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

February 17, 2016

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

SUBJECT: PEACH BOTTOM ATOMIC POWER STATION UNITS 2 AND 3 MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS (MELLLA+) LICENSE AMENDMENT REQUEST

Dear Chairman Burns:

During the 631st meeting of the Advisory Committee on Reactor Safeguards, February 4-6, 2016, we completed our review of the license amendment request and the associated NRC staff draft safety evaluation to allow operation of Peach Bottom Atomic Power Station (PBAPS), Units 2 and 3, in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain under the NRC-approved extended power uprate (EPU) conditions of 3951 MWt. The Power Uprates Subcommittee reviewed this application on December 2, 2015. During the review, we had the benefit of discussions with representatives of the staff, Exelon Generation Company, LLC (Exelon or the licensee) and their contractors. We also had the benefit of the documents referenced.

RECOMMENDATION

The Exelon application for operation of PBAPS Units 2 and 3 in the MELLLA+ domain should be approved, subject to the limitations and conditions identified in the staff's draft safety evaluation.

BACKGROUND

Peach Bottom Units 2 and 3 are of the BWR/4 design with Mark I containments. Each of these units began commercial operation in 1974 with an original thermal power of 3293 MWt. On August 25, 2014, the NRC granted an EPU to increase their thermal power to the current licensed thermal power (CLTP) of 3951 MWt. These units currently operate in the Maximum Extended Load Line Limit Analysis (MELLLA) domain. MELLLA+ operation would expand their operating domain to core flows as low as 83% of the rated value at CLTP. This expanded domain increases operating flexibility by allowing control of reactivity at higher powers with changes in the core recirculation flow rather than control rod insertion or withdrawal. These units have a power density of 58 kW/liter and can operate at a thermal power to flow ratio above 50 MWt/Mlbm/hr. These features make these units susceptible to power oscillations when operating in the MELLLA+ domain. As a result, enhanced protection against instabilities must be provided to enable such operation safely.

In support of the license amendment request, Exelon submitted the safety analysis report NEDC-33720P. This report documents results from evaluations to support MELLLA+ operation. The licensee evaluated the applicability of generic GE-Hitachi assessments to PBAPS Units 2 and 3. Where such generic assessments were not applicable, the licensee provided plant-specific evaluations. These units use GNF2 fuel, which is approved for MELLLA+ operation. The licensee plans to apply the Detect and Suppress Solution - Confirmation Density (DSS-CD) methodology to protect against the increased susceptibility to instabilities in the MELLLA+ operating domain.

DISCUSSION

Operating flexibility is improved when flow adjustments can be used to control power. Allowing lower flows at higher powers requires additional compensating measures to reduce the likelihood of power oscillations. License conditions and technical specification changes are proposed that include applicable generic license conditions and limitations for MELLLA+ operation. Generic or plant-specific evaluation results demonstrate that acceptable safety margins will be maintained during MELLLA+ operation by a combination of the following measures:

- Maintaining feedwater temperature above 371.5°F at rated steady-state power conditions
- Increasing isotopic enrichment of boron-10 in the Standby Liquid Control System (SLCS)
- Demonstrating operator response times for critical actions during accidents
- Implementing the DSS-CD methodology to detect and suppress power oscillations
- Prohibiting single-loop operation in the MELLLA+ domain
- Adopting analytical conservatisms to assure fuel integrity and adequate core cooling

Our review considered the effects of MELLLA+ operation on thermal and hydraulic design, fuel and nuclear design, plant systems response, and transient and accident analyses. In particular, we examined variations in operator response times and other parameters that affect predictions of anticipated transient without scram (ATWS) instabilities.

Thermal and Hydraulic Design

The proposed MELLLA+ power-flow operating domain is similar to the domain currently in use at PBAPS. The primary difference occurs at higher power-to-flow operating conditions. Higher void fractions associated with higher operating power at lower flow can affect plant response during ATWS events and increase susceptibility to power oscillations.

The licensee will implement the DSS-CD methodology to help protect from a coupled neutronic and thermal-hydraulic instability. The DSS-CD methodology uses a confirmation density algorithm to detect the inception of power oscillations and generate a power suppression signal prior to significant oscillation amplitude growth and minimum critical power ratio degradation. False scrams are minimized by requiring density confirmation from multiple power range monitors and a higher scram setpoint. Other protection features include an automatic backup scram system and the manual reactor scram.

A penalty is imposed on the calculated safety limit minimum critical power ratio (SLMCPR) to account for uncertainties in predicted power distributions at higher void fraction conditions. For operation at power-to-flow conditions that exceed 42 MWt/Mlbm/hr, plant-specific evaluations apply the increased SLMCPR penalties. The staff compared plant-specific evaluations with power range measurement data from five previous fuel cycles and found the proposed penalties acceptable.

Fuel and Nuclear Design

Limited data are available to quantify uncertainties in power distributions at higher power levels and increased void fractions. Plant-specific core power distribution assessments are required to consider the effect of additional uncertainties at higher core power to flow ratios. Exelon addressed this requirement by assuming more conservative PBAPS cycle-specific SLMCPRs in their evaluations for steady-state operation. These higher SLMCPRs must be applied in evaluations performed for each cycle-specific reload analysis report.

The operating limit minimum critical power ratio (OLMCPR) and the maximum average planar linear heat generation rate (MAPLHGR) are set to assure that specified fuel design limits are not exceeded during anticipated transients and loss of coolant accidents (LOCAs), respectively. Evaluations of anticipated operating occurrences indicate that conditions at CLTP with 83% flow are slightly more limiting for OLMCPR than conditions possible in MELLLA operation at CLTP. The licensee determined acceptable MAPLHGR limits by examining the effects of MELLLA+ operation during large and small break LOCAs assuming different power and flow conditions with top-peaked and mid-peaked power shapes. Predictions for peak cladding temperature (PCT), local cladding oxidation, and core-wide metal-water reactions are slightly higher than values predicted for EPU conditions but well below 10 CFR 50.46 acceptance criteria.

Plant System Response

A technical specification was previously revised to increase the boron-10 enrichment of the solution used in the SLCS. This change increases the effectiveness of neutron absorption by boron injected from the SLCS, allows shutdown to occur earlier, and reduces integrated heat loads to the containment.

Evaluations indicate that the MELLLA+ operating domain does not significantly increase heat addition to the suppression pool following the limiting LOCA and transient events compared to MELLLA operation. Suppression pool temperatures are predicted to remain below the heat capacity temperature limit (HCTL) following an ATWS event because less thermal energy is released to the suppression pool due to the increased effectiveness of reactor shutdown from the SLCS boron-10 enrichment.

Plant-specific analyses were performed to evaluate overpressure protection under MELLLA+ conditions. The limiting overpressure event is main steam isolation valve closure with scram on a high flux signal. The predicted peak pressure response is dependent on several input values, including setpoints and drift tolerances of safety relief valves based on PBAPS valve performance testing. Analyses indicate that reactor vessel pressure limits are met without increasing the number of operable safety relief valves or changing assumptions related to relief valve performance.

MELLLA+ conditions could increase the steam moisture content due to reduced steam separator efficiencies at lower flows. Effects of increased moisture carry-over from the steam dryer were evaluated using generic analyses combined with measurements. Exelon will continue these measurements and incorporate any trends into their existing monitoring programs.

Transient and Accident Analyses

The licensee provided evaluations to assess the effects of MELLLA+ operation on the radiological consequences of off-normal events. Results from licensee evaluations for design basis accidents show that radiological consequences during MELLLA+ operation are bounded by results from analyses for the current operating domain. The licensee analyzed several anticipated operating occurrences at CLTP for increased core flow (110%) and at MELLLA+ for reduced core flow (83%) conditions. Plant-specific analyses show that reactor vessel peak pressures remain within applicable limits and that the specified limits for PBAPS are adequate for MELLLA+ operation.

Two approaches are available to the licensee for the analysis of limiting ATWS events: the licensing basis methodology using the ODYN code and a best estimate methodology using the TRACG04 code. Licensing basis calculations assume reactor vessel water level is controlled at five feet above the top of the fuel, and the suppression pool is allowed to heat up even if the HCTL is reached. ODYN calculations for both CLTP and MELLLA+ conditions resulted in suppression pool temperatures less than the HCTL. As noted above, the licensee increased the enrichment of boron-10 in the SLCS. With the increased boron-10 enrichment, ODYN calculations indicate that the suppression pool temperature remains below the HCTL, and a best estimate TRACG04 calculation is not required to establish a suitable depressurization approach.

In addition, the licensee evaluated stability during ATWS events. The results of these best estimate analyses show that mitigation actions in existing PBAPS emergency operating procedures are effective and that no additional operator actions are required for the MELLLA+ operating domain. The licensee focused on two actions that are considered time critical:

- Initiate manual scram via SLCS boron injection within 120 seconds
- Initiate manual reactor water level reduction within 120 seconds

PBAPS has completed simulator training for these actions for all five operating shift crews.

Times to accomplish these actions ranged from 45 to 103 seconds for SLCS initiation and 61 to 105 seconds for water level reduction. During an audit, the staff observed a PBAPS crew successfully accomplish these actions within the allotted times. The licensee will ensure that operators are trained on plant procedures and other aspects associated with the MELLLA+ operating domain expansion.

For PBAPS, the limiting ATWS instability event with respect to PCT is the turbine trip with bypass. Calculations assuming operator actions to reduce feedwater flow at 120 seconds and initiate SLCS boron injection at 120 seconds indicate that a unit will enter a period of flow and power oscillations lasting a few minutes. The calculated PCTs increase during this transient and remain below the regulatory limit of 2200°F. However, the PCT depends on the minimum temperature for stable film boiling (T_{min}), which is uncertain. The staff has become aware of limited test data suggesting that there is additional uncertainty in using the modified Shumway correlation to predict T_{min}. The staff will conduct additional testing to improve understanding of the instability phenomena and reduce uncertainties. To provide insights on the margins during ATWS instability, the staff requested sensitivity studies for PBAPS assuming the homogenous nucleation temperature rather than the modified Shumway correlation for T_{min}. Exelon performed these calculations assuming turbine trip with bypass and dual recirculation pump trip ATWS instability events. In the turbine trip with bypass analyses, Exelon varied their assumptions related to T_{min}, operator action timing, and feedwater temperature response. In the dual recirculation pump trip analysis, Exelon varied the assumptions related to T_{min}, operator action timing, and limiting rod heat flux. Sensitivity analyses identified several cases where a limited number of fuel rods may experience PCTs greater than 2200°F, providing insights related to the impact on safety if operator actions are delayed, if feedwater cooling occurs more rapidly, or if T_{min} is lower than values predicted with the modified Shumway correlation. However, the ATWS acceptance criterion for maintaining a coolable core geometry was met in all cases.

SUMMARY

There is reasonable assurance that the health and safety of the public will not be adversely affected by operation of PBAPS Units 2 and 3 in the expanded MELLLA+ domain. The Exelon application for PBAPS operation in the expanded MELLLA+ domain should be approved, subject to the conditions and limitations identified in the staff's draft safety evaluation.

Sincerely,

/RA/

Dennis C. Bley
Chairman

REFERENCES

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4. GE-Hitachi Nuclear Energy Americas LLC, NEDC-33006P-A, “Maximum Extended Load Line Limit Analysis Plus,” Revision 3, June 2009 (ML091800530).

5. GE-Hitachi Nuclear Energy Americas LLC, NEDC-33075P-A, "GE Hitachi Boiling Water Reactor Detect And Suppress Solution - Confirmation Density," Revision 8, November 2013 (ML13324A098).

6. GE-Hitachi Nuclear Energy Americas LLC, NEDE-33147P-A, "DSS-CD TRACG Application," Revision 4, August 2013 (ML13224A306).

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8. U.S. Nuclear Regulatory Commission, Review Standard 001, “Review Standard for Extended Power Uprate,” December 2003 (ML033640024).

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