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

October 19, 2017

Mr. Victor McCree
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SAFETY EVALUATION FOR TOPICAL REPORT ANP-10300P, REVISION 0, "AURORA-B: AN EVALUATION MODEL FOR BOILING WATER REACTORS; APPLICATION TO TRANSIENT AND ACCIDENT SCENARIOS"

Dear Mr. McCree:

During the 647th meeting of the Advisory Committee on Reactor Safeguards, October 5-6, 2017, we completed our review of topical report ANP-10300P, Revision 0, "AURORA-B: An Evaluation Model For Boiling Water Reactors; Application to Transient And Accident Scenarios," and the associated NRC staff's safety evaluation (SE). Our Subcommittee on Thermal-Hydraulic Phenomena also reviewed this matter on August 22, 2017. During these reviews, we benefitted from discussions with representatives of the staff, their contractor, and AREVA. We also benefitted from the referenced documents.

CONCLUSION AND RECOMMENDATION

AURORA-B, with the staff-imposed limitations and conditions, provides an acceptable methodology to estimate transient safety margins for boiling water reactors operating up to extended flow window conditions, which include extended power uprate conditions. The staff's safety evaluation should be issued.

BACKGROUND

AURORA-B is a code system developed for predicting the dynamic response of boiling water reactors (BWRs) during a variety of transient and accident scenarios. Based on the methodology described in ANP-10300P, AREVA has proposed to apply AURORA-B to most of the transient and accident events described in Chapter 15 of the NRC's Standard Review Plan. AURORA-B is not intended to be used for instability events, calculations of later stages of anticipated transient without scram scenarios, and control rod withdrawal error events. AREVA has submitted for staff review supplements to the AURORA-B methodology to calculate loss-of-coolant accidents and control rod drop accidents.

AREVA has requested NRC approval of the AURORA-B methodology for operating BWRs up to extended power uprate conditions within the extended flow window (EFW). The staff review has benefited from a number of audits of the applicant's methodology.

DISCUSSION

Codes and Methods

AURORA-B is based on four independent computer codes:

1. RODEX4 fuel thermal-mechanical code [EMF-2994(P)(A)], which has been previously approved for use in BWRs loaded with ATRIUM-10 and ATRIUM-10XM fuel.
2. S-RELAP5 thermal-hydraulic system code [EMF-2100(P)], which has been previously approved for pressurized-water reactor applications.
3. MICROBURN-B2 (MB2) [EMF-2158(P)(A)], which is the approved steady-state core simulator.
4. MB2-K neutron kinetics code (2A4-MB2-K-0), which is an extension of MB2, and the first licensed application of MB2-K.

All these codes, except MB2-K, have previously been reviewed and approved by the NRC for different applications; therefore, the staff concentrated its review on the areas where modifications to the codes were made to accommodate the AURORA-B application to BWRs. These areas include:

1. S-RELAP5 was developed for pressurized-water reactor transients and loss-of-coolant accidents. AREVA added models to extend its applicability to BWRs, including a jet pump model, a mechanistic steam separator model, and critical power correlations. Interfacial drag, interfacial heat and mass transfer, and pressure drop models were improved.
2. RODEX4 models were not modified, but some of its models were incorporated in S-RELAP5 to calculate fuel properties during transients.
3. MB2 is the steady state simulator, which provides initial conditions for AURORA-B calculations. It has not been modified.
4. MB2-K solves the time dependent two-group neutron diffusion equation using high-order nodal methods. It is an extension of MB2.

The staff has reviewed these methodology modifications and concludes that they are acceptable.

The staff found the application of approved AREVA fuel critical power ratio correlations acceptable for use in AURORA-B methodology. For applications with non-AREVA co-resident fuel, the staff reviewed the methodology in EMF 2245(P)(A), “Application of Siemens Power Corporation’s Critical Power Correlations to Co-Resident Fuel,” and found it acceptable. This is because fresh AREVA fuel is likely to be limiting.

Applicability to Extended Power Uprate and Extended Flow Window

The staff reviewed the impact of high void fractions on the accuracy of the MB2 methods to interpolate nuclear cross sections. For nodes with less than 85% void fraction, the MB2 predictions were in excellent agreement with results from the more detailed CASMO4 lattice code. The MB2 uncertainty increases for void fractions greater than 85%. But, under EFW conditions, less than 4% of the core locations have void fractions greater than 85%, and these

locations have low power and small transient reactivity feedback. Thus, the staff found the MB2 cross section methodology acceptable for EFW operation.

AREVA presented benchmarks of measured data against MB2 calculations at high power-to-flow ratios typical of EFW operations. The staff found no statistically significant increase in error of the data as the power to flow increases. Based on these benchmarks and MB2 versus CASMO4 cross section calculations at void fractions up to 85%, the staff concluded that the AURORA-B methodology does not warrant additional safety limit minimum critical power ratio penalties for operation in the portion of the EFW region covered by these data. EFW operation with AREVA methods, however, is approved on a plant-specific basis, and the adequacy of safety limit minimum critical power ratio penalties will continue to be evaluated for each plant.

Uncertainty Analysis

AREVA's overall framework for applying AURORA-B in plant-specific licensing applications involves two steps. For the initial application, AREVA will perform both nominal analyses and non-parametric statistical uncertainty analyses to determine the nominal and one-sided upper tolerance limit values for all relevant figures of merit. For subsequent analyses with no significant changes to the plant design or operating strategy, AREVA is not required to repeat the non-parametric statistical analysis. Rather, AREVA may opt to perform a deterministic analysis using bias factors determined from the most recent application of the non-parametric statistical uncertainty methodology. The staff has found this approach acceptable with specific limitations and conditions as noted in the SE.

Code Updates and Changes

The SE specifies how the AURORA-B codes may be updated or changed without requiring staff review. These updates are limited to changes that do not affect the methodology or validation basis used for the current review. However, the SE allows for changes in source code and structure (for example to allow execution on a different computer platform, including parallel processors), and changes to include approved correlations for future fuel types. Specifying a code-update process provides significant value and removes future regulatory uncertainty.

Limitations and Conditions

The staff SE specifies nineteen limitations and conditions to the range of applicability of the AURORA-B methodology. Most of them deal with specific details of the treatment of uncertainties, and they also enforce limitations to use the methodology within the validated range of applicability. The staff SE also specifies seven limitations and conditions to the allowed code updates and changes. They clearly identify the code changes that are allowed without additional staff review.

We concur with these limitations and conditions.

SUMMARY

AURORA-B, with the staff-imposed limitations and conditions, provides an acceptable methodology to estimate transient safety margins for BWRs operating up to EFW conditions, which include extended power uprate conditions. The staff's SE should be issued.

Sincerely,

/RA/

Dennis Bley
Chairman

REFERENCES

1. AREVA NP, ANP-10300P, "AURORA-B: An Evaluation Mode for Boiling Water Reactors; Application to Transient and Accident Scenarios," Revision 0, December 2009 (ML100040163).

2. AREVA NP, ANP-10300Q1P, "AURORA-B: An Evaluation Mode for Boiling Water Reactors; Application to Transient and Accident Scenarios: Responses to NRC Acceptance Review Questions," Revision 0, July 2011 (ML112160537).

3. AREVA, ANP-10300Q2P, "Response to NRC Request for Additional Information On AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Revision 1, June 2016 (ML1722A190).

4. U.S. Nuclear Regulatory Commission, Safety Evaluation, "Final Safety Evaluation by the Office of Nuclear Reactor Regulation for the Review of Topical Report: ANP-10300P, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Draft Revision 0 (ML17283A403).

5. U.S. Nuclear Regulatory Commission, NUREG-0800, Standard Review Plan, Chapter 15, "Transient and Accident Analysis," March 2007.

6. AREVA NP, EMF-2994(P), "RODEX4: Thermal-Mechanical Fuel Rod Performance Code Theory Manual," Revision 4, December 2009 (ML11217A054).

7. AREVA NP, EMF-2100(P), "S-RELAP5 Models and Correlations Code Manual," Revision 14, December 2009 (ML093630804).

8. Siemens Power Corporation, EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," Revision 0, October 1999 (ML003698556).

9. AREVA NP, 2A4-MB2-K-0, "Theory Manual: A Code for Advanced Neutron Kinetics Method for BWR Transient Analysis," Revision 0, December 2009 (ML093630521).

10. AREVA NP, BAW-10247PA, “Realistic Thermal Mechanical Fuel Rod Methodology for Boiling Water Reactors,” Revision 0, April 2008 (ML081340220).

11. AREVA NP, ANP-2831P, “Identification of Code Capabilities and PIRT Development for BWR Transient Analyses,” Revision 1, December 2009 (ML093630525).

12. Framatome ANP, BAW-10255(P)(A), “Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code.” Revision 2, January 2006 (ML060330499).

13. Siemens Power Corporation, EMF 2245(P)(A), “Application of Siemens Power Corporation’s Critical Power Correlations to Co-Resident Fuel.” Revision 0, August 2000 (ML003753226).

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