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 5.4.8, "Reactor Water Cleanup System," 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.

5.4.8 Reactor Water Cleanup System

5.4.8.1 Regulatory Criteria

The ABWR DCD, Revision 7, includes changes to address three major areas as defined in interim staff guidance (ISG)-019, DC/COL-ISG-019, "Review of Evaluation to Address Gas Accumulation issues in Safety Related Systems and Systems Important to Safety," issued September 16, 2011 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML111110572): (1) identification of potential gas accumulation locations and intrusion mechanisms, (2) addition of inspection, tests, analyses, and acceptance criteria (ITAAC) to confirm identification and prevention measures, and (3) development of procedures for surveillance and venting. The changes in Chapter 5 of the DCD provide features that mitigate the possible accumulation of gases in safety-related systems and other important piping systems.

In a letter dated July 20, 2012 (ADAMS Accession No. ML12125A385), the NRC staff identified 28 items for GEH's consideration as part of their application to renew the ABWR design certification. The applicant was requested in Item No. 10 to address the three major review areas of DC/COL-ISG-019. In a follow-up letter dated July 7, 2015 (ADAMS Accession No. ML15188A255), GEH proposed a revision that included changes to important piping systems such as reactor water cleanup system (RWCS) to include a high point vent at the reactor pressure vessel (RPV) head spray line to the main steam line to avoid accumulation of hydrogen generated during normal reactor operation by radiolysis. To address further staff concerns that were discussed in a public teleconference on August 13, 2015 (ADAMS Accession No. ML15230A204), followed by a letter dated September 21, 2015 (ADAMS Accession No. ML15267A060), GEH provided supplemental information to clarify the proposed change to the RWCU system vent with respect to DC/COL-ISG-019. The new vent line does not introduce a high pressure to low pressure interface and therefore does not impact the inter-system loss-of-coolant accident information in the ABWR DCD. Furthermore, at the request of

the staff during a public teleconference dated June 14, 2018 (ADAMS Accession No. ML18173A050), GEH proposed an additional ABWR DCD revision in a letter dated June 22, 2018 (ADAMS Accession No. ML18173A050), to add a combined license (COL) Information Item that would specifically address gas accumulation in the emergency core cooling systems (ECCS) pump suction line piping including an analysis of the ECCS suction piping to determine potential gas accumulation locations and gas intrusion mechanisms.

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 FSER supplement and will correspondingly be evaluated using the regulations in effect at renewal. The applicable regulatory requirements for evaluating the ABWR DCD modification to address gas accumulation are as follows:

- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," (GDC) 34, "Residual Heat Removal," as it relates to the ABWR Residual Heat Removal (RHR) system, requires the capability to transfer decay heat and other residual heat from the reactor such that fuel and pressure boundary design limits are not exceeded. Compliance with GDC 34 enhances plant safety by providing assurance that decay and RHR will be accomplished and the reactor coolant system (RCS) pressure boundary and fuel cladding integrity will be maintained, thereby minimizing the potential for the release of fission products to the environment.

- GDC 35, "Emergency Core Cooling," as it relates to the ECCS system, requires the capability to provide an abundance of core cooling to transfer heat from the core at a rate such that fuel and clad damage changes in core geometry will be such that the core remains amenable to effective core cooling and clad metal-water reaction is limited to a negligible amount. Compliance with GDC 35 requires that an ECCS be provided that is capable of transferring heat from the reactor core, following a loss of reactor coolant, at a rate sufficient to ensure that the core remains in a coolable geometry, and that the calculated cladding oxidation and hydrogen generation meet the specified performance criteria.

- TMI Action Plan- Item II.B.1 of NUREG–0737, "Clarification of TMI Action Plan Requirements," issued November 1980 (TMI Action Plan), equivalent to 10 CFR 50.34(f)(2)(vi) for applicants subject to 10 CFR 50.34(f), requires that reactor coolant system vessel head high-point vents be provided with remote operation from the control room with valve position indication. In addition, their operation shall not lead to an unacceptable increase in the probability of a loss-of-coolant accident or an unacceptable challenge to containment integrity.

5.4.8.2 Summary of Technical Information

DCD Tier 1, Section 2.6.1 includes an ITAAC requirement to inspect and confirm that the as-built RWCS high-point vent line to the RPV head spray line has the proper slope consistent with the design configurations. The applicant added the following ITAAC text to DCD Tier 1, Table 2.6.1:

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitments	**Inspections, Tests, Analyses**	**Acceptance Criteria**
7. RPV Head Spray line will have a high point vent line with the proper slope to prevent buildup of Hydrogen Gas during operation.	7. Inspections will be performed on the as built CUW piping to confirm proper elevation and slope.	7. RPV Head Spray line will have a high point vent line with the proper slope to prevent buildup of Hydrogen Gas during operation.

- DCD Tier 2, Section 5.4.8 includes the following text:

  A vent line down to the main steam line is provided at the high point of the RPV head spray line in order to avoid accumulation of hydrogen generated by radiolysis of reactor water during normal reactor operation.

- DCD Tier 2, Section 5.4.15 includes the following COL Information Item:

  The COL applicant shall develop periodic (monthly) surveillance procedures to ensure the Main Steam Equalizing Valve and the Main Steam Drain Valve are opened for short durations to vent any potential accumulation of hydrogen in the main steam vent and equalizing lines.

DCD Tier 2, Table 1.9-1 includes the COL Information Item above. DCD Tier 2, Figures 5.1-3 and 5.4-12, piping and instrumentation diagram (P&ID), include the new vent line modification to the Main Steam and RWCU Head Spray piping.

In the letter dated June 22, 2018, GEH proposed a COL Information Item to address gas accumulation in the ECCS pump suction line piping regarding potential gas accumulation locations and gas intrusion mechanisms.

- DCD Tier 2, Section 5.4.15 include the following COL Information Item:

  The COL applicant shall perform an analysis of the ECCS pump suction piping configuration to determine potential gas accumulation locations and gas intrusion mechanisms.

  In addition, the COL applicant shall address the potential for gas accumulation in ECCS on a programmatic basis that includes verification of adequate vents and other design features to prevent or mitigate gas accumulation in the pump suction line.

In the ABWR DCD Revision 7, the applicant has updated the DCD Tier 2, Table 1.9-1 with the COL Information Item discussed above.

5.4.8.3 Technical Evaluation

Experience from operating plants indicates that gas accumulation in ECCS and systems important to safety may render the system inoperable during a transient event. Prior to 2005, there have been at least five gas accumulation events of GE designed reactor plants that resulted in an ECCS or system important to safety being declared inoperable. Gas accumulation is known to cause water hammer, gas binding in pumps, and inadvertent relief

valve actuation that may damage pumps, valves, piping, and supports. The NRC issued DC/COL-ISG-019 to provide guidance regarding safety-related systems to supplement NUREG–00800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," and other standard review plans for systems important to safety because they did not include specific concerns and guidance to the extent covered in Generic Letter 2008-01, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal and Containment Spray Systems," dated January 11, 2008, (ADAMS Accession No. ML072910759).

In support of the piping vent line configuration changes, the applicant included an ITAAC in DCD Tier 1, Table 2.6.1, to inspect and confirm that the as-built RWCU System vent piping slopes is consistent with detailed design drawings. In addition, the staff noted that the changes to the vent line include one isolation valve that connects the head spray line to the main steam line from where the accumulated gas is vented through two valves in series. The three valves are controlled from the control room, and valve position is indicated. The staff also noted that having these valves in series satisfies the TMI action item requirement that at least two vent valves must be in series to minimize the challenges to the ECCS from an inadvertent opening of a new or existing vent line.

In addition, GEH added a COL Information Item to develop periodic surveillance procedures to ensure the main steam equalizing valve and the main steam drain valve are opened for short durations to vent any potential accumulation of hydrogen in the main steam vent and equalizing lines.

The staff evaluated the configuration changes described above and finds that the changes comply with TMI Action Plan Item II.B.1, as required by 10 CFR 50.34(f)(2)(vi), in removing potential hydrogen that may adversely affect core cooling. The staff confirmed the changes are reflected in the ABWR DCD, Revision 7.

While GEH proposed the addition of a high point vent and the main steam vent changes that satisfy the TMI action item as described in DCD Revision 6, they did not fully address DC/COL-ISG-019 guidance and, therefore, the requirements of GDC 34 and 35 with respect to gas accumulation in safety-related systems and systems important to safety. Therefore, in its letter dated June 22, 2018, GEH proposed a COL Information Item to address gas accumulation in the ECCS pump suction line piping by means of an analysis to identify the potential gas accumulation locations and gas intrusion mechanisms. In addition, a COL applicant referencing this design would need to address the potential for gas accumulation in ECCS on a programmatic basis that includes verification of adequate vents and other design features to prevent or mitigate gas accumulation in the pump suction line. The staff evaluated the ECCS subsystems piping configuration to determine that the COL Information Item sufficiently addresses the DC/COL-ISG-019 guidance as summarized below.

The ABWR ECCS consists of the following subsystems: (1) high pressure core flooder (HPCF), (2) low pressure flooder (LPFL) Mode of the RHR System, (3) reactor core isolation cooling (RCIC) system, and (4) automatic depressurization system (ADS). ADS is not considered in this evaluation because the gas accumulation is not a factor for a system composed of reactor safety relief valves (SRVs). The remaining ECCS subsystems are designed to maintain the suction piping line water filled during normal operations.

The HPCF subsystem is designed with two independent loops that take their primary suction from the condensate storage tank (CST) and secondary suction from the containment

suppression pool. The HPCF pumps are located at an elevation which is below the water level of the suppression pool. This assures the pump suction line remains full. Also, for each loop, a full flow line is provided with discharge to the suppression pool to allow for a full flow test of the system during normal operation. The ABWR technical specifications specify a periodic full flow system functional test on a 92-day basis. The COL Information Item added by the applicant directs a COL applicant to perform an analysis to determine potential gas accumulation locations and gas intrusion mechanisms.

The staff finds that the HPCF design in the ABWR DCD is acceptable because the suction piping line is configured below the elevation level of the makeup sources, the suction piping line is periodically purged during the functional test, and the COL Information Item directs a COL applicant to address the suction piping to ensure consistency with guidance in DC/COL-ISG-019.

The RHR system has a LPFL subsystem mode that pumps water from the suppression pool into the reactor vessel at low reactor pressure. During normal plant operation, the RHR loops are in a standby condition with the RHR pumps not running. The RHR system is designed to have the pumps start and deliver water into the reactor vessel within 36 seconds after receipt of the low-pressure permissive signal following system initiation. Any gas accumulation in the suction line may delay the injection beyond 36 seconds, which may impact and invalidate the transient analysis. Therefore, the suction line of the RHR design includes water leg pumps (line fill pumps) which are normally running to keep the pump discharge lines filled while the RHR system is in standby mode.

However, operating plant experience has shown that the water leg pumps may become air bound unable to perform their intended function; thus, gas accumulation may occur during normal power operation. The proposed GEH COL Information Item from the letter dated June 22, 2018, directs a COL applicant to address the potential for gas accumulation in the ECCS on a programmatic basis that includes other design features to prevent or mitigate gas accumulation in the pump suction line. The staff evaluated the applicant's changes and finds that the design of the RHR system in the ABWR DCD, Revision 7, is acceptable because the water leg pumps are designed to prevent gas accumulation in the discharge line piping, the periodic functional test provides purging of the suction line, and the COL Information Item directs a COL applicant to evaluate the suction piping to ensure the design satisfies the guidance in DC/COL-ISG-019.

The RCIC system is designed to provide makeup water from the CST or the suppression pool to the reactor vessel during a reactor shutdown in which feedwater flow is not available. The system is started automatically on a low reactor water level signal or manually by the operator. Also, a design flow functional test of the RCIC system is performed periodically during normal plant operation by drawing suction from the suppression pool and discharging through a full flow test return line to the suppression pool. This test is performed to assure the system design flow and head requirements are attained within 30 seconds to support the transient analysis. During normal plant operation, the RCIC is in standby mode with the pump suction line kept filled. The flow test has the capability of removing any potential gas that may have accumulated during the 92-day testing interval as specified in the technical specifications. The COL Information Item directs a COL applicant to perform an analysis to determine potential gas accumulation locations and gas intrusion mechanisms and the necessity for additional venting and filling.

In regard to gas accumulation, the staff evaluated the RCIC design and finds that it is acceptable because the measures undertaken in the design prevent potential gas accumulation

including the COL Information Item that directs a COL applicant to address the guidance in DC/COL-ISG-019 and therefore, the requirements of GDC 34 and 35 are satisfied for safety related and important to safety systems.

In summary, the staff determined that the ECCS system conforms with the guidance in DC/COL-ISG-019 because: (1) the HPCF, RCIC and RHR subsystem suction piping is below the elevation of the makeup sources, (2) the RHR LPFL subsystem suction piping has water leg pumps that maintain the discharge piping water filled, (3) ECCS subsystems are functionally tested, which also allows the purging of the suction piping, (4) the discharge piping is periodically vented and filled as specified in the technical specifications on a 92-day interval, and (5) the COL Information Item directs a COL applicant to address the analysis to be conducted to determine the necessity for additional venting and filling. Therefore, the staff finds the applicant's ABWR DCD, Revision 7, changes acceptable.

The staff confirmed that the applicant provided the requested COL information regarding ECCS gas accumulation in the ABWR DCD, Revision 7, which incorporates the changes described in the applicant's letter dated June 22, 2018. Therefore, Confirmatory Item 5.4.8-1 from the staff advanced safety evaluation with no open items for the ABWR DC renewal is resolved and closed.

5.4.8.4 Conclusion

The staff reviewed the changes for renewal of the ABWR DC as described in the DCD Tier 1 and Tier 2 sections of ABWR DCD, Revision 7, that address conformance with DC/COL-ISG-019 and TMI Action Plan Item II.B.1. Based on the staff's technical evaluation described in this FSER supplement, the staff found that the changes meet the guidance specified in DC/COL-ISG-019 to reduce gas accumulation in safety-related systems and systems important to safety. Regarding the TMI Action Plan, the changes add the capability of removing hydrogen from the reactor vessel head with high-point vents remotely operated from the control room. The staff finds that the changes comply with 10 CFR 50.34(f)(2)(vi), meet the guidance specified in DC/COL-ISG-019 and TMI Action Plan Item II.B.1, and do not alter the safety findings made in NUREG-1503 and its Supplement 1, the staff FSER for the original ABWR DC. Therefore, the staff concludes that the amendments to the ABWR DCD associated with the design changes outlined above meet the requirements of GDC 34 and GDC 35 and are acceptable.

References

1. 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants.”

2. 10 CFR Part 50, Appendix A, GDC 34, “Residual Heat Removal,”

3. 10 CFR Part 50, Appendix A, GDC 35, “Emergency Core Cooling.”

4. 10 CFR 50.34, “Contents of applications; technical information.”

5. 10 CFR Part 52, Appendix A, “Design Certification Rule for the U.S. Advanced Boiling Water Reactor.”

6. 10 CFR 52.59, “Criteria for Renewal.”

7. NRC, DC/COL-ISG-019, “Review of Evaluation to Address Gas Accumulation Issues in Safety Related Systems and Systems Important to Safety,” September 16, 2011 (ADAMS Accession No. ML111110572).

8. NRC, NUREG–0737, “Clarification of TMI Action Plan Requirements,” November 1980 (ADAMS Accession No. ML051400208).

9. NRC, NUREG–00800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (ADAMS Accession No. ML051400208).

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).