ACRSR-2016

December 20, 2002

The Honorable Richard A. Meserve
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Dear Chairman Meserve:

SUBJECT: FRAMATOME ANP S-RELAP5 REALISTIC LARGE-BREAK LOSS-OF-COOLANT ACCIDENT CODE

During the 498th meeting of the Advisory Committee on Reactor Safeguards, December 5-7, 2002, we met with representatives of Framatome ANP and the NRC staff to review the Framatome ANP S-RELAP5 realistic large-break loss-of-coolant accident (LOCA) methodology and its application to pressurized-water reactor (PWR) accident analyses. Our Subcommittee on Thermal-Hydraulic Phenomena reviewed this matter during meetings held on January 16-18 and November 12-14, 2002. We also had the benefit of the documents referenced.

RECOMMENDATIONS

1. The S-RELAP5 code should be approved for application to realistic large-break LOCA analyses.

2. The staff should confirm that zirconium oxide spallation during a LOCA is not a significant phenomenon that needs to be modeled in realistic codes.

3. The staff should continue to accept the treatment of the break size as a statistical variable.

4. Future submittals of this code should include:

   - Improved documentation that can be more readily understood by technically knowledgeable reviewers
   - Assessment of the sensitivity of code predictions to terms in the momentum equations
   - Comprehensive nodalization studies

5. The staff should investigate ways to facilitate updating of the computer platforms on which approved codes can be run.

6. The staff should make independent audit calculations as part of the assessment of vendor codes. This will be facilitated when the TRAC-M code becomes operational.

DISCUSSION

Framatome ANP has developed a realistic or “best estimate” version of its large-break LOCA code, S-RELAP5. The code is based on the MOD2 and MOD3 versions of the NRC RELAP5 code. A realistic version of the code employs analytical models that more accurately describe the physics and reduces the need for conservative assumptions. Use of a realistic code requires an estimate of the uncertainty in the calculated results, as specified by a 1988 revision to the Emergency Core Cooling System Rule. Framatome has elected to follow the basic approach specified in the Code Scaling, Applicability, and Uncertainty (CSAU) Methodology and has chosen to employ the non-parametric order statistics methodology.

As part of its analysis of uncertainties, Framatome performed a comprehensive sensitivity analysis of the influence of parameters in the code. Those that proved to be important were included in a probabilistic analysis to determine with 95 percent confidence that the predicted Peak Cladding Temperature (PCT) would lie within the 95^{th} percentile of possible values. Framatome also showed that the other evaluation criteria, the degree of nodal clad oxidation and total maximum clad oxidation, would be satisfied with high probability. In performing this analysis, Framatome treated the break size as a statistical variable. We consider this novel approach appropriate because the “worst” break size is itself dependent on the particular choice of all of the other statistical parameters in the analysis.

The S-RELAP5 code is developed from the RELAP5 code, which has a history of thirty years of evolution and application. The staff has accepted the basis of the code and has performed an extensive review of its technical details, such as correlations for fluid mechanical phenomena and heat transfer. In some instances, the staff examined and evaluated parts of the source code itself. The staff also made independent assessments of the code using data from the 2D/3D LOCA test program and performed parametric studies of the effect of wall drag coefficients on the predicted PCT in a PWR. The staff also compared the code predictions against selected FLECHT-SEASET data. Their assessment of the code confirmed that it is acceptable for calculations of PCT following a large-break LOCA.

Although we support the staff’s assessment of S-RELAP5 for the large-break LOCA scenario, we continue to have difficulty understanding some features of the code from the documentation provided. While experience shows that the code works effectively, its theoretical basis and functional implementation should be made clear. Framatome has reassured us that this will be improved in later editions of the documentation, which we expect to review in association with future submittals. In particular, the development of the momentum equations is unclear and incomplete. Applications of these equations to nodes that are not components of one-dimensional ducts introduce significant distortion of the actual physics, which is reflected in approximations to several terms in the equations.

The success of the code in predicting integral system test results indicates that, for the purposes of large-break LOCA analyses, the PCT is insensitive to these approximations. However, this may not be true for other applications or other evaluation criteria. One way to assess whether the momentum equation in its present form is adequate is to apply multipliers, or correction factors, to the various terms, such as the inertia and momentum flux terms, to reflect the uncertainties that are known to exist in the physical modeling. Sensitivity studies can then be performed to see if these correction factors matter. If they do, then more precise models, or an appropriate statistical treatment of these uncertainties, may be required for some purposes.

The results obtained from codes are known to depend on the particular nodalization that is employed. For this reason, the shapes, numbers, and physical modeling of nodes are treated as an experimental process until an arrangement is found that satisfactorily predicts a chosen database. The nodalization is then frozen for application to a nuclear system. This prevents assessment of possible scaling effects that might be nodalization dependent. It is contrary to practice in other areas of computational fluid dynamics where nodalization of an actual system is systematically varied until adequate convergence is demonstrated. The present strategy is based on arguments of computational complexity and requirements for computer time that should no longer be valid. It would be more convincing to both the technically informed public and the users of the code if this convergence were to be more explicitly demonstrated. The staff should require such demonstrations in the future.

In the move to reduce conservatisms, it is important that the bounding of omitted, but pertinent, phenomena not be lost. In examining realistic LOCA models, the staff should ensure that the bounding of omitted phenomena has been retained, or that the previously omitted phenomena are now included in the analysis. An example that was revealed during our review of this application is the effect of oxide spallation and thermal shock on the kinetics of clad oxidation during a LOCA. Conservative Baker-Just oxidation kinetics (in some imperfect way) bound these unmodeled processes, whereas more realistic Cathcart-Pawel kinetics may not, particularly for high burnup fuel. The staff needs to confirm that the evaluation criteria are still met when these additional processes are evaluated, along with more realistic descriptions of the reaction kinetics.

We were surprised to learn that a major impediment to more extensive and thorough testing of the code is the difficulty of transferring it to up-to-date computer systems. The source of this difficulty is the quality assurance requirement for licensing codes imposed by Appendix B to Title 10, Part 50, of the *Code of Federal Regulations*. The staff should investigate ways in which this transfer can be facilitated.

The NRC has been developing the TRAC-M code by synthesizing and improving the capabilities of existing codes. The staff needs its own computer code in order to perform an independent audit of results obtained from proprietary vendor codes. TRAC-M was not used in this capacity to assess S-RELAP5 because it is not yet fully operational. There is a pressing need for TRAC-M to be made available, and for the staff to acquire experience with it, so that it can be routinely used for such purposes.

Sincerely,

/RA/

George E. Apostolakis
Chairman

<u>References</u>:

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7. Memorandum dated October 7, 2002, from Virgil E. Schrock, ACRS Consultant, Regarding Questions for Framatome on S-RELAP5.
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