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

September 24, 2008

The Honorable Dale E. Klein
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: DEVELOPMENT OF THE TRACE THERMAL-HYDRAULIC SYSTEM ANALYSIS CODE

Dear Chairman Klein:

During the 555th meeting of the Advisory Committee on Reactor Safeguards, September 4-5, 2008, we discussed the development of the TRACE thermal-hydraulic system analysis code and the outcome of the recently completed peer review. Our Subcommittee on Thermal-Hydraulic Phenomena also discussed this matter on July 7, 2008. During these meetings, we had the benefit of discussions with representatives of the NRC staff and of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

The peer review identified no major deficiencies that preclude the use of TRACE for confirmatory analyses of postulated loss-of-coolant accidents (LOCAs) in current light water reactors (LWRs). Several improvements have been recommended by the peer reviewers and the staff has proposed a plan to address them. We agree with the recommended improvements and endorse the staff's plan.

1. Significant progress has been made toward the incorporation of TRACE into the regulatory process.

2. Further peer review should be conducted to evaluate the applicability of TRACE to new LWR designs, as well as for analysis of coupled reactor physics-thermal hydraulics issues related to extended power uprates (EPUs) and expanded operating domains.

3. The capability to evaluate uncertainties in its predictions should be incorporated into TRACE.

4. Continued development of TRACE is necessary to keep pace with evolving industry capabilities.

BACKGROUND

Until the early 1970s, analyses of vapor-liquid flow and heat transfer in postulated accidents treated the fluids as homogenized mixtures and, therefore, could not capture some key phenomena such as countercurrent flows. To capture such safety-significant phenomena, multifield models were introduced in the late 1970s that conserved mass, momentum, and energy in each phase and coupled them by accounting for interfacial transfer of the conserved quantities. The NRC played a central role in bringing about these developments and codifying them in a series of computational tools: TRAC in its various versions for pressurized water reactors (PWRs) and boiling water reactors (BWRs), and RELAP5 which evolved as a multifield version of the mixture-model code series, RELAP.

In the mid-1990s, the NRC determined that the maintenance and further development of several versions of TRAC and RELAP5 were inefficient. A decision was made to consolidate the codes into one thermal-hydraulics code with improved capabilities based on TRAC, now called TRACE. In this report, we address the progress in the development, validation, documentation, and incorporation of TRACE into the regulatory process for confirmatory analyses.

While the NRC has been engaged in developing TRACE, development of RELAP5 has continued within its own user community and among various vendors, as has development of versions of TRAC, sometimes in combination with other codes such as COBRA. These efforts have yielded codes with extended capabilities, such as incorporation of droplet fields for reflood problems. As a result, some vendors already have advanced codes that go beyond the current capabilities of TRACE.

DISCUSSION

In our March 22, 2007, report, we recommended that the schedule for documenting and peer reviewing TRACE as well as its incorporation into the regulatory process be accelerated. The staff responded by documenting the then-current version of TRACE and submitting it for peer review. We commend the staff for its timely actions.

The peer review addressed whether there were major deficiencies in TRACE that would preclude its use in thermal-hydraulic analyses of postulated LOCAs and whether there could be significant errors in its predictions. Also, the peer reviewers recommended how the capabilities of the code could be improved.

The peer review has been completed. No major deficiencies were found that would introduce significant errors or preclude the use of TRACE for analysis of postulated LOCAs in current LWRs. Certain corrections were recommended for the momentum equations, which could be particularly important for passively cooled systems, though TRACE was not explicitly reviewed for applicability to such systems. Furthermore, the reviewers recommended revision and improvement of the user manual, development of user guidelines, and continuing assessment and development in certain specific areas, e.g., condensation during emergency coolant injection. We agree with the staff's plan to address these recommendations. In addition, the peer reviewers suggested incorporation of a separate droplet (and perhaps a separate bubble) field to improve the fidelity of simulations. The staff should evaluate whether its current efforts in this direction should be accelerated to keep pace with evolving industry capabilities.

The staff has achieved a major milestone in its development of TRACE. With the implementation of the recommended improvements, as the staff proposes to do, TRACE should have improved capability for conducting confirmatory analyses of LOCAs in current LWRs.

TRACE is now being used for performing small-break and large-break LOCA confirmatory analyses for the Browns Ferry Nuclear Plant EPU. Plant decks are also being prepared to assist EPU reviews of other BWR designs, as well as Westinghouse, Combustion Engineering, and Babcock & Wilcox PWRs. Analyses of anticipated operational occurrences (AOOs) and chimney instabilities for the economic simplified boiling water reactor (ESBWR) and assessments of applicability to other new reactor designs are in progress. Versions of TRACE coupled with the NRC-developed reactor physics code PARCS are being validated and incorporated into the regulatory process for analyses of transients where coupled thermal hydraulics-reactor physics calculations are required, such as AOOs and anticipated transient without scram (ATWS). This effort should be continued with high priority to facilitate further incorporation of TRACE into the regulatory process.

A second phase of peer review should be initiated to address the applicability of TRACE to the new LWR designs and the coupled reactor physics-thermal hydraulics issues that arise in EPU and expanded operating domains.

The development of TRACE will need to continue. The capability to economically evaluate uncertainties in its predictions should be incorporated into TRACE. The staff should propose a plan to achieve this objective, which we would like to review, and implement the necessary developments expeditiously.

As discussed previously, serious consideration should also be given to extending the capabilities of TRACE to incorporate dispersed fluid fields, which could improve its predictions of phenomena such as reflood and critical heat flux.

We commend the staff for the progress made in this difficult and important endeavor.

Sincerely,

/RA/

William J. Shack
Chairman

References:

1. Memorandum dated June 18, 2008, from Farouk Eltawila, Director, Division of Safety Analysis, Office of Nuclear Regulatory Research, to Frank Gillespie, Executive Director, ACRS, Subject: Transmittal of Support Documents for the TRACE Computer Code Briefing on July 7, 2008, (ML081640398) with enclosures.

2. Theory Manual (ML071000097).

3. Assessment Manual and Appendices A, B, and C (ML071200456, ML071200466, ML071200473).

4. Users Manual, Volume 1 (ML071200473) and Volume 2 (ML071720510).

5. Draft Reports from Peer Reviewers: Dominique Bestion (ML081640540), Peter Griffith (ML081640551), Marv Thurgood (ML081640564), and George Yadigaroglu (ML081640560).

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