19 SEVERE ACCIDENTS

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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 19, “Severe Accidents,” Section 19.2.3.3.4, “ABWR Containment Vent Design,” 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.

19.2.3.3.4 ABWR Containment Vent Design

In ABWR DCD, Revision 7, GEH identifies the ABWR containment vent system as the containment overpressure protection system (COPS). The COPS is a subsystem of the non-safety-related Atmospheric Control System (ACS). COPS is relied upon to function during beyond-design-basis events (e.g., severe accidents). The design basis of the COPS is discussed in DCD Tier 2, Section 6.2.5.2.6.2,” Containment Overpressure Protection System,” DCD Tier 2, Section 19E.2.8.1, “Containment Overpressure Protection System,” and DCD Tier 2, Section 19K.11.6, “Containment Overpressure Protection System (COPS).” In the staff evaluation documented in Section 19.2.3.3.4 of NUREG-1503, the staff FSER for the original ABWR DC, the staff approved the COPS design for the ABWR DCD, Revision 4. In a letter dated January 8, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16008A079), GEH proposed increasing the COPS pipe diameter and rupture disk in DCD Tier 2, to reflect a correction to an error in the original system flow rate calculations, and to conform with the required minimum capacity COPS flow rate in DCD Tier 1, Section 2.14.6, “Atmospheric Control System.”

19.2.3.3.4.1 Regulatory Criteria

As stated GEH made changes as reflected in ABWR DCD, Revision 7, to correct an error and to address an inconsistency between DCD Tier 1 and Tier 2. The changes to the COPS in the ABWR DCD corrects an error and inconsistency in the existing DC and therefore, they are “modifications,” as that term is defined in Chapter 1 of this FSER supplement and will correspondingly be evaluated using the regulations applicable and in effect at the initial ABWR certification.

The applicant included the COPS in the original ABWR design to address Commission policy goals related to severe accidents, as documented in SECY-90-016, “Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationships to Current Regulatory

Requirements," dated January 12, 1990 (ADAMS Accession No. ML003707849), and the associated staff requirements memorandum (SRM), dated June 26, 1990 (ADAMS Accession No. ML003707885), rather than to meet regulations that existed at the time of initial certification. Therefore, the staff reviewed the COPS changes to ensure the ABWR DC renewal continues to meet the Commission's position for inclusion of a dedicated containment vent path in the ABWR. In the SRM, the Commission approved the use of COPS in the ABWR subject to the results of a comprehensive regulatory review to fully weigh the potential "downside" risks with the mitigation benefits of the system. In addition, the Commission directed the staff to ensure that the design should provide full-flow capability to maintain control over the venting process. This Commission position was used in the review of the COPS for the original ABWR design, as discussed in Section 19.2.3.3.4 of NUREG–1503, the FSER for the original ABWR DC. The staff reviewed the COPS modifications made in the ABWR DCD, Revision 7, to ensure the conclusions reached in its review of the original ABWR DC remain valid.

19.2.3.3.4.2 Summary of Technical Information

By letter dated January 8, 2016 (ADAMS Accession No. ML16008A079), GEH submitted proposed changes to the ABWR COPS. GEH stated that during the process of confirming the detailed design of the COPS pipe diameter in an ABWR under construction, the required minimum capacity COPS flow rate of 28 kilograms per second (kg/s) specified in DCD Tier 1, could not be achieved with the certified DCD Tier 2 design information since the original system flow rate calculations did not adequately account for pipe losses. To address this issue, GEH proposed changes to the ABWR DCD to maintain the DCD Tier 1 flow rate of 28 kg/s. The design changes increase the diameter of the COPS piping from 250 millimeters (mm) (10 inches (in)) to 350 mm (14 in), and the rupture disk size from 200 mm (8 in) to 250 mm (10 in). GEH states that these DCD Tier 2 design changes to correct the flow rate calculation error will achieve the minimum COPS flow rate of 28 kg/s as described in DCD Tier 1, Section 2.14.6.

In letters dated February 18, 2016 (ADAMS Accession No. ML16049A044), April 19, 2016 (ADAMS Accession No. ML16110A154), June 16, 2016 (ADAMS Accession No. ML16168A302), and October 11, 2016 (ADAMS Accession No. ML16285A132), GEH provided additional ABWR DCD changes and supporting technical information in regard to the COPS.

19.2.3.3.4.3 Staff Evaluation

The staff approved the COPS design as a part of the original ABWR DC review which is documented in Section 19.2.3.3.4 of NUREG–1503, the staff FSER for the original DC. The staff review of the DC renewal COPS design changes focused on assessing the potential impacts on the COPS performance analyses in support of the originally certified ABWR design and associated staff findings.

The staff reviewed the applicant's changes in Chapters 6, "Engineered Safety Features," and Chapter 19, "Response to Severe Accident Policy Statement," of the ABWR DCD, Revision 6, to determine if the COPS is able to meet the required minimum flow rate specified in DCD Tier 1, Section 2.14.6. Fluid flow in piping is accompanied by friction and this friction is reflected in the system performance (e.g., flow rate). In a system with a given pressure input (e.g., actuation pressure for a rupture disk), as the system friction decreases (e.g., due to increasing pipe diameter), the flow rate increases. Therefore, the staff determined that GEH's approach to increase the size of piping and components in the COPS flow path is a reasonable approach to reduce friction losses in order to meet the required minimum flow capacity for COPS.

A staff analysis confirmed that the applicant's original system flow rate calculations did not properly account for pipe losses. In a public teleconference on September 22, 2016 (ADAMS Accession No. ML17004A315), the staff requested that GEH provide details on the calculated piping losses. In its letter dated October 11, 2016 (ADAMS Accession No. ML16285A132), GEH provided the overall system resistance coefficient for its calculations. The staff review and analysis confirmed that the applicant's revised COPS design and analysis properly account for pipe losses and provide assurance that the COPS flow requirement in DCD Tier 1, Section 2.1.4 is met. In addition, DCD Tier 1, Table 2.14.6, "Atmospheric Control System," Inspections, Tests, Analyses and Acceptance Criteria 2.14.6-04, requires a combined license holder to confirm that the design meets the Tier 1, Section 2.1.4, COPS flow rate based on the as-built plant layout and the as-built system loss coefficients. Therefore, staff finds the applicant's DCD Tier 2, changes meet the DCD Tier 1, COPS flowrate acceptance criterion.

In a supplemental letter dated April 19, 2016 (ADAMS Accession No. ML16110A154), GEH stated that they reviewed the applicable severe accident analyses and evaluations performed for the ABWR DC and identified those items potentially affected by the COPS design changes. Based on the review, GEH identified the impact of flashing during venting to be the only analysis affected by the change, particularly related to the suppression pool surface response to a decompression wave. Since the increase in the COPS sizing maintains the original COPS performance characteristics (e.g., rupture disk setpoint of 0.72 Megapascal (MPa), minimum COPS flow rate of 28 kg/s), the staff determined that the original analyses, other than the COPS pressure loss error, remain valid, including the thermal-hydraulic accident sequence and core melt progression analyses.

In DCD Tier 2, Section 19E.2.3.5.1, "Response of Suppression Pool Surface to Decompression Wave," GEH describes the evaluation of the response of the suppression pool surface to a decompression wave. DCD Section 19E.2.3.5.1 states that the decompression resulting from the COPS rupture disc opening during an accident is not large enough to cause pool pressure to drop below its saturation pressure of 330 kilopascals (kPa) at its initial temperature of 410 kelvin (K), or 137 degrees Celsius °(C) (738 degrees Rankine (R) or 278 degrees Fahrenheit °(F)) and that the pool surface would move upward at only a negligible velocity for the transmitted decompression. GEH reevaluated the response of the suppression pool surface to a decompression wave for the new COPS piping and the rupture disk sizes to confirm that the conclusions in the certified ABWR DCD are unchanged and provided associated changes to DCD Tier2, Section 19E.2.3.5.1.

The staff review identified errors in three equations in DCD Tier 2, Section 19E.2.3.5.1.2, "The Gas Discharge Rate," Equations 19E.2-41a, 19E.2-41d, and 19E.2-41k. The (k + 1) term in the denominator of the exponential term in Equations 19E.2-41a and 19E.2-41d should be corrected as (k – 1). In these equations, k represents the specific heat ratio for an ideal gas because the applicant assumed that the nitrogen and steam mixture in the COPS piping would behave as an ideal gas. To check the validity of this assumption the staff calculated the suppression pool surface response to a decompression wave using thermodynamic properties of a mixture of nitrogen and saturated steam instead. The magnitude of the decompression wave transmitted into the water pool and the resulting pool rise velocity, as presented in DCD Tier 2, Section 19E.2.3.5.1.6, "Water Dynamic and Thermodynamic Response," did not change (up to two significant figures). Therefore, the staff determined that applicant's assumption is acceptable. The Ct/r in the exponential term in Equation 19E.2-41k should be corrected as Ct/R. In this equation, C, t, r, and R represent the acoustic speed, time, distance from the

center of COPS piping at the entrance to the suppression pool, and radius of COPS piping at the entrance to the suppression pool, respectively. The staff found that these errors did not affect the results provided in the certified ABWR DCD or in the DC renewal application. In its calculations GEH used the corrected form of Equations 19E.2-41a and 19E.2-41d and a conservatively simplified version of Equation 19E.2-41k that did not contain the erroneous term.

In the applicant's letters dated February 19, 2016 (ADAMS Accession No. ML16049A043), and June 16, 2016 (ADAMS Accession No. ML16168A301), GEH stated that after its review, it agreed with the staff on these errors. Corrected the equations and provided proposed DCD changes in ABWR DCD, Revision 6, markups.

The staff's review of GEH's February 19, 2016, and June 16, 2016, letter submittals confirms that the increase in COPS piping and the rupture disk sizes did not affect the conclusions in the certified ABWR DCD that; (1) the decompression resulting from the COPS rupture disk opening during an accident is not large enough to cause pool pressure to drop below its saturation pressure of 330 kPa at its initial temperature of 410 K or 137°C (738 R or 278°F), and (2) that the pool surface would move upward at only a negligible velocity for the transmitted decompression. The staff's review also finds GEH's changes to DCD Tier 2, Section 19E.2.3.5.1 acceptable.

The applicant provided the necessary information as described above in the ABWR DCD, Revision 7, which incorporated the changes described in the applicant's letter submittals. Therefore, Confirmatory Item 19.02-1 from the staff's advanced safety evaluation with no open items for the ABWR DC renewal is resolved and closed.

19.2.3.3.4.4 Conclusion

Based on the evaluation provided in this supplemental FSER section, the staff concludes that the changes do not alter the safety findings made in Section 19.2.3.3.4 of NUREG–1503, the FSER for the certified ABWR DC and remain consistent with the Commission's position for inclusion of a dedicated containment vent path in the ABWR, as documented in SECY-90-016 and the associated SRM. Therefore, the staff finds that the design, as modified, satisfies the NRC's regulations applicable and in effect at initial certification.

References

1. 10 CFR Part 52, Appendix A, “Design Certification Rule for the U.S. Advanced Boiling Water Reactor.”

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

3. 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).

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

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

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