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

ACRSR-2154

September 23, 2005

Luis A. Reyes
Executive Director for Operations
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REPORT ON A PROPOSED TECHNICAL BASIS FOR REVISION OF THE EMBRITTLEMENT CRITERIA IN 10 CFR 50.46

Dear Mr. Reyes:

During the 525th meeting of the Advisory Committee on Reactor Safeguards (ACRS), September 8-10, 2005, the staff made a presentation concerning a proposed technical basis for revision of the embrittlement criteria in 10 CFR 50.46. Our Reactor Fuels Subcommittee also heard a presentation on this matter during a meeting on July 28, 2005. During these reviews, we had the benefit of discussions with representatives of the staff, the Electric Power Research Institute, Westinghouse, and Framatome. We also had the benefit of the document referenced.

RECOMMENDATIONS

- The requirements of 10 CFR 50.46(b) concerning the coolability and geometric integrity of a reactor core during a design-basis loss-of-coolant accident (LOCA) and the aftermath of such an accident should be updated to facilitate the use of better reactor materials and improved understanding of phenomena and processes that affect core integrity and core coolability.
- The updated requirements should be written at a high level so that they are as technology-neutral and materials-neutral as practicable. Methods acceptable to the staff for demonstrating that specific cladding materials meet the high-level requirements of the regulations should be described in regulatory guides.
- The process developed by the staff for the qualification of zirconium alloy cladding provides a basis for a regulatory guide for such materials. The research needed to validate this process should be completed.

DISCUSSION

Regulations dealing with reactor core behavior during design-basis LOCAs (10 CFR 50.46(b)) require that core coolability be maintained during the accident and its aftermath. Coolability can be maintained if the overall core geometry is maintained and reactor fuel is retained within the fuel cladding, which may be “ballooned” and even ruptured. These requirements for core coolability can be achieved if the fuel cladding is not extensively embrittled and retains some ductility once cooled.

Regulatory requirements to achieve these ends are written currently with reference to specific cladding materials (Zircaloy and ZIRLO) and particular oxidation rate correlations. Since the regulations were written, technology has progressed and our understanding of accident

phenomena has advanced. New cladding materials are being introduced that allow fuel to be taken safely to higher levels of burnup. Because of the material specificity of the current regulations, exemption requests must be prepared by licensees and reviewed by the NRC staff to take advantage of the newer, better materials. Fortunately, these additional burdens have not stifled the adoption of newer, better fuel cladding, though the potential for such inhibition exists. This is, of course, the danger posed by anachronistic safety regulations. They can create burdens that inhibit licensees and even regulators from adopting improved technology and forego opportunities for having safer nuclear power plants.

The NRC's Office of Nuclear Regulatory Research (RES) has undertaken, in cooperation with the nuclear industry, a confirmatory research program to understand the behavior of fuel cladding at the higher levels of fuel burnup that are becoming common within the nuclear power industry. This research has identified new mechanisms of cladding embrittlement and has improved the understanding of embrittlement mechanisms known at the time the current regulations were written. Based on these early research findings, the RES staff is proposing a revision to the embrittlement criteria that support the regulations that would eliminate reference to specific types of zirconium alloy cladding. The proposed changes would include in the revised regulation a six-step process for the qualification of new fuel cladding:

(1) Determine the extent of oxidation, at 1477 K, of unirradiated cladding that reduces residual ductility to a critical level (nominally 2%), when measured at 408 K.
(2) Determine the time to "breakaway" oxidation rates at lower temperatures (about 1073-1477 K) during accident transients.
(3) Establish the corrosion kinetics of cladding during normal operations.
(4) Calculate the extent of cladding oxidation, including pre-existing corrosion, during design-basis LOCAs accidents to show that residual ductility is retained.
(5) Assure that the duration of cladding exposure to high temperatures in excess of about 1073 K do not lead to "breakaway" oxidation and the absorption of hydrogen that will exacerbate embrittlement during clad cooling.
(6) Use the Cathcart-Pawel correlation for the analysis of the kinetics of steam oxidation of zirconium alloy cladding.

The proposed changes to the embrittlement criteria have a good technical foundation. They would be relatively easy to implement and would not result in major changes to current practices by either the licensee or the regulatory staff. The proposed changes are supported by several representatives of the nuclear industry.

To be sure, the proposed changes to the current regulatory requirements do eliminate reference to specific cladding materials. However, any particular requirements for qualification of cladding may well become anachronistic and burdensome as technology improves and technical understanding advances in the future. Utilization of reactor fuel to ever higher burnups yields both economic and societal benefits. Development of new cladding materials to facilitate this trend in fuel usage is anticipated to continue. Certainly, industry representatives have assured us that new cladding alloys are under development and will be introduced to the fuel market before current plant licenses and extended licenses expire. It would be better to revise the current regulations at a high level, emphasizing the safety needs for retention of coolability

and core geometry without codifying methods for qualifying specific fuel claddings based on currently available clad materials and current understanding of the phenomena and processes that affect these materials. Methods acceptable to the staff for the qualification of specific reactor materials and reactor technologies can be developed in regulatory guides.

There is not an urgent safety issue prompting this recommendation for updating the regulations. Current discussions of other aspects of 10 CFR 50.46 make it opportune to consider proposed changes at the high level advocated here.

The database that supports the proposed steps for the qualification of zirconium-based cladding alloys is not extensive. Further investigations are warranted and are being proposed in the cooperative research effort being undertaken by RES and the nuclear power industry. We suggest also that the staff:

- consider requiring that clad oxidation and measurements of residual ductility be done with hydrogen-loaded cladding alloys that better replicate clad that has been exposed to normal operating conditions prior to an accident, and
- investigate the effects on ductility of clad cooling or quenching in tests versus the cooling rates in hypothesized design-basis LOCA.

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

Sincerely,

/RA/

Graham B. Wallis
Chairman

Reference:
R. Meyer, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," September 8, 2005 (Power Point Slides)

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