5 REACTOR COOLANT SYSTEM AND CONNECTED SYSTEMS

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Appendix A, "Design Certification Rule for the U.S. Advanced Boiling Water Reactor," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," constitutes the standard design certification (DC) for the U.S. Advanced Boiling Water Reactor (ABWR) design. To document the U.S. Nuclear Regulatory Commission (NRC) staff's review supporting initial certification of the ABWR, the staff issued a final safety evaluation report (FSER) in NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design," in July 1994 and NUREG-1503, Supplement 1, in May 1997.

The staff is documenting its review of the GE-Hitachi Nuclear Energy (GEH or the applicant) application for renewal of the ABWR DC in Supplement 2 to NUREG-1503. Chapter 1 of this supplemental FSER describes the staff's review process for the ABWR DC renewal. This supplemental FSER section documents the NRC staff's review specifically related to Chapter 5, "Reactor Coolant System and Connected Systems," Section 5.4.7.1.1.10, "AC-Independent Water Addition (ACIWA) Mode," of the GEH Design Control Document (DCD), Revision 7. Except as modified by this supplement to the FSER, the findings made in NUREG-1503 and its Supplement 1 remain in full effect.

5.4.7.1.1.10 ACIWA Mode

5.4.7.1.1.10.1 Regulatory Criteria

In the ABWR DCD, Revision 7, GEH proposed a change to add an alternating current (ac) independent water addition (ACIWA) subsystem to Loop B of the ABWR residual heat removal (RHR) system, and to add the component designation "C" for the existing ACIWA subsystem components in Loop C of the RHR system. The ACIWA subsystem on Loops B and C of the RHR system consists of piping and valves that connect the non-safety/safe-shutdown portion of the fire protection system (FPS) to the safety-related RHR system to allow for injection of water into the reactor vessel, the drywell or wetwell spray header, or the spent fuel pool (SFP) during events when ac power is unavailable from both onsite and offsite sources. The safety-related portion of the ACIWA subsystem includes gate valves RHR-F101B/C and RHR-F102B/C (which isolate the FPS from the RHR system and are normally locked closed), instrument valves RHR-F790B/C, test connection valves RHR-F591B/C, and vent and drain valves RHR-F592B/C.

GEH also provided in DCD Tier 1, Section 2.4.4, "Reactor Core Isolation Cooling System (RCIC)," and Tier 2, Section 5.4.6.1.1.1, "Residual Heat" a design enhancement to the reactor core islolation cooling (RCIC) system to allow system operation at a suppression pool maximum temperature condition up to 121 degrees Celsius (C) /[250 degrees Fahrenheit (F)] during a beyond-design-basis event (BDBE) including the loss of onsite and offsite ac (e.g., extended station blackout (SBO)). The RCIC system is a safety system consisting of a steam turbine, pump, piping, valves, accessories, and instrumentation designed to provide sufficient reactor water inventory without ac power for at least 2 hours. Combined license (COL) applicants shall provide the analyses as part of the COL inspections, tests, analyses, and acceptance criteria (ITAAC) for the as-built facility to demonstrate that the facility has the design basis 2-hour reactor inventory capability and non-design basis 8-hour SBO capability. In addition, GEH enhanced the ACIWA subsystem design by expanding the diesel driven ACIWA pump fuel capacity and provided additional flooding protection to further ensure availability of the ACIWA

subsystem under adverse conditions for an extended time up to 72 hours as described in the ABWR DCD Tier 2, Section 19.8.1.3, "Features Selected." GEH also clarified the description in the ABWR DCD Tier 2, Sections 19.8.2.3, "Selected Features" and 19.9.7, "Procedures and Training for use of AC-Independent Water Addition System," on the existing wetwell spray and spent fuel makeup capabilities that are part of the original design.

In a letter dated July 20, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12125A385), the NRC staff identified 28 items for GEH's consideration as part of its application to renew the ABWR DC. In Item No. 26 of the July 20, 2012, staff letter, GEH was asked to address ABWR DCD design changes related to aspects of the NRC Fukushima Near-Term Task Force (NTTF) Recommendation 4.2 regarding mitigation strategies for beyond-design-basis external events. This recommendation was based on the NRC Commission policy at that time outlined in a staff requirements memorandum for SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," dated February 17, 2012 (ADAMS Accession No. ML12039A111).

Subsequently, during the pending draft mitigation of beyond-design-basis events (MBDBE) rule (10 CFR 50.155, "Mitigation of beyond-design-basis events"), the Commission decided not to impose mitigation strategies requirements on DCs.[1] The final rule was published in the *Federal Register* on August 9, 2019 (84 FR 39684) and became effective September 9, 2019.

Therefore, In a letter dated January 23, 2017 (ADAMS Accession No. ML17025A386), GEH submitted a revised response which removed references to the NTTF Recommendation 4.2 based on SECY-12-0025 and described the design changes in the renewal application that it had retained related to Item No. 26, as proposed design enhancements, to the ABWR certified design including the addition of an ACIWA mode to Loop B of the RHR system. As a result, future ABWR COL applicants could use these design enhancements to satisfy the MBDBE rule requirements.

These changes do not fall within the definition of a "modification." Therefore, in accordance with 10 CFR 52.59(c), these design changes are "amendments," as this term is defined in Chapter 1 of this supplemental FSER, and will correspondingly be evaluated using the regulations in effect at renewal. The applicable regulatory requirements for evaluating the proposed DCD design changes to add an ACIWA subsystem to Loop B of the RHR system and related changes as discussed above are as follows:

- 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," (GDC) 1, "Quality Standards and Records," as to the requirement that structures, systems, and components be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- GDC 34, "Residual Heat Removal," as it relates to the ABWR RHR system, which requires the capability to transfer decay heat and other residual heat from the reactor such that fuel

[1] In the MBDBE proposed rule regulatory analysis (ADAMS Accession No. ML15266A133), the Commission proposed to not make the MBDBE proposed rule applicable to existing DCs, which included the ABWR, because "[t]he issues that may be resolved in a DC and accorded issue finality may not include operational matters, such as the elements of the [MBDBE] proposed rule."

and pressure boundary design limits are not exceeded. Compliance with GDC 34 enhances plant safety by providing assurance that decay and RHR system functions will be accomplished and the reactor coolant system pressure boundary and fuel cladding integrity will be maintained, thereby minimizing the potential for the release of fission products to the environment.

- 10 CFR 50.55a, "Codes and Standards," as to the establishment of minimum quality standards for the design, fabrication, erection, construction, testing, and inspection of components of boiling and pressurized water reactor nuclear power plants by requiring conformance with appropriate editions and addenda of industry codes and standards incorporated by reference in 10 CFR 50.55a.

- 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the certified design has been constructed and will be operated in conformity with the certified design, the provisions of the Atomic Energy Act (AEA), and the NRC's regulations.

The staff used the following guidance to determine if the design of systems and components meets the regulatory requirements given above:

- Regulatory Guide (RG) 1.26, Revision 5, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," February 2017.

- RG 1.29, Revision 5, "Seismic Design Classification for Nuclear Power Plants," July 2016.

5.4.7.1.1.10.2 Summary of Technical Information

In its January 23, 2017, letter, GEH provided in Enclosure 1, Table 1, the enhanced design features that it had retained as part of its response to the staff Item No. 26 request regarding mitigation strategies for beyond-design-basis external events. This SER evaluates Items 1, 2, 3 and 5 of Table 1 of the January 23, 2017, letter enclosure which included the following DCD Changes:

- ACIWA subsystem enhancements (Item 1) described in DCD Tier 1, Section 2.4.1, and Figure 2.4.1.b, Tier 2, Table 1AA-2, Table 3.2-1, Table 3.9-8, Attachments 3MA.2.2 and 3MA.2.3, Sections 5.4.7.1, 5.4.7.1.1.10, 5.4.7.1.1.10.4, and Section 5.4.7.2.6, Figure 5.4.-10 SH 5 and 7;

- The diesel driven ACIWA pump fuel capacity (Item 2) described in DCD Tier 2, Section 19.8.1.3;

- The RCIC operation to 121°C/ [250°F] (Item 3) described in DCD Tier 1, Sections 2.4.4, and Table 2.4.4, DCD Tier 2, Section 5.4.6.1.1.1, and Table 5.4-2, "Design Parameters for RCIC System Components," during BDBEs; and

- The enhanced functional description for the wetwell and SFP markup capabilities described in DCD Tier 2, Section 19.8.2.3, Tables 19.8-2 and 19.8-7, and Section 19.9.

In ABWR DCD, Tier 1, Section 2.4.4, the applicant revised the DCD to state that the RCIC system is capable of injecting sufficient water to the vessel to maintain core cooling with suction aligned to the suppression pool, and a suction temperature of 121°C (250°F) during BDBEs (e.g., extended SBO). To account for the higher operating temperature 121°C (250°F) during BDBEs, the applicant revised DCD Tier 2, Table 5.4-2, for the acceptable range of the RCIC pump operating water temperature to add "40°C to 121°C during BDBEs (e.g., extended SBO).

5.4.7.1.1.10.3 Technical Evaluation

The NRC staff reviewed ABWR DCD, Revision 7, to verify that the provisions for the ACIWA subsystem valve design, qualification (functional, environmental, and seismic), and in-service testing (IST) programs are performed in accordance with the applicable regulations, and that DCD Tier 2, Table 3.2-1, "Classification Summary," specifies the required classification for the safety-related portion of the ACIWA subsystem as Safety Class 2, Quality Group B, and seismic Category I, with 10 CFR Part 50, Appendix B, quality assurance requirements. The staff also reviewed the specific design for the additional ACIWA subsystem and its isolation valve classification for consistency with RG 1.26 and RG 1.29 and that the classification is in accordance with the requirements of 10 CFR 50.55a.

DCD Tier 2, Table 3.9-8, "Inservice Testing Safety-Related Pump and Valves," specifies the IST provisions for valves RHR-F101B/C and RHR-F102B/C as Safety Class 2, Category B active valves, and an exercise frequency of every 3 months. The staff determined that the exercise frequency for valves RHR-F101B/C and RHR-F102B/C is consistent with the requirements in 10 CFR 50.55a and ASME/ANSI OMa-1988 Addenda to ASME/ANSI Standard OM-1987, "Operation and Maintenance of Nuclear Power Plants."

In DCD Tier 1, Section 2.4.4, the applicant revised the DCD to state that the RCIC system is capable of injecting sufficient water to the vessel to maintain core cooling with its suction aligned to the suppression pool, and a suction temperature of 121°C [250°F] during postulated BDBEs (e.g., extended SBO). To account for the potential higher operating temperature 121°C [250°F] during BDBEs, the applicant also revised DCD Tier 2, Table 5.4-2, "Design Parameters for RCIC System Components," for the acceptable range of the RCIC pump operating water temperature to add 40°C up to a maximum wetwell temperature of 121°C [250°F] in the event of a BDBE (e.g., extended SBO).

During a postulated BDBE (e.g., extended SBO), the RCIC pump performance requirements could exceed their original safety-related design and performance specifications. Therefore, the applicant added ITAAC No. 11 in ABWR DCD Tier 1, Table 2.4.4, "Reactor Core Isolation Cooling System," with the design commitment that the RCIC system has the capability of injecting sufficient water to the vessel to maintain core cooling with suction aligned to the suppression pool, and a suction temperature of up to 121°C [250°F] during postulated BDBEs (e.g., extended SBO). ITAAC No. 11 also states that analyses will be performed of the as-built RCIC system to assess the system capability with 121°C [250°F] water at the pump suction.

An ABWR COL applicant will address operation of the RCIC system as described in ITAAC No. 11 of DCD Tier 1, Table 2.4.4 and the ACIWA subsystem for vessel injection, drywell or wetwell spray operation, and SFP makeup as described in DCD Tier 2, Section 19.8.2.3. The enhanced DCD descriptions of these modes of operation will enable an applicant to develop the necessary procedures for operation in any of these modes for preventing and mitigating severe

accidents. The ACIWA subsystem valves are shown in DCD Tier 2, Figure 5.4-10. The diesel fire pump will start automatically when the ACIWA subsystem is properly aligned. If the normal firewater system water supply is unavailable, the alternate water supply can be made available by opening the manual valve between the diesel driven fire pump and the alternate water supply. This valve is shown in DCD Tier 2, Figure 9.5-4, "Fire Protection Water Supply System." If it is necessary to use a fire truck, valve F103B/C must be opened, as described in DCD Tier 2, Section 19K.11.5, "AC-Independent Water Addition (Firewater) System," in addition to operation of the valves discussed above for ACIWA subsystem operation. The valve for operation of the ACIWA subsystem using the fire truck is also shown in DCD Tier 2, Figure 5.4-10. All the valves required for ACIWA subsystem operation are manually operable so that in the event of a BDBE (e.g., extended SBO), the system can be aligned for use as necessary.

The NRC staff reviewed and verified that ABWR DCD, Revision 6, includes the following provisions for the design, qualification, and IST programs for the ACIWA subsystem valves. DCD Tier 2, Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures," specifies design provisions for Class 1, 2, and 3 valves in accordance with ASME Boiler and Pressure Vessel Code (BPV Code), Section III requirements. DCD Tier 2, Sections 3.9.3, 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment," and DCD Tier 2, Section 3.11, "Environmental Qualification of Safety-Related Mechanical and Electrical Equipment," specify provisions for functional, seismic, and environmental qualification for the ACIWA subsystem valves. DCD Tier 2, Section 3.9.6, "Testing of Pumps and Valves," specifies IST to be performed in accordance with the requirements of ASME/ANSI OMa-1988 Addenda to ASME/ANSI Standard OM-1987. The NRC staff notes that valves RHR-F790B/C, RHR-F591B/C and RHR-F592B/C (i.e., vent, drain, instrument, and test valves) are exempt from the ASME OM IST program by code due to size and function. In addition, the NRC regulations in 10 CFR 50.55a(f)(4) require a COL holder for an ABWR nuclear power plant to update its IST program to the latest ASME OM Code incorporated by reference in 10 CFR 50.55a a specific time period before fuel load for the initial 120-month IST program interval.

The staff reviewed the design changes as described in the GEH January 23, 2017, letter, Enclosure 1, Table 1, Items 1, 2, 3, and 5 and determined them to be acceptable design enhancements that meet the applicable regulations for the following reasons:

1. The proposed design enhancements in Item No. 1 of the GEH January 23, 2017, letter, provide an additional ACIWA subsystem to Loop B of the RHR system, and add the component designation "C" for the existing ACIWA subsystem components in Loop C of the RHR, which provides additional safe-shutdown capabilities for the ABWR and continue to meet GDC 34.

2. The proposed design enhancements in Item No. 2 provide additional requirements to ensure the availability of the ACIWA subsystem under adverse conditions for up to 72 hours based on an increase of the fire diesel fuel capacity which could be used to meet requirements of the final MBDBE rule and GDC 34.

3. The extension of the RCIC operating temperature (Item No. 3) for beyond-design-basis operating conditions up to a maximum of 121°C [250°F] extends the capability of the RCIC during a loss of all ac power which could be used to meet requirements of the final MBDBE rule and GDC 34.

4. The proposed changes in Item No. 5 provide clarification on the use of the ACIWA for wetwell spray operation and SFP makeup capabilities which allows a potential COL applicant a means to develop the applicable procedures for operations regarding the enhanced functional description for the wetwell and SFP makeup capabilities using the ACIWA subsystem with the capabilities that had already existed and would continue to meet quality assurance requirements of GDC 1.

These proposed ABWR DC Renewal design enhancements could be used by a prospective COL applicant to meet the final MBDBE rule requirements and would continue to meet all the applicable requirements as described above.

5.4.7.1.1.10.4 Conclusion

The NRC staff reviewed the proposed GEH design enhancements that were evaluated as ABWR DCD amendments as described in the GEH letter dated January 23, 2017, Enclosure 1, Table 1, Items 1, 2, 3, and 5. The staff determined them to be acceptable design changes to the ABWR DCD because the proposed additional ACIWA subsystem to Loop B of the RHR system provides additional capabilities for plant cooldown in the event of a loss of all ac power and provides additional flooding protection and diesel fuel capacity for the non-safety fire diesel to ensure the availability of the ACIWA subsystem under adverse conditions for 72 hours. Additionally, the ABWR DCD clarifications as outlined in Item No. 5 of the January 23, 2017, applicant letter for wetwell spray operation and SFP makeup enhance a potential COL applicant's ability to develop the necessary operating procedures that could be used to meet the requirements of the final MBDBE rule. In addition, since the safety-related RHR system that interfaces with the proposed additional ACIWA subsystem will not be affected by this amendment due to the isolation valves testing, alignment, and safety design, the RHR system will function as previously designed with the additional enhancements of operation and additional flexibility such that the GDC 34 requirements are maintained and/or enhanced, and therefore these design enhancements are acceptable.

Since the safety-related portion of the ACIWA subsystem isolation valves that interface with the safety-related RHR system are classified as Safety Class 2, Quality Group B, and seismic Category I, with 10 CFR Part 50, Appendix B, quality assurance requirements the additional isolation valves added for Loop B are acceptable. These manual valves are designed to separate the safety-related portions of the RHR system from the non-safety portions of the fire protection system. Additional isolation valves for this function were added as part of the additional ACIWA subsystem added to the RHR system Loop B. These additional ACIWA subsystem isolation valves for Loop B are the same as previously used for the re-designated Loop C valves and the design and classifications are consistent with RG 1.26 and RG 1.29, and are therefore acceptable.

DCD, Tier 2, Table 3.9-8, specifies the IST provisions for valves RHR-F101B/C and RHR-F102B/C as Safety Class 2, Category B active valves, and an exercise frequency of every 3 months. The exercise frequency for valves RHR-F101B/C and RHR-F102B/C is consistent with the requirements in 10 CFR 50.55a, and ASME/ANSI OMa-1988 Addenda to ASME/ANSI Standard OM-1987. A COL applicant would use the latest version of the ASME OM Code incorporated by reference in 10 CFR 50.55a a specific time period before fuel load for the initial 120-month IST program interval for the development of its IST program. Therefore, the ABWR DCD specified IST provisions are acceptable.

The NRC staff finds that the testing and inspection requirements in proposed ABWR DCD ITAAC No. 11 to analyze the RCIC system (including the RCIC pump) provide the necessary testing verification to ensure that the RCIC pump will operate at the pump suction water temperature up to 121°C [250°F] during BDBE conditions and meets the requirements of 10 CFR 52.47(b)(1) to include the proposed ITAAC that are necessary and sufficient to provide reasonable assurance of RCIC operation in a beyond design basis condition. Therefore, this proposed testing and inspection requirements are acceptable.

Based on the above, the NRC staff finds the ACIWA subsystem addition and the related design enhancements to be acceptable. The design enhancements meet the applicable regulations as stated above including the valve classification and the provisions for the design, qualification (functional, environmental, and seismic), and IST programs.

References

1. 10 CFR 50.155, “Mitigation of Beyond-Design Basis Events,” MBDBE Rule.

2. 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.”

3. 10 CFR 50.55a, “Codes and Standards.”

4. 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants.”

5. 10 CFR Part 50, Appendix A, GDC 1, “Quality Standards and Records.”

6. 10 CFR Part 50, Appendix A, GDC 34, “Residual Heat Removal.”

7. 10 CFR Part 52, Appendix A, “Design Certification Rule for the U.S. Advanced Boiling Water Reactor.”

8. 10 CFR 52.47, “Contents of Applications; Technical Information.”

9. 10 CFR 52.59, “Criteria for Renewal.”

10. NRC, NUREG-1503, “Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design,” July 1994 (ADAMS Accession No. ML080670592).

11. NRC, NUREG-1503, “Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design,” Supplement 1, May 1997 (ADAMS Accession No. ML080710134).

12. GEH, ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 5, Tier 1 and Tier 2, December 2010 (ADAMS Accession No. ML110040323).

13. GEH, ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 6, Tier 1 and Tier 2, February 2016 (ADAMS Accession No. ML16214A015).

14. GEH, ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 7, Tier 1 and Tier 2, December 2019 (ADAMS Accession No. ML20007E371).

15. NRC, RG 1.26, Revision 5, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” February 2017 (ADAMS Accession No. ML16082A501).

16. NRC, RG 1.29, Revision 5, “Seismic Design Classification for Nuclear Power Plants,” July 2016 (ADAMS Accession No. ML16118A148).

17. NRC, SECY-12-0025, “Proposed Orders and Requests for Information in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Tsunami,” February 17, 2012 (ADAMS Accession No. ML12039A111).

18. ASME/ANSI, OMa-1988 Addenda to ASME/ANSI Standard OM-1987, “Operation and Maintenance of Nuclear Power Plants.”

19. ASME, Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” 1989 Edition.

20. ASME, Boiler and Pressure Vessel Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” 1989 Edition.