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

ACRSR-2246

April 23, 2007

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

SUBJECT: REVISION 3 TO STANDARD REVIEW PLAN SECTION 4.2, "FUEL SYSTEM DESIGN"

Dear Mr. Reyes:

During the 541st meeting of the Advisory Committee on Reactor Safeguards, April 5-7, 2007, we reviewed Revision 3 to NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 4.2, "Fuel System Design." Our Subcommittee on Materials, Metallurgy, and Reactor Fuels previously reviewed this matter on April 3, 2007. During these reviews, we had the benefit of discussions with representatives of the NRC staff, industry, and of the documents referenced.

RECOMMENDATIONS

1. We concur with the issuance of Revision 3 to SRP Section 4.2, "Fuel System Design," including the interim criteria in Appendix B, but have the following recommendations for improvements to Appendix B before issuance of the final criteria.

2. The methodology used to adjust the reactivity initiated accident (RIA) experimental data to account for differences between test reactor conditions and power reactor conditions should be justified before the final criteria in Appendix B are developed.

3. A clearer rationale should be supplied to justify the pellet cladding mechanical interaction (PCMI) limit line before the final criteria in Appendix B are developed.

DISCUSSION

Revision 3 to SRP Section 4.2 is a comprehensive update addressing safety issues associated with fuel design and analysis. The guidance addresses several new issues identified by the staff from operating experience, research, and reviews of advanced fuel designs and cladding materials.

With the exception of Appendix B, the SRP Section is in its final form. Because the staff has concluded that there are no RIA safety concerns with currently operating plants, the interim criteria will be applied only to new plants. Also, it is important to note that the majority of the fuel cladding in operating plants has significantly greater corrosion and hydriding resistance than older cladding materials and should be more resistant to failure during RIAs.

The staff plans to reevaluate the interim criteria and guidance in light of new RIA test data that are expected to become available over the next 18 months, and to issue final criteria in revisions of Regulatory Guides 1.77, 1.195, and 1.183. At that time the staff will determine the appropriate implementation schedule for operating plants.

The staff and industry agree on the need for new RIA failure criteria that better account for high burnup fuel behavior. They also agree on the PCMI mechanisms controlling RIA failures. These failures are controlled by the rapid thermal expansion of the fuel pellet during the RIA transient and the reduced ductility of the fuel cladding due to corrosion and hydriding during normal operation. Therefore the interim criteria relate the threshold fuel enthalpy change capable of failing fuel to the hydrogen concentration in the fuel cladding.

We concur with the revision to SRP Section 4.2 but have recommendations for improvements to Appendix B before issuance of the final criteria. The first relates to the uncertainties in the methods used to adjust the experimental data for differences between test reactor and power reactor conditions. The second relates to the rationale used to establish the PCMI limit line.

RIA data from test reactors are not generally applicable to power reactors without adjustment. Factors that must be addressed in making adjustments include: differences between test reactor and power reactor RIA pulse widths, differences in cladding ductility at test reactor and power reactor temperatures, differences in the properties of uranium dioxide and mixed oxide fuels, and differences in the ductility of fuel cladding due to oxide scaling. The staff has made adjustments to the experimental data using its own fuel behavior models. Industry has applied models developed by the Electric Power Research Institute to adjust the same data analyzed by the staff and found significantly larger corrections to the data. These differences need to be explained.

The adjusted experimental data are used to define a limit line marking the boundary between failed and intact fuel. The limit line is used as the failure criterion. While it may be possible to theoretically establish asymptotic values for the limit line at very low and very high corrosion/hydride values, the paucity of experimental data makes it difficult to define a unique limit line, particularly in the mid-burnup region. Additional data will be needed to increase confidence in the selected limit line. The methodology used to adjust the experimental data and to define the limit line, as well as the uncertainty associated with the predicted failure limits, should be justified before the final RIA criteria are established.

Appendix B includes two new criteria that are not currently applied to fuel in operating plants:

1. Mechanical energy generated as a result of (a) non-molten fuel-to-coolant interaction and (b) fuel rod burst must be addressed with respect to reactor pressure boundary, reactor internals, and fuel assembly structural integrity.

2. There should be no loss of coolable geometry due to (a) fuel pellet and cladding fragmentation and dispersal or (b) fuel rod ballooning.

Methods to demonstrate compliance with these new criteria will need to be developed.

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

Sincerely,

/RA/
Mario V. Bonaca
Acting Chairman

References

1. Memorandum from Thomas O. Martin, Director, Division of Safety Systems, NRR to Frank P. Gillespie, Executive Director, ACRS/ACNW, Subject: Transmittal of Proposed Revision to Standard Review Plan NUREG-0800 Section 4.2, Rev. 3, "Fuel System Design," dated February 22, 2007.

2. Letter from James H. Riley, Director, Engineering, Nuclear Generation Division, Nuclear Energy Institute, to Chief, Rules and Directives Branch, NRC, Subject: Interim Acceptance Criteria in an Upcoming Revision to the NUREG-0800, Standard Review Plan, Section 4.2, "Fuel System Design," dated March 5, 2007.

3. International Conference on Advances in Nuclear Power Plants 2006, Paper 6111, Authors: Charles L. Beard, David B. Mitchell, William H. Slagle, Subject: RIA Limits Based on Commercial PWR Core Response to RIA," June 4-8, 2006.

4. Memorandum from Ralph Landry, Acting Chief, Nuclear Performance and Code Review Branch, NRR, to Thomas Martin, Director, Division of Safety Systems, NRR, Subject: Technical and Regulatory Basis for the Reactivity-initiated Accident Interim Acceptance Criteria and Guidance," dated January 19, 2007.

5. Memorandum from Ashok C. Thadani, Director, Office of Nuclear Regulatory Research, to James E. Dyer, Director, Office of Nuclear Reactor Regulation, Subject: Research Information Letter No. 0401, An Assessment of Postulated Reactivity-initiated Accidents for Operating Reactors in the U.S., dated March 31, 2004.

6. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.77, "Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors," May 1974.

7. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.195, "Methods and Assumptions for Evaluating Regulatory Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors," May 2003.

8. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000.

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

Sincerely,
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Mario V. Bonaca
Acting Chairman

References

1. Memorandum from Thomas O. Martin, Director, Division of Safety Systems, NRR to Frank P. Gillespie, Executive Director, ACRS/ACNW, Subject: Transmittal of Proposed Revision to Standard Review Plan NUREG-0800 Section 4.2, Rev. 3, "Fuel System Design," dated February 22, 2007.

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