UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

November 15, 2016

The Honorable Stephen G. Burns
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: MONTICELLO NUCLEAR GENERATING PLANT LICENSING AMENDMENT REQUEST FOR OPERATION IN THE EXTENDED FLOW WINDOW DOMAIN

Dear Chairman Burns:

During the 638th meeting of the Advisory Committee on Reactor Safeguards (ACRS), November 3-5, 2016, we reviewed the license amendment request by Xcel Energy (or applicant) regarding the Monticello Nuclear Generating Plant (Monticello) for operation in the Extended Flow Window (EFW) domain using AREVA fuel and methods, as well as the NRC staff's draft safety evaluation report (SER). Our Thermal-Hydraulics Phenomena Subcommittee reviewed this matter in subcommittee meetings on July 7, 2015, September 19, 2016 and October 5, 2016. During these reviews, we had the benefit of discussions with the staff and representatives from Xcel Energy and AREVA. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATION

The use of AREVA ATRIUM 10XM fuel and AREVA methods for Monticello in the EFW operating domain is acceptable with the limitations and conditions imposed by the staff to ensure an acceptable safety margin under EFW operation. We recommend that the Xcel Energy license amendment request for Monticello be approved.

BACKGROUND

Monticello is a General Electric boiling water reactor (BWR/3 design) with a Mark I containment. The core contains 484 fuel assemblies and at 2004 MWth is relatively small compared to the remainder of the domestically licensed fleet of BWRs. In contrast, most domestic BWRs have cores that contain greater than 700 fuel assemblies. In addition, the core power density and peak bundle power at Monticello remain below the BWR fleet average with a power to flow ratio that does not exceed 50 MWth/Mlbm/hr.

Xcel Energy submitted a license amendment request for Monticello. The proposed amendment would revise Monticello's Technical Specifications and Facility Operating License to allow operation in the EFW domain. In 2014, Monticello was approved to operate in the GE Hitachi

(GEH) Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain, which is a similar power-flow regime to the EFW operating domain. The staff approved the transition to the AREVA ATRIUM 10XM fuel, under the condition that Monticello operate in the MELLLA domain.

If approved, this license amendment request would allow Monticello to operate in the EFW domain with a transition core, consisting of previously burned GE14 fuel and fresh batches of ATRIUM 10XM fuel, and subsequently, a core composed solely of ATRIUM 10XM fuel.

Xcel Energy is seeking approval to operate Monticello in the EFW domain on a fuel-specific basis. This involves the AREVA methods and codes applied to Monticello at higher power-to-flow conditions. The staff reviewed the AREVA methods in their SER for specific application to Monticello in the EFW domain. This review focused on the AREVA computational methods used to evaluate plant performance under normal operating conditions, anticipated operational occurrences and special events, and the application of these methods to Monticello.

DISCUSSION

The staff used the extended power uprate (EPU) standard as a general framework for the review of this application and reviewed a range of subject areas for the applicant's license amendment that include:

- Evaluation methods
- Fuel system design
- Nuclear design
- Thermal and hydraulic design
- Accident and transient analyses

<u>Evaluation Methods</u>

The AREVA analysis methods are not explicitly approved for EFW (or MELLLA+) conditions. The staff reviewed the validity of application of these previously approved AREVA methods for application in EFW analyses specifically for Monticello. A complete list of the evaluation models and methods for cycle-specific reload analyses is given in Revision 3 of AREVA report ANP-3295P. These evaluation methods encompassed a dozen computer codes used for neutronics, fuel, and thermal-hydraulic analyses.

The staff reviewed whether the models and methods listed in ANP-3295P are qualified and benchmarked for application at high void fractions and low flow conditions expected during EFW operating conditions for Monticello. ANP-3135P reviews the AREVA licensing methodologies and their applicability to operation of Monticello including EPU conditions as well as the EFW. The applicability of the AREVA licensing methodologies for EPU at Monticello was addressed in ANP-3224P, Revision 2.

In their review of the AREVA methods, the staff considered the implications, if any, of EFW operation on the limitations and conditions from the existing approved SERs. The staff also considered the fact that AREVA presented validation data from other operating plants with power-to-flow ratios that bound Monticello conditions in the EFW domain. All these codes are already approved for use on high power density plants that bound the conditions in the Monticello EFW domain. AREVA methods have been benchmarked against operating data in the fleet, and the uncertainties reproducing measured power distribution data is incorporated in the safety limit minimum critical power ratio (SLMCPR) methodology. In addition, AREVA has provided prototypic test data that benchmarks their methods to measurements with high void fractions (close to 100 percent). The staff found that application of the AREVA methods and correlations to the Monticello EFW domain is an acceptable extension to their existing application.

For transients and abnormal occurrences that are not directly affected by the particular fuel loaded, such as a depressurization anticipated transient without scram (ATWS) without instability, Monticello relied on the analysis-of-record performed for Monticello by GEH that was previously reviewed by the staff during the MELLLA+ license amendment request. The staff found this approach acceptable.

In addition to the approved codes, two new computer codes were used for analysis of ATWS events with instabilities (ATWSI). These codes are referenced in the EFW license amendment request and were found acceptable by the staff for use in the EFW domain. The AISHA code, described in ANP-3274P and ANP-3284P, is a coupled neutronics/thermal-hydraulics code used to calculate the transient response of the BWR core region using boundary conditions for the vessel and balance of plant. It is used primarily for stability calculations during ATWSI events. The SINANO code is also described in ANP-3274P and ANP-3284P and is a single channel detailed thermal-hydraulic model using the same model assumptions as AISHA with one exception. SINANO uses the inlet flow boundary condition from AISHA to calculate the thermal response for the limiting bundle and fuel rod under these accident conditions. This approach is similar to other approved AREVA methodologies, where a detailed channel model, for example XCOBRA-T, is used to calculate detailed thermal limits based on the boundary conditions from a system code, COTRANSA.

AISHA was developed by AREVA to simulate core-wide and regional severe power oscillations associated with core instabilities unsuppressed by scram. The BWR core and downcomer are modeled as a recirculation loop that allows for regional oscillation modes driven by the plant system conditions (e.g., inlet feedwater temperature) with neutronic power feedback. The pressure drop components that contribute to the momentum balance for natural circulation flow have acceleration, gravitation, and friction components. The fuel pin heat conduction is modeled with radial temperature variation. The boiling heat transfer model considers a ‘wet’ heat transfer coefficient before the critical heat flux (CHF) boiling transition and a ‘dry’ post-CHF heat transfer coefficient with a transient critical power correlation model (CPROM) that determines the thermal-hydraulic conditions causing this boiling transition.

AISHA and SINANO thermal-hydraulic models have been benchmarked against measured stability data obtained from the KATHY facility for the ATRIUM 10XM fuel design. Experimental data were obtained from the KATHY facility for a range of thermal-hydraulic conditions, including those expected in Monticello. The tests employed a full-scale electrically heated ATRIUM 10XM bundle tested under realistic ATWSI conditions of unstable density wave oscillations with reactivity feedback. A 'wet' heat transfer coefficient was used to model the tests in nucleate boiling and demonstrated good agreement with test data. A 'dry' heat transfer coefficient value was used to successfully bound the observed transient heat transfer coefficient data and the response for post-CHF conditions.

The CPROM correlation was benchmarked against steady-state data from the KATHY facility for the AREVA ATRIUM 10XM fuel design. This same data was used to develop the AREVA Critical power Evaluator (ACE) correlation, which is a steady-state critical power ratio (CPR) correlation. AREVA also generated a CHF correlation for the GE14 fuel based on simulated Monticello CHF conditions and the associated GE CPR correlation. The correlation performance is not affected by operation in the EFW region because it is only dependent on the local conditions in the fuel bundle. The staff concluded that the use of this methodology in the Monticello EFW domain is acceptable.

The staff reviewed key aspects of these ATWS codes such as the neutron kinetics model and the thermal hydraulic models including the CPROM dryout correlation. This analysis approach was able to predict the thermal response of the KATHY test bundle in a bounding manner for Monticello conditions. Staff concluded that the use of these codes for ATWSI analysis specifically for the Monticello license amendment request is acceptable. Given the empirical nature of these model assumptions and analyses and the data for which they have been benchmarked, additional work would be needed to allow usage of these methods and codes beyond this Monticello EFW application.

Fuel System Design

The staff reviewed Monticello's analyses related to the effects of the proposed EFW operating domain on the fuel system design, control systems, and reactor core. They concluded that Monticello has adequately accounted for the effects of the proposed operating domain extension on the fuel system and demonstrated that: 1) the fuel system is not likely to be damaged as a result of normal operation and anticipated operational occurrences (AOOs); 2) any fuel system damage, if it occurs, is not likely to prevent control rod insertion when required; 3) the number of fuel rod failures has not been underestimated for postulated accidents; and, 4) coolability is likely to be maintained. The staff found the EFW operating domain to be acceptable for the fuel system design.

Nuclear Design

The representative core design consists of a total of 484 fuel assemblies, including fresh ATRIUM 10XM and irradiated GE14 assemblies. The core design analysis was performed using an approved AREVA neutronics methodology that includes CASMO-4 and MICROBURN-B2. The models use burnup gradient and spectral history gradient methods for accurate representation of the in-reactor configuration. A full three-dimensional pin power reconstruction method is utilized. Traversing in-core probe (TIP, neutron and gamma detectors) and local power range monitor (LPRM) response models are included and compare well with calculated and measured instrument responses.

Steady-state thermal hydraulics models define the flow distribution among the assemblies. Models for the calculation of CPR, linear heat generation rate (LHGR), and maximum average planar linear heat generation rate (MAPLHGR) are included in the model for direct comparisons to the operating limits. The staff reviewed Monticello's analyses related to the effect of the EFW operating domain on the nuclear design of the fuel assemblies, control systems, and reactor core. The staff concluded that Monticello has: 1) adequately accounted for the effects of the proposed operating domain extension on the nuclear design and 2) demonstrated that the fuel design limits will not be exceeded during normal operation or AOOs. Also, effects of postulated reactivity accidents will not cause significant damage to the pressure boundary or impair the ability to cool the core. The EFW operating domain was acceptable with respect to the nuclear design.

Thermal-Hydraulic Design

The Monticello specific thermal-hydraulic design analyses are documented in ANP-3295P including the uncertainty methodology used in the determination of the SLMCPR and the stability limits as affected by the CPR correlation, void fraction models, and bypass voiding.

SLMCPR: Following the approved methodology in ANP-10307P, the SLMCPR is calculated as the minimum CPR value that assures that <0.1% of the fuel rods experience CHF boiling transition. To confirm this criterion, a conservative power shape is used. The radial power uncertainty used in the analysis includes the effects of up to one TIP machine out-of-service or the equivalent number of TIP channels or up to 50% of the LPRMs out-of-service. This uncertainty is included in calculations through increased uncertainties for assembly radial peaking and nodal power. The staff noted that EFW operation increases the core-average void fraction, and Monticello lacks sufficient operating experience in the region above 42 MWth/Mlbm/hr. An added CPR operating margin of 0.03 is, therefore, imposed, consistent with that required for operation in the MELLLA+ domain.

CPR Correlation: For the steady state and transient analyses, ATRIUM 10XM fuel is analyzed and monitored with the ACE critical power correlation. The GE14 fuel is analyzed and monitored with the approved Siemen's Power Corporation B (SPCB) critical power correlation, which has been reviewed and approved. The SPCB additive constants and additive constant uncertainty for the GE14 fuel were developed using an indirect approach. To generate the SPCB parameters for GE14 fuel, AREVA provided a database of operating conditions and employed a separate database of critical power at these conditions using the approved GE14 GEXL CPR correlation. This provided pseudo-test data, which was then processed to generate these SPCB parameters. For both, steady state and transient analyses, the internal structure of the codes requires a check of the CPR correlation to ensure that it is used within the accepted range of applicability. The staff concluded that both CPR correlations (ACE and SPCB) are being used within the acceptable parameter range.

Void Fraction: A key issue for operation in the EFW domain is the increased power-to-flow ratio, which results in higher void fractions during steady state operation, as well as during transients. An evaluation of void correlations is based on void fraction test data from the KATHY facility, which measured the in-channel void fraction using gamma densitometry. Key features of AREVA ATRIUM 10XM are represented in the KATHY facility, including part-length rods and expansion/contractions caused by water rods. The staff reviewed validation data for the void fraction correlation models used in the analysis methods. A large number of experimental data points are available that represent the exact geometry of the AREVA ATRIUM 10XM fuel and bound all the expected range of operation at Monticello in the EFW domain. The void model predictions are in good agreement with the experimental data. The bounding errors on void correlation models were evaluated and the staff concluded that impact on the operating limit CPR (OLMCPR) was insignificant. The use of the proposed void fraction models is acceptable for application to the Monticello EFW operating domain.

Bypass Voiding: Bypass voiding may be a concern because it has the potential of de-calibrating the LPRM detectors. A limit of 5% bypass voiding is typically applied to avoid de-calibration. The proposed methods (steady-state and transient) explicitly include a check for all calculations of the bypass voiding. The maximum bypass voiding calculated at the LPRM detectors in Monticello is much less than 5% (at the low core flow boundary of the extended power/flow map). Therefore, bypass voiding has been addressed for Monticello.

Long-term Stability Solution: Monticello will implement the long-term stability solution enhanced option III (EO-III) for EFW operation. EO-III includes: 1) the channel instability exclusion region, 2) the required OLMCPR margin as a function of oscillation power range monitor setpoints, and 3) the backup stability exclusion region. The licensing basis for EO-III remains unchanged from the previously approved Solution III, which has been in operation without problems for several years at Monticello. When the period-based detection algorithm detects an oscillation in the oscillation power range monitor of amplitude greater than the setpoint, the reactor scrams. An exclusion region enforces the requirement that the individual channel thermal-hydraulics be stable. This assures the well-behaved structure of the Delta over Initial MCPR Versus Oscillation Magnitude (DIVOM) correlation used to calculate the setpoint. The staff concluded that Monticello's implementation of the EO-III stability solution takes no deviations from the approved method and is, thus, an acceptable long-term stability solution for operation in the EFW domain.

Accident and Transient Analysis

The staff reviewed the complete set of accident analyses documented in ANP-3295P, including AOOs events and found them to be acceptable for EFW operation. For ATWS events, overpressure analyses indicate that acceptance criteria are maintained without scram available, as long as only one safety relief valve is allowed to be out-of-service. The isolation ATWS analysis of record is still applicable to EFW operation with ATRIUM 10XM fuel. Depressurization events, such as a pressure regulator valve failing open are not impacted by EFW operation and do not challenge thermal limits.

Monticello implements a critical operator action to initiate reduction of vessel water level within 90 seconds of any ATWS initiation. This was part of the MELLLA+ licensing amendment and is also part of the EFW license amendment request. Lowering water level mitigates the oscillations by reducing the core flow and thereby pre-heating the feedwater with steam. This action reduces the power level and the oscillation amplitude. Simulations indicate that, when the Monticello operator takes prompt action, oscillations do not develop for turbine trip with bypass ATWSI events. Sensitivity analyses indicate that the operator has sufficient time to reduce water level before any oscillations develop.

At Monticello, the limiting ATWSI event is the two-recirculation pump trip (2RPT). Best estimate Monticello simulations indicate that the 2RPT ATWS event still does not result in oscillations. To artificially induce oscillations, Monticello assumed reduced feedwater temperature below expected values from equilibrium natural circulation conditions. This ATWS analysis followed similar assumptions to the MELLLA+ analysis of record. In this analysis, the protection system detects power oscillations but fails to scram at about 300 seconds after pump trip. The combination of this time and the additional 90 second operator action delay amounts to 400 seconds before any operator action is taken. This delay may allow power oscillations time to grow and produce significant clad temperature oscillations. Even with the conservative assumptions employed in the analysis, simulations show that the fuel cladding temperatures are within acceptable limits.

These calculations do not take credit for the required manual scram immediately following a 2RPT.

In addition, Monticello will replace the current installed stability protection system with the AREVA solution (Enhanced Option III), which is approved for application in extended flow domains. Part of the solution enforces an exclusion region that provides an automatic scram on 2RPT, which will minimize the probability of unstable power oscillations developing before operator action at Monticello.

SUMMARY

The staff review concluded that use of AREVA ATRIUM 10XM fuel and AREVA methods at Monticello for the EFW domain is acceptable. The staff imposed the following limitations and conditions to ensure an acceptable safety margin under EFW:

- Only one safety relief valve is allowed to be out-of-service when operating in the EFW domain.
- Feedwater heater out-of-service operations are not permitted in the EFW domain.
- Single-loop operation is not permitted in the EFW domain.
- The methods used to determine LHGR and MAPLHGR values will not be changed.
- The long-term stability solution oscillation power range monitor amplitude setpoint is initially determined. If Monticello changes this amplitude setpoint then a corresponding change will be made to the OLMCPR margin based on the calculations documented in ANP-3295P.

- There is no change in operator actions times. Operator actions to initiate reduction of reactor vessel water level are assumed to occur within 90 seconds of an ATWS.
- Operation in the EFW region increases the core-average void fraction, and insufficient operating experience exists in this region. For this reason an added CPR operating margin of 0.03 is necessary to be consistent with the Monticello MELLLA+ license amendment request.

We conclude that use of AREVA ATRIUM 10XM fuel and AREVA methods for Monticello in the EFW operating domain is acceptable with the limitations and conditions imposed by the staff to ensure safe operation in EFW domain. We recommend that the Xcel Energy license amendment request for Monticello be approved.

Dr. Jose March-Leuba did not participate in this discussion.

Sincerely,

/RA/

Dennis C. Bley
Chairman

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