and within that region TRACE does treat momentum as a vector quantity. The root of the problem with correct prediction of pressure drops in vessels is not a question of missing the vector nature of momentum. The primary problem is related to the small number of volumes typically used to resolve turns in flow direction within the 3-D region, and the interaction of these volumes with averaging procedures built into the TRACE numerical methods. The corrections that the staff has made to improve results relate to changes in averaging procedures. These corrections reduce the magnitude of the problem (and in certain configurations, eliminate it entirely), and permit users to obtain reasonable results through the use of system-specific loss coefficients.

As has been discussed at previous ACRS meetings, the particular formulation of the momentum equation in TRACE is not the conservative form. However, we point out that momentum equations of the conservative[1] formulation are subject to the same mesh-size related errors mentioned in the last paragraph. The staff recommends investigating the use of the conservative form of the momentum equations as a way to resolve errors in momentum transfer associated with two-phase flow, particularly two-phase flow with very abrupt changes in local void fraction. The TRACE level tracking model also addresses this problem. Based on discussions with the peer review group, the staff believes this is consistent with the recommendations of those reviewers. During the peer review, formulation of the momentum equation was a specific review topic and improvements to TRACE were made based on the peer review group's findings. As part of the staff's revisions to TRACE, numerous test problems were generated to quantify potential deficiencies. These test problems showed the most significant errors occurred for single-phase liquids with high velocities, and verified that the revisions recently made to TRACE eliminated the significant errors. Simply switching from our current equation set to the conservative form will not significantly improve the pressure drop predictions.

The NRC staff supports the Committee's call to investigate reformulating the momentum equations into the conservative form. However, we must balance the need for this development with other desired improvements or modifications to TRACE. A revision of the momentum equations as proposed in your letter and by the peer review group is a major development effort that will require a significant amount of programming and

[1] In the discussion presented here , the use of the term "conservative" or "non-conservative" refers to the technical sense of conservation of momentum. This does not imply that one method of solving the momentum equation is more conservative from a reactor safety perspective.

verification and validation testing to ensure the capability is robust and ready for general use. Such an effort will need to be planned and prioritized consistent with other development needs.

The NRC staff appreciates the Committee's continued interest in TRACE, and we look forward to future interactions to review TRACE developments and assessments.

Sincerely,

/RA Martin Virgilio for/

R. W. Borchardt
Executive Director
for Operations

cc: Chairman Jaczko
Commissioner Klein
Commissioner Svinicki
SECY

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