



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

December 18, 2008

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

**SUBJECT: TECHNICAL BASIS AND RULEMAKING STRATEGY FOR THE REVISION OF  
10 CFR 50.46(b) LOSS-OF-COOLANT ACCIDENT EMBRITTLEMENT  
CRITERIA FOR FUEL CLADDING MATERIALS**

Dear Chairman Klein:

During the 558<sup>th</sup> meeting of the Advisory Committee on Reactor Safeguards, December 4-6, 2008, we reviewed the technical basis and rulemaking strategy proposed by the staff for revising the fuel cladding embrittlement criteria in 10 CFR 50.46(b). Our Subcommittee on Materials, Metallurgy, and Reactor Fuels also reviewed this matter on December 2, 2008. During these reviews, we had the benefit of discussions with representatives of the NRC staff, Electric Power Research Institute (EPRI), Westinghouse, AREVA, and Global Nuclear Fuels.

**CONCLUSIONS AND RECOMMENDATIONS**

1. There are sufficient data and understanding of the cladding embrittlement phenomena to justify and proceed with rulemaking.
2. The rule should include the proposed optional testing program to allow licensees to demonstrate compliance with post-quench-ductility (PQD) criteria on an alloy-specific and temperature-specific basis.
3. A round robin test program would be beneficial in the validation of the test procedures used to demonstrate compliance with PQD and breakaway-oxidation criteria.

**DISCUSSION**

In our report of May 23, 2007, we summarized the current understanding of the various phenomena governing the embrittlement of fuel cladding during loss-of-coolant accidents (LOCAs), the status of research in progress to resolve outstanding issues, and the deficiencies in current regulations. In addition, we provided recommendations for future work.

During our December 2008 meetings, the staff presented additional information and analyses supporting the decision to proceed with rulemaking concurrent with the completion of remaining research. We agree with this decision and the staff's proposed approach.

The planned rule would use performance-based regulatory requirements to ensure adequate cladding ductility. These new requirements are based on a sound understanding of the phenomena controlling cladding embrittlement and would be applicable over the full range of licensed burnups for both large-break and small-break LOCAs. The rule would permit the use of current and future zirconium alloys that meet the performance acceptance requirements without the need for exemptions.

A local oxidation requirement would establish a minimum PQD criterion of 1% plastic strain and define bounding equivalent cladding reacted (ECR) values and pre-transient cladding hydrogen concentrations below which the PQD criterion is met. An optional test program would allow licensees to demonstrate compliance with PQD criteria on an alloy-specific and temperature-specific basis.

In addition, a requirement addressing the breakaway-oxidation phenomenon would be established to ensure cladding ductility for small-break LOCAs. The breakaway-oxidation criterion would be met if the cladding did not absorb greater than 200 weight parts per million hydrogen, as demonstrated by prescribed laboratory tests.

Acceptable test procedures for demonstrating compliance with the PQD criterion and the breakaway-oxidation criterion would be detailed in other guidance. It is important that the reproducibility of these test procedures be validated. A round robin test program, in which identical materials are independently tested at different laboratories, would be beneficial to validate the proposed laboratory tests procedures.

The staff intends to issue an Advance Notice of Proposed Rulemaking (ANPR) in parallel with completion of remaining research. This research includes development of the test procedures to demonstrate compliance with the new criteria, completion of planned PQD tests in the intermediate hydrogen concentration range, and investigation of the influence of more prototypic time-temperature profiles on the breakaway-oxidation criterion.

The ANPR is a useful mechanism for the staff to solicit public input on specific topics and alternative formulations of a rule to address known safety issues. Some issues to consider for this proposed ANPR include:

- The need for the rule to address explicitly the phenomenon of breakaway oxidation rather than leaving this as a phenomenon to be addressed in evaluation models.
- The test procedures needed to demonstrate compliance with the requirements of the rule.
- The need for periodic testing to ensure that manufacturing processes have not changed in a manner to increase susceptibility to breakaway oxidation.

Although industry representatives agree with the staff on many technical matters, they continue to have objections to certain positions currently taken by the staff. These objections have merit and will be addressed in the rulemaking process. Specifically, EPRI and industry are performing tests and analyses to demonstrate that:

- High burnup cladding embrittlement is ameliorated by the much lower peak temperatures calculated for this cladding in a large-break LOCA. Thus, the rule should permit lower temperature testing to demonstrate PQD of such fuel.
- Requirements to use two sided oxidation and assumptions of fuel-to-clad bonding are overly restrictive and not supported by data.
- Rule mandated periodic testing to demonstrate breakaway-oxidation resistance of fuel cladding is not justified since tests of modern cladding alloys used in U.S. reactors show significant margin.

The staff should proceed expeditiously with the formulation of draft rule language, identification of specific questions to be included in the ANPR, and completion of remaining research.

Dr. Shack did not participate in the Committee's deliberations regarding this matter.

Sincerely,

*/RA/*

Mario V. Bonaca  
Vice Chairman

References:

1. U.S. Nuclear Regulatory Commission, Argonne National Laboratory, NUREG/CR-6967, ANL-07/04 Cladding Embrittlement During Postulated Loss-of-Coolant Accidents, M. Billone, Y. Yan, T. Burtseva, R. Daum, July 31, 2008 (ML082130389)
2. Report from Mario V. Bonaca, Vice Chairman, Advisory Committee on Reactor Safeguards, to Chairman Dale E. Klein, Chairman, U.S. Nuclear Regulatory Commission, "Proposed Technical Basis for the Revision to 10 CFR 50.46 LOCA Embrittlement Criteria for Fuel Cladding Materials," May 23, 2007 (ML0714306393)

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