ACRSR-2021

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Dr. William D. Travers
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: PRESSURIZED THERMAL SHOCK (PTS) REEVALUATION PROJECT: TECHNICAL BASES FOR POTENTIAL REVISION TO PTS SCREENING CRITERIA

Dear Dr. Travers:

During the 499th meeting of the Advisory Committee on Reactor Safeguards, February 6-8, 2003, we reviewed a draft report that the NRC's Office of Nuclear Regulatory Research (RES) staff has prepared to document its work to develop technical bases for revising the pressurized thermal shock screening criteria in the PTS rule (10 CFR 50.61). Our Subcommittee on Materials and Metallurgy also reviewed this matter on February 5, 2003. During our review, we had the benefit of discussions with representatives of the NRC staff and the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. The PTS Reevaluation Project has developed comprehensive technical bases for analyzing the susceptibility of reactor pressure vessels to PTS and to support rulemaking to revise the current PTS Rule 10 CFR 50.61. Plant-specific studies show that the current PTS screening criteria are very conservative for the given plants. This work may also provide a basis for reducing unnecessary conservatism in current regulation on operational limits on pressure vessel heatup and cooldown (Appendix G to 10 CFR Part 50).

2. The draft technical bases summary report needs substantial revision to describe more clearly the basic phenomena, issues, approaches, and conclusions. Topical reports on some important technical tasks have not yet been completed.

3. We support plans for an external peer review of the technical work.

DISCUSSION

The PTS Rule 10 CFR 50.61 was established to ensure the integrity of irradiation-embrittled reactor pressure vessels. Reactor pressure vessel steels undergo a transition from highly ductile behavior at high temperatures to brittle behavior at low temperatures. This change in behavior occurs abruptly over a narrow range of temperatures, and a temperature RT_{NDT} can be defined to characterize the transition in fracture behavior. Under irradiation, the transition temperature RT_{NDT} increases, making the vessel susceptible to brittle fracture at higher temperatures.

Estimation of the frequency of vessel failure requires (1) identification of sequences that could lead to rapid cooling of the vessel and estimation of their frequencies of occurrence; (2) determination of the pressure, temperature, and heat transfer coefficient adjacent to the embrittled portion of the vessel for each of the event sequences and use of these to determine the thermal stress on the vessel and the fracture toughness of the vessel material; and (3) probabilistic fracture mechanics analyses to determine the probability of failure under the induced thermal and pressure stresses on the embrittled vessel.

The studies conducted by the PTS Reevaluation Project to assess the frequency of vessel failure are much more comprehensive than those done in the early 1980s. These recent studies include systematic consideration of uncertainties in (1) the frequency of initiating events for PTS scenarios, (2) the thermal-hydraulic conditions that provide the driving forces for crack propagation and initiation, and (3) the assessment of the fracture toughness of the vessel materials. Substantial work has also been done to develop more realistic distributions for flaw density and geometry and improve the accuracy and rigor of the probabilistic fracture mechanics code, FAVOR, which is used in these analyses.

The results from detailed plant-specific studies of Oconee Nuclear Station, Unit 1; Palisades Plant; and Beaver Valley Power Station, Unit 1, show that the current PTS screening criteria are very conservative for these plants. Two of these plants are among the most susceptible to irradiation embrittlement in the reactor fleet. Moreover, the staff has presented good arguments as to why these results can be considered representative of the entire fleet of pressurized water reactors. The staff also currently has additional studies under way to further confirm the generic applicability of these results.

The distributions of the predicted vessel failure frequency are very broad. There are about three orders of magnitude between the 5th and 95th percentiles of the failure frequency. The distributions are also highly skewed, so that the mean and 95th percentiles are virtually identical. At embrittlement levels corresponding to the current screening criterion, the mean frequency of vessel failure is about 1×10^{-8}/year. This is a factor of about 500 lower than the current acceptance level. For plant lifetimes of 60-80 years, the predicted mean vessel failure frequencies will range from 5×10^{-10}/year to 5×10^{-8}/year.

Based on current estimates, 10 plants will be within 20°F of the current screening criteria at the end of their original 40-year licenses. Because the transition temperature increases about 1°F per year of operation, revision of the current PTS screening criteria could significantly impact the licensees decisions regarding whether to pursue license renewal for these plants.

The staff has concurred with our recommendation in our report of July 18, 2002, that a risk-informed acceptance criterion for vessel failure frequency should be based on considerations of large early-release frequency and not on core damage frequency. The scoping studies presented by the staff suggest that it is likely that the performance of containment systems after vessel failure will be adequate to ensure that a vessel failure frequency criterion of 1×10^{-6}/year will be adequate to ensure that the risk due to PTS is acceptably low. These studies also provide an approach for developing a risk-informed failure frequency criterion. Nevertheless, further consideration of the possibility of late containment failure may be needed and should be pursued if rulemaking is undertaken.

The documentation of the technical bases is currently inadequate and incomplete. Topical reports on some important technical tasks have not yet been completed. For example, no referenceable reports are available on the experiments and analyses that were performed to assess the potential for strong temperature gradients in the downcomer region near the beltline region that would invalidate the one-dimensional treatment of the thermal boundary conditions used in the probabilistic fracture mechanics analyses. Similarly, no referenceable reports are available on the studies undertaken at the University of Maryland that were used to develop a method to address thermal-hydraulic uncertainties, or to document the methods and approaches used for the probabilistic risk assessments used to determine the frequency of PTS events. A meaningful peer review cannot be performed without more complete documentation.

The draft technical bases summary document needs substantial revision to describe more clearly the basic phenomena, issues, approaches, and conclusions. Because this study synthesizes technical information from several engineering disciplines, it is important to explain how these disciplines interact and how the synthesis influences the conclusions. For example, the staff has identified a wide range of changes that reduce conservatism in the analyses. These include changes in the crack distribution model, finer binning of thermal-hydraulic sequences, removal of conservative bias in the toughness model, and crediting of operator actions. The staff also identified changes that increase the failure frequency, such as inclusion of medium and large-break loss-of-coolant accidents and errors of commission. The staff has shown that it has a good understanding of the relative importance of these various factors in producing the change in the predicted frequency of vessel failure. The staff has also made a systematic attempt to assess the impact of uncertainties. A clear explanation of which factors have the largest impact on the change in the predicted frequency of failure would focus attention on understanding those uncertainties that have the greatest impact.

The staff also needs to revise the discussion of the treatment of uncertainties. Although the studies have attempted to distinguish between aleatory and epistemic uncertainties and the FAVOR code implements methods that account for the different ways they impact the failure frequencies, the current document does not always make clear that the epistemic and aleatory uncertainties were correctly handled.

We commend the staff for an outstanding multidisciplinary study and look forward to reviewing the staff's final reports.

Sincerely,

/RA/

Mario V. Bonaca
Chairman

References:

1. Memorandum dated December 31, 2002, from Ashok C. Thadani, Office of Nuclear Regulatory Research, NRC, to Samuel J. Collins, Office of Nuclear Reactor Regulation, NRC, transmitting Draft NUREG-????, “Technical Basis for Revision of the Pressurized Thermal Shock (PTS) Screening Criteria in the PTS Rule (10CFR50.61),” December 2002.
2. Letter dated July 18, 2002, from George Apostolakis, ACRS Chairman, to William D. Travers, Executive Director for Operations, NRC, Subject: Risk Metrics and Criteria for Reevaluating the Technical Basis of the Pressurized Thermal Shock Rule.