5.0 Reactor Coolant System and Connected Systems

5.4.8 Reactor Water Cleanup System

5.4.8.1 Regulatory Criteria

In the GE-Hitachi Nuclear Energy (GEH), Advanced Boiling-Water Reactor (ABWR) Design Certification Document (DCD) Revision 6, the applicant proposed a change to address three major areas as defined in Interim Staff Guidance (ISG)-019, September 16, 2011, "Evaluation to Address Gas Accumulation Issues in Safety Related Systems and Systems Important to Safety," (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 change would 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 Nuclear Regulatory Commission (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 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 staff concerns, in a letter dated September 21, 2015 (ADAMS Accession No. ML15267A060), GEH provided supplemental information to clarify the proposed change with respect to ISG-019, to update the reactor water cleanup system, and to address intersystem loss of coolant accident as a result of the proposed DCD amendment. Furthermore, at the request of the staff, in a letter dated June 22, 2018 (ADAMS Accession No. ML18173A050), GEH proposed a change to add a Combined Operating License (COL) Action Item to address gas accumulation in the emergency core cooling systems (ECCS) pump suction line piping and analysis of the ECCS suction piping to determine potential gas accumulation locations and gas intrusion mechanisms.

These proposed changes do not fall within the definition of a "modification." Therefore, in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 52.59(c), these design changes are "amendments," as this term is defined in Chapter 1 of this supplement and will correspondingly be evaluated using the regulations in effect at renewal. The applicable regulatory requirements for evaluating the proposed DCD modification to address gas accumulation are as follows:

General Design Criteria (GDC) 34, "Residual Heat Removal," as it relates to the ABWR Residual Heat Removal (RHR) system, which 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,” equivalent to 10 CFR 50.34(f)(2)(vi) for applicants subject to 10 CFR 50.34(f), requires that RCS 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

ABWR DCD, Revision 6, 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 elevations and slopes consistent with the design configurations. The following ITAAC text was added to Table 2.6.1 as shown below.

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.

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.

Tier 2, Section 5.4.15 includes the following COL action 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.

Tier 2, Table 1.9-1 includes the COL action item above.

Tier 2 piping and instrumentation diagram (P&ID) Figures 5.1-3 and 5.4.-12 include the new vent line modification to the Main Steam and RWCU Head Spray piping.

In a letter dated June 22, 2018 (ADAMS Accession No. ML18173A050), GEH proposed a COL action item to address gas accumulation in the ECCS pump suction line piping regarding potential gas accumulation locations and gas intrusion mechanisms.

Tier 2, Section 5.4.15 will include the following COL action 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.

The next revision to Tier 2, Table 1.9-1 will include the COL action item above, incorporation of the proposed COL action item will be tracked as **Confirmatory Item 5.4.8-1**.

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. ISG-019 was issued to provide supplemental guidance regarding safety-related systems in the NRC NUREG–00800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: (LWR Edition),” Standard Review Plans (SRPs) and systems important to safety SRPs because they did not include specific concerns and guidance to the extent covered in Generic Letter (GL) 2008-01, “Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal and Containment Spray Systems,” January 11, 2008, (ADAMS Accession No. ML072910759).

To address gas accumulation in safety-related systems, GEH proposed the following amendments as described in the previous section to the ABWR design certification.

In support of the piping configuration change, an ITAAC was included in DCD Tier 1, Table 2.6.1 to inspect and confirm that the as-built RWCU System vent piping elevations and slopes are consistent with detailed design drawings. In addition, the proposed change includes 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. 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 proposed to add a COL action 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.

Therefore, the staff finds the above proposed changes comply with the TMI Action Plan Item II.B.1 of NUREG–0737 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 in the ABWR DCD Revision 6.

While the 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 do not fully address 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 a letter dated June 22, 2018 (ADAMS Accession No. ML18173A050), GEH proposed a COL action 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, the COL applicant will 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 action item sufficiently addresses the ISG-019 guidance as summarized below.

The ECCS consists of the following subsystems: (a) High Pressure Core Flooder (HPCF), (b) Low Pressure Flooder (LPFL) Mode of the RHR System, (c) Reactor Core Isolation Cooling (RCIC) System and (d) 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 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. A full flow test return line is consistent with established boiling-water reactor practice

to test the safety related system at the normal injection flow rate. An additional benefit of this flow test is the capability of removing any potential gas that may have accumulated between the periodic testing. The ABWR technical specifications specify a periodic full flow system functional test on a 92-day basis. The proposed COL action item requires a COL applicant to address providing an analysis to be performed to determine the necessity for additional venting and filling.

The staff finds that the DCD HPCF design 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 proposed COL action item requires a COL applicant to address the suction piping to ensure consistency with ISG-019 guidance.

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, plant experience has shown that the water leg pumps may become air bound and not be able to perform their intended function; thus, gas accumulation may occur during normal power operation. The proposed COL action item requires the 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. Therefore, the staff finds that the ABWR DCD Revision 6 RHR system design 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 proposed COL action item requires a COL applicant to address the evaluation of the suction piping to ensure the design satisfies ISG-019 guidance.

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, 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 proposed COL action item requires a COL applicant to address an analysis to be performed to determine the necessity for additional venting and filling.

In regard to gas accumulation, the staff finds that the ABWR DCD Revision 6 RCIC design is acceptable because the measures undertaken in the design to prevent potential gas accumulation, including the proposed COL action item which requires a COL applicant to address the ISG-019 guidance is met and therefore the requirements of GDC 34 and 35 are satisfied for safety related and important to safety systems.

In summary, the ECCS system conforms with ISG-019 guidance because: (1) the HPCF, RCIC and RHR subsystems suction piping is below the elevation of the makeup sources, (2) RHR LPFL subsystem suction piping has water leg pumps which maintain the discharge piping water filled, (3) ECCS subsystems are functionally tested, which also allows purging of suction piping, (4) the discharge piping is periodically vented and filled as specified in the technical specifications on a 31-day interval, and (5) the GEH proposed COL action item requires 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 proposal acceptable.

The staff confirmed the original GEH proposed changes in ABWR DCD Revision 6; however, the GEH change proposal submitted on June 22, 2018, will be included in the next revision, and is being tracked as **Confirmatory Item 5.4.8-1**.

5.4.8.4 Conclusion

The staff reviewed the proposed changes to the GEH ABWR design certification renewal in DCD Tier 1 and Tier 2 sections that address conformance with ISG-019 and NUREG–0737, TMI Action Plan Item II.B.1. Based on the staff's technical evaluation described in this final safety evaluation report (FSER) section supplement, the staff found that the proposed changes support the guidance specified in ISG-019 to reduce gas accumulation in safety-related systems. In regard to NUREG–0737, the proposed changes add the capability of removing hydrogen from the reactor vessel head with high point vents remotely operated from the control room. The staff found the proposed changes are in compliance with 10 CFR 50.34(f)(2)(vi), meet ISG-019 and TMI Action Plan Item II.B.1 guidance, and do not alter the safety findings made in the FSER for the original ABWR certification. Therefore, the staff concludes that the proposed amendment to the ABWR DCD associated with the design changes outlined above meets the requirements of a GDC 34 and GDC 35 and are therefore acceptable. Inclusion of the proposed changes in Revision 7 of the DCD is being tracked by the **Confirmatory Item 5.4.8-1** discussed above.