. . . .

February 23, 2000

MEMORANDUM TO: Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

FROM: Ashok C. Thadani, Director **/RA/** (M. Federline for)
Office of Nuclear Regulatory Research

SUBJECT: RES RESPONSE TO NRR REQUEST ON RESEARCH USER NEED FOR DEVELOPMENT OF MULTIPLE ISSUES TO PREPARE FOR REVIEWING AMENDMENTS ASSOCIATED WITH MIXED-OXIDE FUEL

This memorandum is in response to your memorandum dated November 5, 1999, on the above stated subject. In your memorandum, the Office of Nuclear Reactor Regulation (NRR) requested the assistance of the Office of Nuclear Regulatory Research (RES) to expand the NRC knowledge base to enable NRR to perform effective reviews of license amendments for use of MOX fuel. NRR sought to expand the NRC knowledge in two areas: (1) the NRC confirmatory analysis codes and (2) the environmental impacts of using MOX fuel in commercial light-water reactors. The technical issues delineated under these two areas are the same technical issues discussed in the agency plan (attached) for confirmatory research associated with the use of MOX fuel in commercial light water reactors which was forwarded to the Commission on February 11, 2000.

As noted in your user need letter, the resources for FY2000 are not in the current budget. RES plans to address this during the upcoming midyear resource review. RES has included resources for MOX fuel initiatives in its FY 2001 budget request. Once resources are made available, RES staff will work closely with NRR staff at the branch level to define the exact work scopes and schedules to address technical issues related to MOX fuel.

Attachment: As stated

February 23, 2000

MEMORANDUM TO: Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

FROM: Ashok C. Thadani, Director **/RA/** (M. Federline for)
Office of Nuclear Regulatory Research

SUBJECT: RES RESPONSE TO NRR REQUEST ON RESEARCH USER NEED FOR DEVELOPMENT OF MULTIPLE ISSUES TO PREPARE FOR REVIEWING AMENDMENTS ASSOCIATED WITH MIXED-OXIDE FUEL

This memorandum is in response to your memorandum dated November 5, 1999, on the above stated subject. In your memorandum, the Office of Nuclear Reactor Regulation (NRR) requested the assistance of the Office of Nuclear Regulatory Research (RES) to expand the NRC knowledge base to enable NRR to perform effective reviews of license amendments for use of MOX fuel. NRR sought to expand the NRC knowledge in two areas: (1) the NRC confirmatory analysis codes and (2) the environmental impacts of using MOX fuel in commercial light-water reactors. The technical issues delineated under these two areas are the same technical issues discussed in the agency plan (attached) for confirmatory research associated with the use of MOX fuel in commercial light water reactors which was forwarded to the Commission on February 11, 2000.

As noted in your user need letter, the resources for FY2000 are not in the current budget. RES plans to address this during the upcoming midyear resource review. RES has included resources for MOX fuel initiatives in its FY 2001 budget request. Once resources are made available, RES staff will work closely with NRR staff at the branch level to define the exact work scopes and schedules to address technical issues related to MOX fuel.

Attachment: As stated
Distribution w/o att.:

File Center	CPaperiello, DEDMRS
DSARE r/f	MTschiltz, OEDO
SMSAB r/f	WOtt, OEDO
PNorian	ASummerour (RES-990266)
SRubin	DSARE 99-127
RLee r/f	

G:\SMSAB\SECYS\Lee.R\scollins1208.99.wpd

*See previous concurrence

To receive a copy of this document, indicate in the box: "**C**"= Copy without attachment/enclosure "**E**" = Copy with attachment/enclosure
"**N**" = No copy

OFFICE	SMSAB	E	C:SMSAB		D:DSARE		D:RES		DD:RES	
NAME	*Lee:mb:mmk		*Eltawila		*CERossi		*MVFederline		*ACThadani	
DATE	1/31/00		1/31/00		2/17/00		2/18/00		2/18/00	

OFFICIAL RECORD COPY

Template= RES-006 **Accession Number** ML003686564 **RES File Code** RES 7-B1

PROGRAM PLAN TO RESOLVE SPECIFIC TECHNICAL ISSUES FOR MOX FUEL

This attachment describes the NRC's confirmatory research that is planned for the near future to enable the staff to develop certain independent capabilities in order to effectively review MOX core license application. The specific technical issues related to the utilization of MOX fuel and the NRC research to address these issues are outlined in this attachment. The RES staff intends to expand the scope of the expert panel currently convened to address high burnup fuel issues as needed to address specific new issues that might arise related to MOX fuel.

1. Reactor Physics

1.1 Issue - Difference Between MOX and Uranium Fuels

The neutron energy spectra of MOX fuel assemblies is hardened compared to that of uranium fuel assemblies. This effect, coupled with the differences in the cross-sections of plutonium and uranium, can lead to large gradients in the neutron energy spectrum as well as thermal flux between the two types of fuel assemblies. The differences in cross-sections between plutonium and uranium also lead to changes in the Doppler (fuel temperature) coefficient, the moderator temperature coefficient, and void coefficient. The energy released per plutonium fission is higher than per uranium fission, and the early decrease in decay heat for MOX fuel would lead to differences under accident conditions. Core design and safety analysis will have to take these differences into account.

NRC Research

The NRC neutronics code will be upgraded to include MOX-specific models. Some of the most critical models that need to be added to the neutronics code include multiple energy groups with up scatter, capability to capture the steep gradients between the two types of fuel assemblies, improved delayed-neutron precursor calculations, a revised decay heat model, and a method to handle local power peaking. In addition, the NRC will acquire the capability (i.e., appropriate lattice physics code) to independently calculate MOX cross-sections for input to the neutronics code.

After the NRC neutronics code is modified, it is necessary to validate it against relevant data. For reactor-grade MOX fuel, NRC will obtain data from the Halden reactor in Norway and the Organization for Economic Cooperation and Development (OECD). Startup and operational data from representative European power reactors that used MOX fuel are useful for code validation. As part of the licensing reviews, the staff expects that the MOX Consortium will provide these data in support of its licensing case, and the data will then be available to the NRC for code validation. RES will work with NRR and the MOX Consortium to obtain the data from the lead test assembly program which the staff needs for the validation of the NRC neutronics code for weapons-grade MOX.

1.2 Issue - Reduced Control Rod Worth

Control rod worth is reduced by MOX fuel because the increased thermal neutron cross-section of plutonium allows the fuel to compete more effectively with the control rod materials. This can reduce reactor shut-down margins. Coupled with a lower delayed neutron fraction (beta value) of MOX fuel, the use of MOX fuel will lead to different reactivity insertion scenarios.

NRC Research

The data NRC obtains from the Halden reactor in Norway, the OECD, and especially the startup and operational data from representative European power reactors using MOX fuel will be used to assist in the evaluation of the shut-down margins for MOX cores. The change in the severity of reactivity insertion accidents with MOX will be addressed.

2. <u>Fuel Behavior</u>

2.1 Issue - Differences in MOX Fuel Properties

For a given fuel rod power, MOX fuel rods operate with higher centerline temperatures because of the reduced thermal conductivity of MOX compared with UO_2. This will increase the initial fuel rod stored energy at the beginning of a postulated transient or accident (e.g., a LOCA). In addition, chemical bonding between the pellets and the cladding, which may be different for MOX pellets and UO_2 pellets, may affect the ballooning process and hence the fuel behavior.

NRC Research

NRC fuel codes (FRAPCON, FRAPTRAN) will be modified for MOX fuel to account for altered materials properties such as thermal conductivity, thermal expansion, and creep rates. To validate these fuel codes, NRC will obtain data from the Halden reactor and other programs. The MOX Consortium may have other sources of data and, as part of the licensing reviews, the staff expects that the MOX Consortium will provide data in support of its licensing case. The data will then be available to the NRC for code validation. With the validated codes, the staff plans to assess the impact of the differences in MOX fuel properties on previously analyzed transients. The staff expects that as part of the licensing reviews, information on the difference between reactor-grade and weapons-grade MOX (as fabricated) will be addressed by the MOX Consortium early in the process to confirm that adequate bases exist to confirm NRC's preliminary conclusion that there is no risk- issue associated with the use of MOX fuels. In addition, as part of the licensing reviews, NRC expects the MOX Consortium will address the concern related to the residual effects of gallium on fuel rod cladding behavior under transient and accident conditions.

2.2 Issue - Inhomogeneous Plutonium Clusters in MOX Fuel

Inhomogeneous plutonium clusters in MOX fuel may affect fuel behavior during reactivity-initiated accidents. These plutonium clusters are formed during the MOX pellets' fabrication, which is similar to the fabrication process used in Europe. In particular, mechanically blending UO_2 and PuO_2 powders, then pressing and sintering them, results in a ceramic that is not homogeneous on a microscopic scale, and the little islands of high plutonium concentration act as hot spots because of their high fissile content.

NRC Research

NRC is negotiating for participation in the Cabri program with the Institut de Protection et de Surete Nucleaire (IPSN) of France, and in the NSRR program with the Japan Atomic Energy Research Institute. NRC will review the data base to address the issue. When significant test results from the Cabri and NSRR test reactor become available (3 to 5 years), the data will be used by the staff to confirm the MOX Consortium's assessment of the acceptability of MOX fuel.

3. <u>Source Terms</u>

3.1 Issue - Difference in Fission Product Gap Inventory

For a given fuel rod power, MOX fuel rods operate with higher centerline temperatures because of the reduced thermal conductivity of MOX compared with UO_2 fuel. Higher temperatures also increase gas release from fuel pellets and, hence, the fission product gap inventory.

NRC Research

The related gap activity may impact some offsite dose calculations. The staff will obtain the data on fission gas release under normal reactor operational conditions for MOX from the NSRR test reactor and the Halden reactor to benchmark the FRAPCON code. The staff plans to use the FRAPCON code to estimate the increase in fission product gas release from the fuel pellet to the gap for both MOX and uranium-based fuel during normal operation. Using the FRAPCON results, the staff plans to perform consequence calculations using the RADTRAD code to evaluate the impact of MOX fuel on offsite consequences.

3.2 Issue - NUREG-1465 Source Terms and Radionuclide Inventory

Because of the way MOX is fabricated (mechanical blending of UO_2 and PuO_2 powders, followed by pressing and sintering), the porosity of MOX may be different from uranium-based fuel porosity. It has been suggested that the different porosity could result in higher releases of volatile radionuclides during the early stages of core degradation.

At any given time, MOX fuel will have more plutonium than UO_2 fuel, and the inventory of other actinides and fission products will also be somewhat different. In particular, higher actinide inventories will be available. Hence, this could affect the consequences of a severe accident.

NRC Research and Analysis

For severe accident conditions, the staff plans to obtain the fission product release data from VERCORS experiment in France and VEGA experiment in Japan through the NRC's Cooperative Severe Accident Research Program. Additional fission product release data may become available from the MAGRAGUE experiment in France within two to three years. The results from these experimental programs will be evaluated to confirm the similarity of MOX and uranium-based fuel with regard to the NUREG-1465 source terms.

The staff plans to perform analyses using radionuclide inventories for a core containing one-third MOX fuel and for a core containing no MOX fuel to estimate the release fractions to the environment for risk-important accidents. Using these release fractions, MACCS code calculations will be performed to evaluate the impact of MOX fuel on offsite consequences.