



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

December 18, 2020

Ms. Margaret M. Doane
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SAFETY EVALUATION FOR TOPICAL REPORT NEDC-33912P,
"BWRX-300 REACTIVITY CONTROL"

Dear Ms. Doane

During the 681st meeting of the Advisory Committee on Reactor Safeguards, December 1-4, 2020, we completed our review of topical report NEDC-33912P, Revision 0, Supplement 1, "BWRX-300 Reactivity Control," and the associated safety evaluation. We met with the staff and representatives from the applicant. We also had the benefit of the referenced documents. Our Accident Analyses Subcommittee also reviewed this topic on November 2, 2020.

CONCLUSION AND RECOMMENDATION

1. The proposed design requirements, acceptance criteria, and regulatory basis for reactivity control functions documented in NEDC-33912P, subject to the staff-imposed limitations and conditions, are appropriate to evaluate the reactivity response of the reactor.
2. The safety evaluation report should be issued.

BACKGROUND

BWRX-300 is an evolutionary light water reactor based on the certified Economically Simplified Boiling Water Reactor (ESBWR) design and relies on the operating experience of the BWR fleet. Rated at 300 MWe, it is a natural-circulation small modular reactor. It is being developed by GE-Hitachi Nuclear Energy Americas, LLC (GEH). The Applicant has employed risk-informed design principles with the goal of reducing overall plant size and minimizing the highest risk contributors from the ESBWR design. The major improvements to achieve these goals are: reduction in the number and size of reactor pressure vessel (RPV) nozzles to minimize the potential of loss-of-coolant accident (LOCA) events; addition of safety features to minimize the consequences of LOCAs; simplification of safety-significant structures, systems and components; improved control rod drive reliability; prioritization of the use of proven components and supply chain; and simplification of plant construction.

DISCUSSION

Topical report NEDC-33912P provides the design requirements, acceptance criteria, and regulatory basis for the BWRX-300 reactivity control functions. It includes design requirements for the reactor protection system and safety systems with reactivity control functions. The U.S. Nuclear Regulatory Commission staff will evaluate the compliance of the BWRX-300 final design with these requirements during future licensing activities in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 or Part 52, as applicable.

The BWRX-300 design is not yet complete, but the proposed concept relies on control rods and burnable poisons for reactivity control. The topical report specifies the following two main design requirements: (1) shutdown will be achieved under all expected conditions, even with the highest-worth control rod pair withdrawn; and (2) control rod actuators will provide diverse means to achieve insertion, the first one is a non-safety-related fine motion control rod drive, and the second one provides a safety-related rapid insertion. The rapid insertion is accomplished using hydraulic components actuated by stored energy in a compressed nitrogen accumulator. Two diverse mechanisms are used to trigger the hydraulic insertion; one of them satisfies the 10 CFR 50.62 requirement of an Alternate Rod Insertion. The electric-motor-driven control rod drive system uses highly redundant power, but it is slow-acting. In addition, it is used regularly to adjust power, which provides high confidence on its operability. The BWRX-300 probabilistic risk assessment is not yet complete, but the combination of three diverse means to insert the control rods suggests that the probability of failure to scram would be low even though all three scram initiation methods use the same set of control blades. To satisfy the intent of 10 CFR 50.62, the staff imposes Condition 5.1, which requires demonstration that the probability of failure to scram is less than 10^{-5} per reactor year. This condition will be verified on future licensing activities, and it can be accomplished via prototypical testing or through a detailed reliability analysis.

For accident conditions, the coolant temperature and level in the downcomer may be adjusted to control core reactivity and the resulting power level, which is functionally equivalent to the recirculation pump trip required by 10 CFR 50.62. In the case of steam line isolation events, however, effective downcomer water level reduction may not be achievable because the RPV water inventory cannot be reduced. The staff should ensure that effective power and pressure control is achievable in the final design, especially under failure to scram scenarios. GEH has stated that power uprates are not planned at this time; these types of scenarios would likely be limiting and would have to be reviewed in detail by the staff.

The BWRX-300 design uses plant-level defense-in-depth concepts based on five defense lines similar to those used by the International Atomic Energy Agency Specific Safety Requirements (SSR)-2/1. For each of the five defense lines, NEDC-33912P provides a brief description and a list of design features or measures associated with reactivity control. The staff did not specifically review or endorse IAEA SSR-2/1 but evaluated the design requirements as documented in NEDC-33912P. GEH and the staff have evaluated several reactivity control events, and how these affected the level of defense in depth of the BWRX-300 design.

The staff reviewed applicable General Design Criteria (GDC) from 10 CFR Part 50, Appendix A. They performed an evaluation and concluded the NEDC-33912P requirements satisfy the intent of the following GDCs: GDC-20, Protection System Functions; GDC-21, Protection System Reliability and Testability; GDC-22, Protection System Independence; GDC-23, Protection

System Failure Modes; GDC-24, Separation of Protection and Control Systems; GDC-25, Protection System Requirements for Reactivity Control Malfunctions; and GDC-29, Protection Against Anticipated Operational Occurrences.

With respect to GDC-12, Suppression of Reactor Power Oscillations, the staff imposes condition 5.3 requiring a stability analysis be performed with an approved methodology to ensure that, if power oscillations were to develop, acceptable fuel design limits would be maintained.

GDC-26, Reactivity Control System Redundancy and Capability, requires two independent reactivity control systems, one of which shall be capable of holding the reactor core subcritical under cold conditions. The staff finds that the intent of GDC-26 is satisfied by the highly reliable control rod actuation systems, combined with downcomer water level control that may be used to compensate reactivity changes during normal operation.

During the meeting, the Applicant indicated its intent to request an exemption from GDC-27, Combined Reactivity Control Systems Capability. They propose a principal design criteria 27 that requires that the reactor achieve full shutdown at cold conditions with a stuck rod pair using exclusively the remaining control rods. The staff finds that the intent of the original GDC-27 could be satisfied by this modification. The staff will confirm this position and conduct a detailed evaluation of the safety-related reactivity control system during future licensing activities.

GDC-28, Reactivity Increase Limits, requires that designs limit the amount and rate of reactivity-increase accidents to ensure that core coolability and vessel integrity are maintained. The staff imposes Condition 5.2 to perform a control rod drop accident analysis for an equilibrium cycle to confirm that established safety criteria are met.

Because of the similarities between the BWRX-300 concept and the ESBWR, it is reasonable to assume that the reactivity and other accident analysis methods approved for ESBWR are applicable. However, the staff should ensure that the Applicant addresses all limitations and conditions imposed by the staff in the ESBWR methods reviews. The review should consider any special BWRX-300 design or operational features or operating ranges (e.g., increased pressure during some accidents) to ensure applicability.

SUMMARY

The proposed design requirements, acceptance criteria, and regulatory basis for reactivity control functions documented in NEDC-33912P, subject to the staff-imposed limitations and conditions, are appropriate to evaluate the reactivity response of the reactor. The safety evaluation report should be issued.

We are not requesting a formal response from the staff to this letter report.

Sincerely,

Matthew W. Sunseri
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission (NRC), "Draft Safety Evaluation for GE-Hitachi Nuclear Energy Americas, LLC, Topical Report NEDC-33912P/NP, Revision 0, Enclosure 1 and 2, 'BWRX-300 Reactivity Control'," September 29, 2020 (ADAMS Accession Nos. ML20275A373 (Publicly Available) and ML20275A372 (Non-Publicly Available)).
2. GE-Hitachi Nuclear Energy Americas, LLC, NEDC-33912P/NP, Revision 0, Supplement 1, "BWRX-300 Reactivity Control," September 30, 2020 (ADAMS Accession Nos. ML20248H544 (Publicly Available) and ML20248H540 (Non-Publicly Available)).
3. GE-Hitachi Nuclear Energy Americas, LLC, NEDC-33912P/NP, Revision 0, Enclosure 1 and 2, "BWRX-300 Reactivity Control," March 31, 2020 (ADAMS Accession Nos. ML20092A030 (Publicly Available) and ML20092A016 (Non-Publicly Available)).
4. GE-Hitachi Nuclear Energy Americas, LLC., "Response to Request for Additional Information eRAI-7961, Licensing Topical Report NEDC-33912P/NP, Revision 0," August 3, 2020 (ADAMS Accession Nos. ML20216A752 (Publicly Available) and ML20216A750 (Non-Publicly Available)).
5. International Atomic Energy Agency, "Safety of Nuclear Power Plants: Design," Specific Safety Requirements No. SSR-2/1, Rev. 1, IAEA (SSR)-2/1, <https://www.iaea.org/publications/10885/safety-of-nuclear-power-plants-design>.

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