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Subject: Catawba Nuclear Station Units 1 and 2; Docket Nos. 50-413, 50-414
McGuire Nuclear Station Units 1 and 2; Docket Nos. 50-369, 50-370
Physics Testing Program in Support of Topical Report DPC-NE-1005P, *Nuclear Design Methodology Using CASMO-4/SIMULATE-3 MOX*

The Nuclear Regulatory Commission (NRC) staff as part of their review of the subject topical report requested a description of the physics testing programs that Duke Power intends to perform for mixed oxide (MOX) fuel lead assembly and batch use that will provide verification of the nuclear analysis methodology described in the topical report. The proposed test program and the reports generated from this program are described in the attachment to this letter. This testing program and the associated reporting were developed based on discussion and communication with the NRC staff.

The proposed test program, while similar in scope to the current Duke physics testing program, contains some restrictions on power levels for neutron flux measurement during power escalation. The proposed test program also includes additional requirements for documentation. As described in the attachment, the proposed test program would be carried out for numerous cycles over many years at the four McGuire and Catawba units, and it would generate a large amount of nuclear data related to the performance of cores containing a mixture of MOX fuel and low enriched uranium fuel. As the test program progresses, Duke may propose modifications to the duration of the program, if such changes are warranted based on the results of the testing and associated analyses.

Four regulatory commitments that relate to the content, performance, timing, and documentation of the described physics testing program are listed at the end of the attachment. Inquiries on this matter should be directed to G.A Copp at (704) 373-5620.

Very truly yours,

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Attachment

A001

cc with attachment:

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Duke Power
Mixed Oxide Fuel Project
Core Physics Testing and Validation Program

Introduction

As part of the initiative to dispose of surplus weapons plutonium in the United States and Russia, Duke Power is planning to use mixed oxide (MOX) fuel derived from surplus weapons grade plutonium at the McGuire and Catawba nuclear power reactors. Duke plans to conduct a lead assembly program in which four MOX fuel lead assemblies will be used for two operating cycles at one of the nuclear units, and one or more of the assemblies will be irradiated for a third cycle. As part of the MOX fuel lead assembly program, core conditions will be measured and monitored during plant startup and operation, and post-irradiation examinations of the fuel will be performed. Following a successful fuel qualification program that includes two cycles of lead assembly irradiation, Duke plans to begin batch-scale use of MOX fuel, contingent on (i) regulatory approval, and (ii) availability of the fuel. In batch implementation, Duke will load a mixture of fresh MOX fuel and fresh low enriched uranium (LEU) fuel, similar to the ongoing practice in European reactors using MOX fuel derived from reactor grade plutonium. The McGuire and Catawba MOX fuel core fractions would increase to approximately 40% over several cycles.

The use of batch quantities of MOX fuel will represent a major change in the core designs of Catawba and McGuire. Accordingly, the physics testing program has been reviewed with respect to (i) protecting public health and safety, and (ii) obtaining measured data to validate computer code predictions. The physics testing programs planned for the MOX lead assembly cores and then the partial batch MOX fuel cores are discussed below.

Physics Testing for MOX Lead Assembly Cores

One of the primary goals of the MOX fuel lead assembly program will be to collect measured neutronic data to validate the computer code predictions. The effect of four MOX fuel assemblies on global core reactivity parameters will be minimal, as demonstrated by analyses that are summarized in Reference 1, Attachment 3, Section 3.7.2.3. Therefore, the valuable neutronic measured data from the MOX fuel lead assembly program will be core power distributions derived from incore neutron flux measurements (flux maps). For a lead assembly program containing four MOX fuel assemblies, Duke will place at least two of the MOX fuel lead assemblies in core locations that are measured directly by the movable incore detector system for the first and second cycles of lead assembly irradiation. For the third cycle of irradiation, core design constraints will dictate whether the placement of the MOX fuel lead assembly is in a measured core location, or not. Not placing the MOX lead assembly in a measured location during the third cycle of irradiation is acceptable because the purpose of this irradiation is to achieve a high burnup on the MOX lead assembly to assess mechanical performance of the fuel assembly.

The physics test program to be used at Catawba and McGuire for cores containing MOX fuel lead assemblies is based on the American Nuclear Society (ANS) Standard for Reload Startup Physics Tests for Pressurized Water Reactor (Reference 2) and the Nuclear Regulatory Commission (NRC)-approved Duke Power reload startup physics test program for McGuire and Catawba (Reference 3), modified to include the dynamic rod worth measurement (DRWM) technique as described in Reference 4. A summary of the planned startup physics testing program is shown in Table 1.

The physics testing program will provide data to assess various physics parameters important to confirming the core design predictions. The physics data will be measured at hot zero power (HZP) and at various power levels during initial cycle power escalation. The HZP measurements will include the all-rods-out critical boron concentration, the isothermal temperature coefficient, and individual bank worths for each of the nine control and safety banks. During the power escalation phase of startup, power distribution measurements will be made at a minimum of two intermediate power levels as well as full power. The final physics test is the measurement of the full power critical boron concentration.

The bank worth measurements will be performed using the Westinghouse DRWM technique. DRWM provides integral and differential bank worth data for all banks. The applicability of the DRWM technique to cores containing MOX fuel assemblies was evaluated in the Duke CASMO-4/SIMULATE-3 MOX nuclear analysis methodology topical report (Reference 5, Section 6).

As noted earlier, the four MOX fuel lead assemblies will have a very small effect on the global reactivity parameters such as boron concentration and temperature coefficients. For these MOX fuel lead assembly cores, the principal measurement of interest will be flux maps, which will provide for a comparison of predicted to measured power distributions.

The power level plateaus for power distribution measurements are chosen based on a number of considerations. The best quality flux maps are taken at full power, steady-state conditions. Obtaining good flux maps at very low power is challenging because core conditions are not as stable and the detector signal strength is low, particularly in peripheral, low power assemblies. Since each full flux map takes several hours to perform at a stable power level, standard practice has been to take the lower power map while the reactor is being held at constant power for other plant system evolutions; *e.g.*, turbine heatup, turbine overspeed tests, and chemistry hold points.

The primary purpose of the first flux map is to provide additional confirmation that the core has been loaded as designed. The types of misloadings that are considered include both assembly misplacement and assembly manufacturing errors. MOX fuel assemblies provide a coincidental enhancement to this check because the MOX fuel instrument tube reaction rates are uniquely lower than comparable LEU fuel assemblies. This effect results from thermal neutron flux depression in MOX fuel due to the higher thermal absorption cross section of plutonium, relative to uranium.

The first power distribution measurement will be made at a power level that is sufficiently low such that it is not credible to exceed a power peaking related safety limit. Successfully meeting the acceptance criteria will provide assurance that the core is loaded properly, that it is operating as designed, and that it is acceptable from a safety perspective to proceed to the next power plateau for further testing.

The second power distribution measurement must be made between 50% and 80% full power. This power plateau is chosen to allow for a quality measurement using the movable incore detector system, while not challenging thermal margin limits. The data from this flux map is analyzed with the following objectives:

1. Confirm that the measured core peaking is within safety analysis limits.

2. Confirm that the predicted power distribution is within the acceptance criteria established for the test.

3. Confirm the trend of changes in the power distribution as a function of power level. This provides assurance that next power plateau will be acceptable.

The third power distribution measurement will be made above 90% full power (generally, this measurement is performed at full power). The acceptance criteria are the same as the second measurement, and this flux map provides further assurance and the core is operating as designed, in accordance with assumptions made in steady-state and transient safety analyses.

Once startup testing is successfully completed, flux maps are taken monthly during cycle operation, typically at steady-state, full power conditions. These core power distribution measurements will provide the primary data base against which the core power distribution predictions of the CASMO-4/SIMULATE-3 MOX codes will be assessed. The assessment of the full power data will be performed as part of the normal core follow program which evaluates important parameters such as core reactivity, $F_{\Delta h}$ and F_q peaking factors, radial power distribution, and core average axial power shape on a monthly basis. For MOX fuel lead assembly cores, the program will be expanded to include the analysis of axial power shapes for the MOX fuel assemblies in instrumented locations.

While the flux map data collected on MOX fuel assemblies during power escalation will provide useful data, the best and most appropriate data for confirming computer code predictions will be obtained from the monthly full power flux maps during cycle operation. This is because the core conditions for the full power flux maps are more stable with respect to spatial transients of fission product poison distributions (e.g., xenon and samarium), core flow, and core temperature distributions. In addition, the McGuire and Catawba reactors operate almost entirely at full power conditions, and it is at full power that steady-state thermal margins are smallest. Therefore, full power operation is the primary condition of concern with respect to the uncertainty associated with computer code predictions.

In summary, at least three core power distribution measurements will be taken during startup of the core with MOX fuel lead assemblies - two measurements at intermediate power conditions and one above 90% power. These measurements, coupled with monthly flux maps during cycle operation, will provide a substantial data base against which core physics calculations of weapons grade MOX fuel assembly performance can be validated.

Physics Testing for Partial Batch MOX Cores

In Reference 5 the CASMO-4/SIMULATE-3 MOX codes were validated against startup testing and operating data from the St. Laurent B1 reactor. Those St. Laurent cores contained a mixture of LEU and reactor grade MOX fuel assemblies. Prior to loading batch quantities of MOX fuel, the MOX fuel lead assembly program will provide additional data. It is expected that these data will further confirm the ability of the Duke nuclear design methods to predict the performance of MOX fuel in mixed cores. Accordingly, the same startup testing program will be followed for partial MOX fuel cores as for the MOX fuel lead assembly cores. This program will be performed on each McGuire and Catawba unit starting with the first operating cycle containing batch quantities of MOX fuel and continuing through the first equilibrium cycle. For the purposes of this test program description, an equilibrium cycle is defined as an operating cycle with a core containing 76 MOX fuel assemblies (feed and reload), or 39.4% of the core.

MOX Core Startup and Operating Reports

Duke will prepare startup reports for all cycles operating with MOX fuel lead assemblies and for all cycles for each unit operating with partial MOX fuel cores until the equilibrium cycle defined above is reached. Each startup report will contain comparisons of predicted to measured data from the zero power physics tests and the three power distribution maps taken during power escalation. The reports will include discussions of any parameter that did not meet acceptance criteria. Duke will provide each report to the NRC within 60 days of measurement of the final power distribution map.

Duke will also prepare operating reports for all cycles operating with MOX fuel lead assemblies and for each unit operating with partial MOX fuel cores until the equilibrium cycle defined above is reached. Each operating report will contain comparisons of predicted to measured monthly power distribution maps and monthly boron concentration letdown values. As noted earlier, these data provide the most benefit with respect to benchmarking the computer code predictions. Duke will provide each cycle operating report to the NRC within 60 days of the end of the fuel cycle.

Summary of Startup Test Commitments for McGuire/Catawba Cores Containing MOX Fuel

The following is a summary of NRC commitments made in this document related to physics testing for MOX fuel cores:

1. For a lead assembly program containing four MOX fuel assemblies, Duke will place at least two of the MOX fuel lead assemblies in core locations that are measured directly by the movable incore detector system for the first and second cycles of lead assembly irradiation.

2. Duke will perform the physics test program defined in Table 1 for all MOX fuel lead assembly cores and for each unit operating with partial MOX fuel cores until the equilibrium cycle defined above is reached. Core power levels at which low and

intermediate power escalation power distribution maps are taken will be consistent from cycle to cycle for each unit (within ± 3 % rated thermal power). Core power level at which power distribution maps are taken may vary among units and between McGuire and Catawba.

3. Duke will prepare a startup report for each operating cycle with MOX fuel lead assemblies and for each unit operating with partial MOX fuel cores until the equilibrium cycle defined above is reached. Each startup report will contain comparisons of predicted to measured data from the zero power physics tests and the power distribution maps taken during power escalation. The reports will include discussions of any parameter that did not meet acceptance criteria. Duke will provide each report to the NRC within 60 days of measurement of the final power distribution map.

4. Duke will prepare an operating report for each operating cycle with MOX fuel lead assemblies and for each unit operating with partial MOX fuel cores until the equilibrium cycle defined above is reached. Each operating report will contain comparisons of predicted to measured monthly power distribution maps and monthly boron concentration letdown values. Duke will provide each cycle operating report to the NRC within 60 days of the end of the fuel cycle.

References

1. Letter, Tuckman, M. S. (Duke Power) to U. S. Nuclear Regulatory Commission, Proposed Amendments to the Facility Operating License and Technical Specifications to Allow Insertion of Mixed Oxide (MOX) Fuel Lead Assemblies and Request for Exemption from Certain Regulations in 10 CFR Part 50, February 27, 2003.

2. ANSI/ANS-19.6.1, Reload Startup Physics Tests for Pressurized Water Reactors, American National Standard, 1997.

3. Letter, Hood, D. S. (U. S. Nuclear Regulatory Commission) to Tucker, H. B. (Duke Power), Transmittal of Safety Evaluation Report for McGuire and Catawba Reload Startup Physics Test Program, May 18, 1988.

4. WCAP-13360-P-A, Revision 1, "Westinghouse Dynamic Rod Worth Measurement Technique," October 1998.

5. DPC-NE-1005P, Duke Power Nuclear Design Methodology Using CASMO-4/ SIMULATE-3 MOX, August 2001.

6. BAW-10231P, COPERNIC Fuel Rod Design Computer Code, Framatome Cogema Fuels, September 1999.

7. DPC-NE-2005P-A, Revision 3, Duke Power Company Thermal-Hydraulic Statistical Core Design Methodology, September 2002.

Table 1
Physics Test Program for
McGuire and Catawba MOX Fuel Cores

Physics Test	Core Condition	Acceptance Criteria
Critical Boron Concentration - All Rods Out	Hot Zero Power	Predicted +/- 50 PPM
Isothermal Temperature Coefficient	Hot Zero Power	Predicted +/- 2 PCM/F
Bank Worth Measurements	Hot Zero Power	**Review Criteria** Individual Banks $\pm$ 15% or 100 PCM (whichever is greater) Sum of all banks $\pm$ 8% of Predicted **Acceptance Criteria**: Sum of all banks $\geq$ 90% of Predicted
Low Power Flux Map (0-40% FP) Full core map including all operable instrument locations	Between 0 and 40 percent Full Power	Normalized reaction rates or assembly power: $\pm$ 10% of Predicted, Root Mean Square error: $\leq$ 0.05
Intermediate Flux Map 1 (50-80% FP) Full core map including all operable instrument locations	Between 50 and 80 percent Full Power	Normalized reaction rates or assembly power: $\pm$ 10% of Predicted, Root Mean Square error: $\leq$ 0.05
High Power Flux Map (> 90% FP) Full core map including all operable instrument locations	Greater than 90 percent Full Power	Normalized reaction rates or assembly power: $\pm$- 10% of predicted, Root Mean Square error $\leq$ 0.05
Critical Boron Concentration - All Rods Out	Greater than 90 percent Full Power	Predicted +/- 50 PPM