UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

June 15, 1998

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Dear Chairman Jackson:

SUBJECT: NRC REACTOR FUELS RESEARCH PROGRAM

During the 453rd meeting of the Advisory Committee on Reactor Safeguards, June 3-5, 1998, we discussed with the NRC staff the proposed plans for the NRC research program on reactor fuels. Our Subcommittee on Reactor Fuels also discussed this program during a meeting on April 23-24, 1998. We also had the benefit of the document referenced.

BACKGROUND

There are large economic incentives for licensees to extend the burnup of reactor fuels. Extended reactor fuel burnup also has significant societal benefits. It is not surprising, then, that over the last two decades fuel burnups at discharge from reactor cores have more than doubled. Today, some nuclear units are approved to extend burnup to 62 GWd/t (peak rod average). The nuclear industry has indicated an interest in further extending fuel burnups to as high as 75 GWd/t. The nuclear industry is currently reluctant to go to yet higher burnups, since fuel enrichments in excess of 5% would be required.

In the past, the NRC maintained an active experimental research program to study the performance of reactor fuels under accident and off-normal conditions. The NRC developed codes (FRAPCON and FRAPTRAN) for predicting changes in fuel and fuel cladding with burnup and these codes are used in reviewing and approving licensee proposals for core reloads. This research program enabled the NRC to establish fuel performance criteria. Licensees were expected to perform analyses and tests needed to demonstrate that their fuel met these criteria. Funding reductions and the press of other needs forced the NRC to curtail its fuel performance research at a time when the experimental database extended to only about 33 GWd/t. Similarly, models of fuel and cladding properties were restricted to this limited database. Although the models were developed based on a database for low burnup fuels, they would still be acceptable at higher burnups if there were no significant changes in the fuel or the cladding.

Unfortunately, changes do occur in fuel and cladding starting at burnups in the vicinity of 50 to 60 GWd/t. The fuel develops a high porosity "rim" of low thermal conductivity. The cladding can undergo rapid or "breakaway" oxidation. Zirconium hydrides precipitate and embrittle the cladding. The effects of these changes in high burnup fuels have been demonstrated in French and Japanese tests of high burnup fuel behavior during reactivity insertions such as might be caused by design-basis control rod ejection accidents or control rod drop accidents. Cladding rupture and fuel dispersal were observed in the tests at energy inputs of 1/3 to 1/10 the levels expected based on current regulatory guides. Analyses of the test results show that cladding oxidation and embrittlement are important contributors to the poor fuel performance. These findings raise questions about the capacity of high burnup fuel to survive other design-basis accidents such as loss-of-coolant accidents (LOCAs) and anticipated transients without scram (ATWS). The test findings and operational events, such as control rod sticking and axial distortion of the neutron flux in reactor cores, show that high burnup fuel does not behave in ways anticipated by simple extrapolation of data for lower burnups. The problems are made more complicated by some evidence that the route to high burnup as well as the burnup level may affect fuel performance.

Regulatory response to these findings has been to limit burnups to 62 GWd/t. The Office of Nuclear Reactor Regulation (NRR) has concluded that the degradation of fuel and cladding at these burnups does not pose a significant threat to the public health and safety. The Office of Nuclear Regulatory Research (RES) has been asked to conduct research to confirm this regulatory decision. RES has not been asked to resume the broad program of exploratory research that it had in the past. Licensees will be expected to provide all the data and analyses needed to support approval to extend fuel burnups beyond the current limit. In addition, it is expected that licensees will implement more aggressive lead test assembly programs and will establish fuel performance monitoring programs.

THE CONFIRMATORY RESEARCH PROGRAM

RES has formulated a confirmatory research program that consists of the following elements:

- continued collaboration with international experimental studies of fuel behavior during reactivity insertions,
- experimental studies of high burnup fuel behavior under LOCA conditions,
- experimental studies of high burnup fuel behavior under ATWS conditions,
- determination of the oxidation behavior and mechanical properties of cladding as a function of burnup,
- upgrading properties correlations in the FRAPCON and FRAPTRAN codes, and
- analyses of uncertainties in neutronic codes used by NRC.

The experimental and analytical studies in this program are limited to the confirmation of the regulatory decision to permit burnups to 62 GWd/t. RES has used risk insights to focus experiments and analyses on the issues of most importance. Resources have been leveraged by collaboration with continued international programs and with an industry-sponsored program.

In addition to the RES confirmatory research program, the Office of Nuclear Material Safety and Safeguards (NMSS) proposes to benchmark its criticality models for fuel with enrichments in excess of 5%.

COMMENTS AND RECOMMENDATIONS

We make the following comments and recommendations:

- The strategy to require licensees to provide all the data and analyses to support extension of fuel burnups beyond current limits seems appropriate. It places the burdens and responsibilities on those who will gain the rewards that come from extending fuel burnup. The strategy does, however, place limits on the technical independence that the NRC will have in establishing fuel performance acceptance criteria. NRR should make it clear that this strategy applies also to burnups within current limits for fuels with new cladding types not previously tested.

- The NRC should ensure that it has the knowledge and the tools to respond quickly to adequately formulated proposals from licensees to extend fuel burnups beyond 62 GWd/t. The staff needs to make clear what data and what analyses will be required to gain approval for extended fuel burnup.

- The overall RES confirmatory research program is well conceived and deserves the support of the Commission.

- The experimental studies of fuel behavior under LOCA conditions need to be augmented to include tests with more realistic time-temperature histories that may impose harsher thermal and mechanical stresses on the cladding and cladding oxides to ensure that Appendix K (10 CFR Part 50) requirements are adequate for high burnup fuels. Greater realism in the LOCA tests may be especially important if, as is now expected, licensees take advantage of the option of using realistic analyses to comply with the requirements of Appendix K. Time-temperature histories need to be selected such that realistic or at least conservative thermal and mechanical stresses are placed on cladding oxides and any potential for breakaway oxidation is revealed. The suggestion from NRR that the route to burnup as well as the burnup level affects fuel performance needs to be addressed by the research program. Tests with more cladding types than are now approved for high burnup operation may be needed. The test matrices would benefit from application of well-known experiment design methods.

- Plans to address issues of fuel performance during ATWS events have not yet been developed. ATWS may be an especially critical event for high burnup fuels.

- The conclusion that high burnup does not affect radionuclide source terms used in regulatory safety analyses is not supported by the technical literature. The research program should include consideration of how burnup may affect core degradation behavior under severe accidents. It may be necessary to confirm the validity of existing core degradation models used to estimate risk for high burnup fuels.

- The confirmatory research program needs to be augmented with an anticipatory component to give the NRC line organizations the tools to respond to inevitable proposals from licensees for extended fuel burnup. RES has stated that fuel performance models are being refurbished to better predict the thermal and mechanical loads on cladding, as well as the embrittlement of the cladding. We have heard no details on this portion of the program. Furthermore, RES should begin now to develop criteria for use by the licensees in proposing fuel performance monitoring programs.

- We can find no immediate justification for work proposed by NMSS for fuel with enrichments in excess of 5%. The nuclear industry indicates a reluctance to use fuels that have higher enrichment. Should this change, there will be ample time to carry out activities proposed by NMSS.

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

Sincerely,

R. L. Seale
Chairman

Reference:
Memorandum dated May 22, 1998, from Thomas L. King, RES, to John T. Larkins, Executive Director, ACRS, Subject: Transmittal of Advance Copy of Agency Program Plan for High-Burnup Fuel (Predecisional)