UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 6, 1998

MEMORANDUM TO: Chairman Jackson
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan

FROM: L. Joseph Callan
Executive Director for Operations

SUBJECT: AGENCY PROGRAM PLAN FOR HIGH-BURNUP FUEL

PURPOSE:

The purpose of this memorandum is to inform the Commission of an agency-wide program plan to deal with issues related to utilization of fuel up to the current limit of 62 GWd/t burnup (average for the peak rod) and a strategy for assessing requests for burnups beyond that limit. This program plan addresses a wide range of issues and was prepared during the past year by RES, NRR, NMSS, and AEOD, with RES taking the lead.

BACKGROUND:

Previous memoranda to the Commission have discussed burnup-related problems with control rod insertion in operating reactors and with regulatory criteria for reactivity accident analysis (September 13, 1994, November 9, 1994, March 7, 1996, November 25, 1996, July 15, 1997, and December 18, 1997). On March 25, 1997, the Commission was briefed on a broader range of high-burnup fuel issues. Following that briefing, a Staff Requirements Memorandum directed the staff, among other things, to assign a primary point of contact with responsibility for integrating the related activities within the NRC. I assigned that responsibility to Ashok Thadani in his new role in RES. One of Mr. Thadani's first actions in that role was to direct the staff to prepare an agency-wide program plan for high-burnup fuel. The plan would cover the broad range of issues discussed at the Commission briefing.

DISCUSSION OF THE PROGRAM PLAN:

The program plan uses several strategies under the Strategic Plan's goal of preventing radiation-related deaths and illnesses due to civilian nuclear reactors. In particular, it focuses efforts on activities that pose the greatest risk, it maintains a research capability that will provide technical independence, and it encourages the industry to propose regulatory criteria that can be endorsed by the NRC.

CONTACT: Ralph O. Meyer, RES
415-6789

Predecisional budget information has been removed from the Attachment

The program plan addresses nine issues that were discussed with the Commission at the briefing of March 25, 1997.

1. Cladding Integrity and Fuel Design Limits
2. Control Rod Insertion Problems
3. Criteria and Analysis for Reactivity Accidents
4. Criteria and Analysis for Loss-of-Coolant Accidents
5. Criteria and Analysis for BWR Power Oscillations (ATWS)
6. Fuel Rod & Neutronic Computer Codes for Analysis
7. Source Term and Core Melt Progression
8. Transportation and Dry Storage
9. High Enrichments (>5%)

Each issue in the program plan is discussed in the following manner: (a) the issue is defined, stating the origin of the concern raised by high-burnup operation; (b) a risk perspective is presented on the issue; (c) a near-term assessment is summarized, explaining why it is satisfactory to wait 3-5 years, in some cases, for research results to achieve final resolution; (d) related NRC research is described; and (e) a description is given of what will constitute final resolution.

The first two issues, related to cladding integrity, fuel design limits, and control rod insertion, are being satisfactorily addressed by industry activities for current fuel designs and the current burnup limit of 62 GWd/t. The last two issues on transportation, storage, and high enrichments are related to expected future actions and indicate the need for new activities rather than the existence of current concerns. A users request for research assistance on one of these issues (transportation and dry storage) was recently issued, and needs for additional research on the high-enrichment issue will be defined later this year. These research requests will have to be prioritized, however, as resources are not sufficient to conduct all requested programs.

The issue on source term and core melt progression is not being addressed actively. A brief consideration of burnup-related factors leads the staff to conclude that it is unlikely that high burnup will have a significant effect on source terms or core melt progression. The current source term is thus considered to be adequate for the foreseeable future. A more thorough assessment of these possible effects, utilizing recent French data, had originally been planned for FY98, but reductions in the severe accident area have eliminated funding for that work.

The remaining four issues are being actively addressed and some highlights are mentioned here. It should be noted that related NRC research described in this paper is intended to confirm safety at the current burnup limit. While this research may also provide insights for burnup extensions, it is the staff's intention to shift the responsibility to the industry for providing research to support extensions beyond the current burnup limit of 62 GWd/t. This point is discussed further in the section on licensing and research strategy.

Criteria and Analysis for Reactivity Accidents

For all transients and accidents analyzed in a licensing safety analysis, one of the most important high-burnup effects is accelerated oxidation of the fuel cladding and the related loss of

cladding ductility. The reactivity accidents are particularly sensitive to this effect. The specific accidents of concern here are the rod ejection accident in a PWR and the rod drop accident in a BWR, and these accidents are evaluated with regulatory criteria from Regulatory Guide 1.77 and Standard Review Plan 4.2. As discussed in the July 15, 1997, memorandum from L. Callan to the Commission, these regulatory criteria are considered to be non-conservative in light of some currently available test data from foreign test reactors on reactivity-initiated accidents. Staff assessment of these data, however, has concluded that there is no reason to change currently approved burnup levels, unless the confirmatory research program demonstrates a need for change. This is because the probability of these accidents is low and generic plant transient calculations imply that energy inputs during such transients are low and will remain below the relevant test data failure levels. Nevertheless, there are large uncertainties associated with these limited test results because the database has substantial limitations (see Table 4 on p. 9 of the attachment). Thus confirmatory work is warranted. To provide a more definitive safety assessment for reactivity accidents, the staff will participate in new programs through international agreements and will reassess present conclusions in 3-5 years when significant new data become available. Two international programs will provide these data. One involves a new water loop in the French Cabri reactor; NRC is discussing joint U.S. support for this program with the Electric Power Research Institute (EPRI). The other involves a new high-temperature capsule in the Japanese Nuclear Safety Research Reactor (NSRR), a program for which we have an information exchange.

Criteria and Analysis for Loss-of-Coolant Accidents (LOCA)

NRC's regulatory criteria for LOCAs (10 CFR 50.46) will be affected by enhanced cladding oxidation and related effects that are experienced at high burnup. However, the current criteria are conservative for fresh fuel and may prove to be adequate at high burnup provided that the oxide accumulation prior to the accident is taken into account. Thus, there is no reason to change currently approved burnup limits unless the confirmatory research program demonstrates a need for change.

In FY 1997, a major experimental program was initiated by the staff to establish a database for confirming or revising LOCA criteria and models utilizing typical high-burnup fuel from U.S. power reactors. Cooperation in this program is being obtained from EPRI, DOE, and several foreign agencies. The cooperation from EPRI is being implemented through the recent Memorandum of Understanding (MOU) with RES on Cooperative Nuclear Safety Research (SECY-97-239) and is substantial. EPRI has taken full responsibility for obtaining fuel rods from appropriate power reactors, for precharacterizing the rods, and for shipping them to our laboratory. The first shipment of fuel rods is expected later this year. EPRI has also taken an active role in pretest planning for the tests.

Consistent with the MOU, cooperation with EPRI will be limited to obtaining the experimental data. Interpretation of the data will be done independently by NRC and EPRI to avoid conflicts of interest. Confirmation of existing criteria and models at current burnup levels, or an indication of need for revision, will be available from the new database starting around 2000.

Criteria and Analysis for BWR Power Oscillations (ATWS)

For BWR power oscillations that follow an ATWS event, fuel vendors currently use a criterion from Regulatory Guide 1.77 and Standard Review Plan 4.2 that was intended for the pulse-type reactivity accidents (e.g., the rod drop accident). This was believed to be a conservative application of that criterion. Based on the test results just discussed for the reactivity accidents, the conservatism in this application is also in question. However, the power oscillations are slower and probably less damaging than the sharp pulses used in the RIA tests and do not necessarily imply unacceptable fuel damage for the power oscillations. Thus, there is no need to change currently approved burnup levels, unless the confirmatory research program demonstrates a need for change.

The staff is doing detailed fuel rod calculations to understand differences in fuel behavior between the power oscillations and a rod drop pulse. Inquiries are also being made about the possibility of performing fuel tests with BWR-type oscillations in test reactors in several foreign programs. The final course of action will depend on the results of ongoing analyses and other factors such as interactions with the industry and international research organizations.

Fuel Rod & Neutronic Computer Codes for Analysis

Three types of analysis codes, whose results are affected by fuel burnup assumptions, are used by the NRC. One is a steady-state fuel rod behavior code that is used to provide input for transient analysis. Another is a transient fuel rod code that can analyze fuel and cladding behavior during transients like LOCA and the BWR power oscillations. The third is a neutron kinetics code that is used to calculate local power for plant transients like a PWR rod ejection accident or BWR power oscillations.

NRC's steady-state fuel rod code had not been kept up to date and was not providing the staff with an adequate tool for reviewing industry submittals. This deficiency was recognized earlier and has been rectified with the issuance of the peer-reviewed FRAPCON-3 code in December 1997. Similar deficiencies were present in NRC's transient fuel rod code, and that code is now being improved. It is anticipated that 3-dimensional neutron kinetics analysis will be needed for some of the reactivity transients. That need is being addressed by adopting Purdue University's PARCS kinetics code and coupling it with NRC's thermal-hydraulic codes. Coupling of these codes should be completed later this year, and assessment activities are planned.

Computer code maintenance and improvement in these areas will have to be conducted on a continuing basis as new cladding types, core materials, and burnup ranges are introduced by the industry.

Licensing and Research Strategy

As discussed earlier, NRC-funded research is directed toward confirming safety at the currently approved burnup levels. However, the program plan provides a licensing and research strategy for further burnup extensions beyond the current limit of 62 GWd/t. There are two unique aspects of this strategy.

First, the industry will have to develop a data base for revised (or confirmed) regulatory criteria for the extended burnup range. In the past, the NRC has always performed its own research and developed its own data base from which it defined regulatory criteria like the LOCA limits in 10 CFR 50.46 and the criteria for reactivity accidents in Regulatory Guide 1.77. NRC research budgets have declined to a level where supporting such research is no longer possible. Thus the industry will have to perform this research and develop the database.

Second, the staff will encourage the industry to develop criteria and other guidelines that may be needed to obtain NRC approval for an extended burnup range. These would be submitted to NRC and, if endorsed, could replace current Regulatory Guide and Standard Review Plan criteria. This, too, is budget driven and is consistent with the role of industry as suggested in the agency's Strategic Plan.

SUMMARY:

The staff has prepared a program plan for high-burnup fuel that: (a) addresses a range of issues that were previously discussed with the Commission, and (b) provides a licensing and research strategy for confirming the safety of currently approved burnup levels and for considering further burnup extensions that the industry is expected to request. For all issues, a basis is given for concluding that there is no need to change the current burnup limit of 62 GWd/t (average for the peak rod) unless confirmatory research work demonstrates a need for change. Confirmatory work is under way for issues where the basis involves large data uncertainties and analyses. The licensing and research strategy for burnup extensions involves a shift in responsibility to the industry for work that the NRC traditionally does to establish regulatory criteria and guidelines.

This memorandum and the attached program plan have been reviewed by the Office of the General Counsel and the Chief Financial Officer, who have raised no objections.

Attachment: Agency Program Plan for
High-Burnup Fuel

cc: SECY
OGC
OCA
OPA
CIO
CFO
ACRS