ACRSR-2010

October 17, 2002

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

Dear Chairman Meserve:

SUBJECT: CONFIRMATORY RESEARCH PROGRAM ON HIGH-BURNUP FUEL

During the 496th meeting of the Advisory Committee on Reactor Safeguards, October 10-12, 2002, we met with representatives of the NRC's Office of Nuclear Regulatory Research (RES) to discuss their confirmatory research program on high-burnup fuel, as well as research they do to support safety regulation of dry cask storage of spent fuel including high-burnup fuel. We also met with representatives of the NRC's Office of Nuclear Reactor Regulation to discuss their plans to review an EPRI topical report on the response of high-burnup fuel to reactivity insertion events. Our Subcommittee on Reactor Fuels met on October 9, 2002, to review these topics in detail and to discuss with representatives of EPRI their work to define fuel failure criteria and coolability criteria for high-burnup fuel exposed to reactivity transients. We also had the benefit of the referenced documents.

**CONCLUSIONS**

- RES has a well-organized and leveraged program of confirmatory research on the behavior of high-burnup fuel under the conditions of reactivity insertion events in pressurized water reactors, design-basis loss-of-coolant accidents (LOCAs), and anticipated transients without scram in boiling water reactors. RES has also undertaken research on creep of high-burnup fuel cladding to support safety regulation of dry cask fuel storage.

- A consensus has emerged that the energy input that will rupture fuel cladding in a reactivity insertion event is much less than that implied by the criteria in existing regulatory guides and decreases with increasing fuel burnup at least above 40 GWd/t.

- RES is nearing resolution of the issues of reactivity insertion events in high-burnup fuel and has initiated experimental investigations of high-burnup fuel under conditions of design-basis LOCAs. We remain concerned that the time-temperature conditions used in the study of high-burnup fuel during design-basis LOCAs may not reveal phenomena unique to high-burnup fuel.

**DISCUSSION**

There are economic and societal incentives to use nuclear fuel to higher levels of burnup. Burnup levels now approved exceed the data bases underlying the models that are used to predict fuel behavior under upset and design-basis accident conditions. French and Japanese tests of high-burnup fuel have shown cladding failure and even fuel dispersal during reactivity insertions at energy levels substantially below the criteria found in Regulatory Guide 1.77.

RES has undertaken a research program to confirm that the current limit on fuel burnup (62 GWd/t) ensures adequate protection of the public health and safety. A research program of experimental and analytic research involving the collaboration of NRC, EPRI, and numerous foreign partners has been organized. Risk-informed methods have been used to select issues of high-burnup fuel to investigate. The program addresses high-burnup fuel behavior under conditions of design-basis LOCAs and boiling water reactor anticipated transients without scram, as well as reactivity insertion events in pressurized water reactors.

RES has upgraded the fuel behavior computer code (FRAPTRAN) and neutron transport code (PARCS) available for regulatory analysis of high-burnup fuel. It has also completed detailed phenomena identification and ranking studies for high-burnup fuel under a variety of conditions. In addition, RES has participated with its foreign partners in the continued experimental study of reactivity transients in high-burnup fuel.

Analyses of data on high-burnup fuel behavior during reactivity transients have progressed in many quarters, including within the RES program and independently by EPRI. It is now broadly accepted that the energy input necessary to fail fuel in a reactivity transient is much less than the criterion in Regulatory Guide 1.77. At least for burnups greater than 40 GWd/t, the energy needed to fail fuel decreases with increasing fuel burnup. This sensitivity to sudden energy inputs is thought to be attributable to embrittlement of the fuel cladding. RES is also showing with realistic analyses that design-basis reactivity transients do not produce energy inputs of the magnitude and speed necessary to fail cladding embrittled at burnups less than 62 GWd/t.

RES anticipates that with the aid of 2 or 3 additional inpile tests in France’s CABRI reactor and tests at elevated temperatures in Japan’s NSRR, it will be able to quantitatively characterize the degradation of the capacity of fuel to sustain sudden energy inputs with increasing fuel burnup. RES is pursuing both empirical and mechanistic pathways to develop this characterization.

Controversy still exists within the reactor fuel community on whether distinct burnup-dependent criteria should be developed for fuel cladding rupture and for the energy input sufficient to cause loss of coolable configuration of the fuel. RES currently supports a single criterion for fuel failure that would also be conservative for coolability, whereas EPRI has proposed the continued use of separate criteria.

Recently, RES initiated out-of-pile tests of individual fuel rod segments under conditions of design-basis LOCAs. The objective is to replicate with high-burnup fuel the investigations of fresh cladding behavior that were the bases for the so-called “embrittlement” criteria specified in 10 CFR 50.46 and Appendix K. These tests involve monotonic heatup of fuel rods to a limiting temperature (2200°F) and monotonic cooling and quenching. We remain concerned that other safety-significant phenomena, such as spallation of pre-existing oxide from the cladding, may be important for high-burnup fuel and may be revealed only when more complicated, and realistic, time-temperature conditions are used in the tests. The single rod segment tests will not reveal features of high-burnup fuel behavior that arise when multiple rods are present.

The behavior of high-burnup fuel during anticipated transients without scram has become a topic of particular interest as power uprates have shortened the time available for operators to respond to the transients in boiling water reactors. Analyses done to date show that high energy inputs can occur during power oscillations in these transients, but the power inputs occur too slowly to produce intense pellet-clad mechanical interactions that threaten cladding integrity. This analytic finding appears to be substantiated by a recent test in Japan's NSRR.

We conclude that the confirmatory research program for high-burnup fuel is well-designed and is making good progress in light of the challenges of inpile and out-of-pile tests with fuel irradiated to high levels of burnup. We remain supportive of this program.

We recognize that this confirmatory research program is not addressing the risk consequences of taking fuel to high levels of burnup. These consequences will be examined in planned studies of high-burnup fuel in beyond design-basis accident conditions. We look forward to hearing about RES plans to explore this important aspect of high-burnup fuel in nuclear power plants.

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

Sincerely,

**/RA/**

George E. Apostolakis
Chairman

References:

1. Memorandum dated July 6, 1998, from L. Joseph Callen, Executive Director for Operations, NRC, to the Commissioners, Subject: Agency Program Plan for High Burnup Fuel.
2. Nuclear Energy Institute, EPRI Report 1002865, "Topical Report on Reactivity Initiated Accidents: Bases for RIA Fuel Rod Failures and Core Coolability Criteria," June 12, 2002.
3. U. S. Nuclear Regulatory Commission, NUREG/CR-6742, "Phenomenon Identification and Ranking Tables (PIRTs) for Rod Ejection Accidents in Pressurized Water Reactors Containing High Burnup Fuel," August 2001.
4. U. S. Nuclear Regulatory Commission, NUREG/CR-6743, "Phenomenon Identification and Ranking Tables (PIRTs) for Power Oscillations Without Scram in Boiling Water Reactors Containing High Burnup Fuel," August 2001.
5. U. S. Nuclear Regulatory Commission, NUREG/CR-6744, "Phenomenon Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel," August 2001.

6. U. S. Nuclear Regulatory Commission, NUREG/CR-6739, Vol. I, “FRAPTRAN: A Computer Code for the Transient Analysis of Oxide Fuel Rods,” August 2001.
7. U. S. Atomic Energy Commission, Regulatory Guide 1.77, “Assumptions Used for Evaluating A Control Rod Ejection Accident for Pressurized Water Reactors,” May 1974.
8. Letter dated March 14, 2002, from George E. Apostolakis, ACRS Chairman, to William D. Travers, Executive Director for Operations, NRC, Subject: Confirmatory Research Program on High-Burnup Fuel.