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

July 19, 2018

The Honorable Kristine Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: BRUNSWICK STEAM ELECTRIC PLANT UNITS 1 AND 2 MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS LICENSE AMENDMENT REQUEST

Dear Chairman Svinicki:

During the 655th meeting of the Advisory Committee on Reactor Safeguards, July 11-13, 2018, we completed our review of the license amendment request (LAR) and the associated NRC draft safety evaluation to allow operation of Brunswick Steam Electric Plant (Brunswick), Units 1 and 2, in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain under the NRC-approved extended power uprate (EPU) of 2923 MWt. Our Power Uprates Subcommittee reviewed this application on May 16, 2018. In addition, our Thermal-Hydraulics Phenomena Subcommittee reviewed the results from plant-specific TRACE/PARCS calculations on May 15, 2018. During these reviews, we had the benefit of discussions with representatives of the NRC staff, Duke Energy Progress (Duke Energy or the licensee), and their contractors. We also had the benefit of the referenced documents.

RECOMMENDATION AND CONCLUSION

1. The application for operation of Brunswick Units 1 and 2 in the MELLLA+ domain should be approved, subject to the limitations and conditions identified in the staff's draft safety evaluation.
2. The analyses and data submitted in support of this application, as well as the proposed testing that will be completed prior to and during implementation of MELLLA+ operation, provide confidence that safety margins will be maintained.

BACKGROUND

Brunswick Units 1 and 2 are of the BWR/4 design with Mark I containments. These units began commercial operation with a thermal power of 2436 MWt in 1975 (Unit 2) and in 1976 (Unit 1). On May 31, 2002, the NRC granted these units an EPU to increase to the current licensed thermal power (CLTP) of 2923 MWt. These units currently operate in the Maximum Extended Load Line Limit Analysis (MELLLA) domain. Although the proposed MELLLA+ operation is similar, it would expand the allowed operating domain (at CLTP, lower limits for core flow would decrease from 99% to 85%). This expanded domain increases operating flexibility. Rather than

control rod insertion or withdrawal, reactivity at higher powers can be controlled using changes in core recirculation flow. Higher void fractions associated with higher operating power and lower flow (above 50 MWt/Mlbm/hr) in the MELLLA+ domain can increase susceptibility to power oscillations. As a result, enhanced protection against instabilities must be provided.

In support of its LAR, the licensee evaluated the applicability of generic GE-Hitachi (GEH) assessments to Brunswick. Where such generic assessments were not applicable, the licensee provided plant-specific evaluations. Framatome (formerly AREVA) fuel was introduced into Brunswick in 2008. Both units now operate with full cores of ATRIUM™ 10XM fuel. This is the first MELLLA+ application in which GEH thermal-hydraulic methods were applied to Framatome fuel. To evaluate Brunswick response in the MELLLA+ domain, ATRIUM™ 10XM fuel geometry, materials, and correlation predictions for thermal-hydraulic and neutronics response were modeled by GEH using nominal values provided by Framatome. Uncertainty ranges for these values were developed jointly by GEH and Framatome.

DISCUSSION

This MELLLA+ application used a hybrid GEH/ Framatome approach. Safety during MELLLA+ operation will be maintained at Brunswick using a combination of license conditions and technical specification changes, which are demonstrated to be effective using approved GEH thermal-hydraulics analysis methods and approved Framatome fuel analysis methods. Safety margins are preserved by several measures, including:

- Increased isotopic enrichment of boron-10 in the standby liquid control system (SLCS)
- Demonstrated adequacy of operator response times during anticipated transient without scram (ATWS) events
- Use of the Detect and Suppress Solution - Confirmation Density (DSS-CD) methodology
- Prohibition of single-loop operation, feedwater heater out of service, and reduced feedwater temperature operation in the MELLLA+ domain

Our review focused on ensuring that appropriate limitations and conditions from approved generic GEH and Framatome methods were identified and addressed. We concentrated on Brunswick evaluations that led the licensee and staff to conclude:

- Less sensitive DSS-CD parameters are appropriate
- No additional penalty is needed to address power range data uncertainties at the higher power to flow conditions associated with MELLLA+ operation
- No additional credit for containment accident pressure (CAP) is required
- Use of more realistic feedwater temperatures in ATWS calculations were justified

DSS-CD Implementation

The power range neutron monitoring system has been modified to implement the DSS-CD methodology to help protect from coupled neutronic and thermal-hydraulic instabilities. The DSS-CD methodology uses a period-based algorithm to detect the inception of power oscillations and then generate a power suppression signal prior to significant oscillation amplitude growth and minimum critical power ratio degradation. Other protection features include the defense-in-depth DSS-CD algorithms that provide backup scram signals and the manual reactor scram. False scrams are minimized by requiring confirmation from multiple power range monitors and changes to setpoints affecting reactor scram.

Duke Energy requested that the applicability envelope of the DSS-CD methodology be extended to include ATRIUM™ 10XM fuel. Using approved processes, the licensee proposed changes in selected DSS-CD setpoints affecting reactor scram. The licensee submitted evaluations of plant data for selected transients to demonstrate that the requested changes would not violate the associated safety limit. These evaluations demonstrate that these changes would avoid spurious scrams, while bounding the anticipated range of instability frequencies. In their review, the staff concluded that the requested changes in the DSS-CD methodology were acceptable for Brunswick operation in the MELLLA+ domain.

During our discussions with the licensee, we learned that extensive testing was completed to assure that the DSS-CD firmware was appropriately installed and that cybersecurity concerns were addressed. Upon approval for MELLLA+ operation, remaining changes will be implemented to activate the DSS-CD solution on this system using approved procedures that include testing to ensure reactor trips are generated for the appropriate conditions.

Reload Safety Analysis Impacts

Duke Energy submitted calculation results to show that reload analysis limits are not impacted by MELLLA+ operation. These reload calculations do not currently require the use of additional penalties in calculating the safety limit for minimum critical power ratio (SLMCPR). As part of this application, Duke Energy requested that no additional SLMCPR penalty be required for MELLLA+ operation and provided evaluations that considered measurements from several previous Brunswick fuel cycles, which were limited to 46 MWth/Mlb/hr, and higher power-to-flow data from a BWR/6 plant. Results indicated that bundle power uncertainties did not increase at higher power-to-flow ratios. In addition, the licensee committed to perform testing at Brunswick prior to the first cycle of MELLLA+ operation to confirm that uncertainties do not increase at higher power-to-flow conditions. The submitted evaluations, along with the licensee commitment to complete confirmatory testing, provide confidence that no additional SLMCPR penalty is warranted for Brunswick operation in the MELLLA+ domain.

Plant System Response to Off-Normal Events

The licensee analyzed several anticipated operating occurrences assuming CLTP with increased core flow (104.5%) and assuming MELLLA+ operation with reduced core flow (85%). Results indicate that reactor vessel peak pressures remain within applicable limits for MELLLA+ operation. Licensee evaluations for design basis accidents, such as main steam line break and loss-of-coolant accidents, show that radiological consequences during MELLLA+ operation are bounded by results for the current operating domain.

The licensee used the approved licensing basis code, ODYN, for evaluation of ATWS events without instability. Analyses considered nominal values for ATRIUM™ 10XM fuel parameters. Sensitivity evaluations were also performed to address uncertainties in GEH modeling of ATRIUM™ 10XM parameters, including thermal-hydraulic channel losses, gap conductance, and direct energy deposition.

The licensee increased the boron-10 enrichment of the SLCS fluid from greater than 47 atom percent to greater than 92 atom percent. This physical change in SLCS fluid enrichment increases the negative reactivity insertion rate, ensures earlier shutdown, and reduces integrated heat load to the containment. The conservative ODYN calculations predicted suppression pool temperatures above the heat capacity temperature limit following a long-term

ATWS event. However, lower peak temperatures were predicted for MELLLA+ conditions than the currently licensed domain because less thermal energy was released to the suppression pool due to the increased effectiveness of reactor shutdown from the SLCS boron-10 enrichment. Hence, criteria associated with ATWS events and limitations and conditions identified in the approved generic LAR for MELLLA+ operation were satisfied without the need for a best estimate TRACG calculation to establish a suitable depressurization approach.

Brunswick is currently approved to take credit for CAP when evaluating the long-term performance of emergency core cooling system pumps for heat removal. Previous evaluations at EPU conditions demonstrate there is adequate margin in the available net positive suction head using the CAP credit approved by NRC. Analyses for the MELLLA+ domain indicate that emergency core cooling system pump performance is bounded by EPU conditions. Thus, the licensee did not request any additional CAP credit.

Limiting Anticipated Transient without Scram Instability Events

BWRs are susceptible to oscillations that may become unstable with decreasing core flow rate and increasing core power. If oscillations are not suppressed, fuel cladding could experience localized dryout, eventually resulting in peak cladding temperatures (PCTs) greater than 2200°F and possibly, in degraded core geometry that is not coolable.

Limiting ATWS events were evaluated using the TRACG code because of its capabilities to model coupled thermal hydraulics and neutronics phenomena associated with BWR instability. Calculation results indicate that a limiting turbine trip with bypass event leads to the largest predicted oscillation growth rate for Brunswick ATWS instability events. For this event, a unit is predicted to enter a period of flow and power oscillations lasting several minutes. TRACG predictions for the cladding temperature rely on a GEH correlation for predicting the minimum temperature for stable film boiling, T_{min}. Recent NRC experiments performed at the KATHY facility indicate that the GEH correlation may be non-conservative and that T_{min} may be better represented by a correlation based upon the homogeneous nucleation and surface contact temperature (HN+CT). Because this alternate correlation results in higher PCT predictions, the staff requested that the licensee perform sensitivity studies evaluating the use of a correlation relying on HN+CT for predicting T_{min}.

The licensee completed these additional evaluations assuming a T_{min} correlation based on HN+CT and a realistic feedwater temperature reduction rate. To justify that this rate was bounding, Brunswick provided operational data for several turbine trip events. Calculation results for a case assuming nominal fuel parameters indicate that the maximum PCT was well below 2200°F. These results, along with results from sensitivity studies assuming conservative fuel parameters, led the staff to conclude that the core would remain coolable.

To increase confidence that GEH methods appropriately considered Framatome fuel uncertainties, the staff completed plant-specific confirmatory TRACE/PARCS calculations. Staff evaluations considered differences in operator action timing, plant performance, core gap conductance, and other inputs that may be uncertain. TRACE/PARCS results were consistent with TRACG calculations in which T_{min} was based on a HN+CT correlation. Hence, these confirmatory evaluations provide additional confidence that Brunswick operation in the MELLLA+ domain is acceptable.

Analyses indicate that mitigation actions in existing Brunswick emergency operating procedures are effective and that no additional operator actions are required for the MELLLA+ domain.

The licensee has reclassified the action to initiate manual reactor water reduction within 120 seconds as a time critical operator action. This action is now tracked and managed in existing plant procedures. During an audit, the staff observed several Brunswick crews successfully accomplish this action within the required time. The licensee will ensure that operators are trained on plant procedures and other aspects associated with the MELLLA+ operating domain expansion.

SUMMARY

There is reasonable assurance that the health and safety of the public will not be adversely affected by operation of Brunswick Units 1 and 2 in the expanded MELLLA+ domain. The Duke Energy application for Brunswick operation in the expanded MELLLA+ domain should be approved, subject to the conditions and limitations identified in the staff's draft safety evaluation.

In addition, results from plant-specific TRACE/PARCS confirmatory calculations provided important insights, increasing our confidence that calculations submitted by the licensee appropriately addressed uncertainties associated with the Framatome fuel using GEH thermal-hydraulic analyses. Also, the KATHY data provided confidence that the T_{min} correlation used in these calculations is conservative. Such insights are only possible because of the agency's commitment to maintain an independent analysis capability.

Sincerely,

/RA/

Michael L. Corradini
Chairman

REFERENCES

1. Duke Energy, "Request for License Amendment Regarding Core Flow Operating Range Expansion," September 6, 2016 (ML16257A418).

2. Duke Energy, "Brunswick, Units 1 and 2 – Response to Request for Supplemental Information for License Amendment Request Regarding Core Flow Operating Range Expansion," November 9, 2016 (ML16330A400).

3. Duke Energy, "Withdrawal of Information Relating to the Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," February 14, 2018 (ML18045A859).

4. Duke Energy, "Response to Request for Additional Information Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," April 6, 2017 (ML17096A482).

5. Duke Energy, "Response to Request for Additional Information Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," November 1, 2017 (ML17305A875).

6. Duke Energy, "Updates to Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8363 and MF8364)," November 1, 2017 (ML17325B599).

7. Duke Energy, “Response to Request for Additional Information Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," February 5, 2018 (ML18037A660).

8. Duke Energy, "Response to Request for Additional Information SNPB-RAI-2 Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," March 1, 2018 (ML18075A330).

9. Duke Energy, "Response to Request for Additional Information Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion (CAC Nos. MF8864 and MF8865)," April 6, 2018 (ML17096A482).

10. Duke Energy, “Additional Testing Information Relating to the Request for License Amendment Regarding Core Flow Operating Range Expansion," March 14, 2018 (ML18073A236).

11. Duke Energy, "Response to Request for Additional Information Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion," March 29, 2018 (ML18090A004).

12. Duke Energy, “Supplement to Response to Request for Additional Information SRXB-RAI-2 Regarding Request for License Amendment Regarding Core Flow Operating Range Expansion,” April 10, 2018 (ML18100A230).

13. U.S. Nuclear Regulatory Commission, “Brunswick Steam Electric Plant, Units 1 and 2 - Issuance of Amendment Regarding Core Flow Operating Range Expansion (MELLLA+) (EPIDL-2016-LLA-0009),” (Proprietary: ML18164A408, Non-Proprietary: ML18172A258).

14. U.S. Nuclear Regulatory Commission, “TRACE/PARCS Analysis of BSEP MELLLA+ ATWS-I – Part 1,” April 25, 2018 (ML18116A497).

15. U.S. Nuclear Regulatory Commission, “TRACE/PARCS Analysis of BSEP MELLLA+ ATWS-I – Part 2,” May 11, 2018 (ML18183A608).

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

17. GE-Hitachi Nuclear Energy, NEDC-33075P-A, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," Revision 8, November 2013 (ML13324A098).

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

19. GE-Hitachi Nuclear Energy, NEDC-33173P-A, “Applicability of GE Methods to Expanded Operating Domains,” Revision 4, November 2012 (ML123130130).

20. AREVA NP, BAW-10247PA, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," Revision 0, April 2008 (ML081340383).

21. Siemens, XN-NF-80-19(P)(A), “Exxon Nuclear Methodology for Boiling Water Reactors – Neutronic Methods for Design and Analysis,” Volume 1, Supplements 1 and 2, March 1983 (ML081850204).

20. AREVA NP, BAW-10247PA, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," Revision 0, April 2008 (ML081340383).

21. Siemens, XN-NF-80-19(P)(A), “Exxon Nuclear Methodology for Boiling Water Reactors – Neutronic Methods for Design and Analysis,” Volume 1, Supplements 1 and 2, March 1983 (ML081850204).

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