2 SITE CHARACTERISTICS

2 SITE CHARACTERISTICS

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 2, "Site Characteristics," Section 2.5, "Geological, Seismological, and Geotechnical Engineering," 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.

2.5 Geological, Seismological, and Geotechnical Engineering

2.5.1 Regulatory Criteria

The GEH ABWR design is certified for plants founded on soil deposits up to 91.5 meters (300 feet), in addition to rock sites. Therefore, there is a potential that larger differential settlements may occur for a deep soil site due to the geologic variation of subsurface materials and non-uniform loading distribution. The applicant added dynamic bearing capacity and differential site parameters to the ABWR DCD in order to ensure that the soil under the foundation and the foundation itself will be able to withstand the foundation dynamic pressure resulting from the combination of all possible loadings. These parameters are ABWR DCD clarifications that demonstrate compliance to applicable regulations at the time of original certification. Therefore, this design change is a "modification," as that term is defined in Chapter 1 of this supplement and will correspondingly be evaluated using the regulations applicable and in effect at the initial ABWR certification.

The applicable regulatory requirements for evaluating the ABWR DCD modifications related to geology, seismology, and geotechnical engineering design parameters are as follows:

- 10 CFR 52.47(a)(1)(iii) (1997) requires DC applicants to provide postulated site parameters, and an analysis and evaluation of the design in terms of such parameters.

- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," (GDC) 2, "Design Bases for Protection Against Natural Phenomena," (1997) with respect to structures, systems, and components (SSC) important-to-safety being designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

- 10 CFR Part 100, Appendix A,[1] Section V.(d) (1997), requires that each applicant determine whether soil instability will result from vibratory ground motion associated with the safe-shutdown earthquake.

2.5.2 Summary of Technical Information

In the ABWR DCD, Revision 7, the applicant presented design parameters and associated combined license (COL) Information Items related to geology, seismology, and geotechnical engineering in DCD Tier 1, Section 5.0, "Site Parameters"; DCD Tier 2, Section 2.0, "Site Characteristics"; and DCD Tier 2, Section 2.3, "COL License Information".

The applicant described seismic design parameters including safe-shutdown earthquake ground motion, bearing capacity, and settlement in DCD Tier 2, Section 2.3.1.2, "Seismic Design Parameters".

COL requirements for basic geologic and seismic information, vibratory ground motion, surface faulting, stability of subsurface material and foundation, site and facilities, field investigations, laboratory investigations, subsurface conditions, excavation and backfilling for foundation construction, effect of ground water, liquefaction potential, response of soil and rock to dynamic loading, minimum soil bearing capacity, earth pressures, soil properties for seismic analysis of buried pipes, static and dynamic stability of facilities, subsurface instrumentation, stability of slopes, and embankments and dams are described in DCD Tier 2, Section 2.3.2.21 through Section 2.3.2.39 respectively.

The applicant added additional information that is related to geology, seismology, and geotechnical engineering design parameters to the ABWR DCD, Revision 7. The additional information (represented below with italicized text) was submitted originally in ABWR DCD, Revision 6 as follows:

DCD Tier 1, 5.0 Site Parameters

DCD Tier 2, Table 5.0 ABWR Site Parameters

Minimum Dynamic Bearing Capacity: 2,700 kPa [392 psi]
Maximum Settlement(9): 75mm [2.95 in.]
Maximum Foundation Angular Distortion: 1/750(10)

Note: (9) Settlement is long term (post construction) value.
(10) Angular distortion is defined as the slope between two adjacent columns. Angular distortion is long term (post construction) value.

DCD Tier 2, 2.0 Site Characteristics

DCD Tier 2, Table 2.0-1 Envelope of ABWR Standard Plant Site Design Parameters

– Maximum Dynamic Bearing Capacity: 2,700 kPa [392 psi]

1 The requirements of 10 CFR Part 100, Appendix A, apply here because 10 CFR Part 100, Subpart B, applies only to applications submitted on or after January 10, 1997.

– Maximum Settlement: 75mm [2.95 in.] †††
– Maximum Foundation Angular Distortion: 1/750 ‡‡‡

Note: ††† Settlement is long term (post construction) value.
‡‡‡ Angular distortion is defined as the slope between two adjacent columns. Angular distortion is long term (post construction) value.

DCD Tier 2, 2.3 COL License Information

DCD Tier 2, Section 2.3.1.2 Seismic Design Parameters

(2) Bearing Capacity

The site soil static bearing capacity at the foundation level of the reactor and control building is 718.20 kPa [104 psi] minimum. *The maximum static bearing demand is compared with the site-specific allowable static bearing pressure, which is obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination. The maximum dynamic bearing demand is compared with the site-specific allowable dynamic bearing pressure, which is obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination.*

The site soil dynamic bearing capacity at the foundation level of the reactor and control building is 2,700 kPa [392 psi] minimum.

(3) Settlement

The maximum settlement of the reactor and control building foundations is 75mm [2.95 in.]. The maximum angular distortion of the reactor and control building is 1/750.

2.5.3 Technical Evaluation

The staff reviewed the ABWR DC renewal modifications related to geology, seismology, and geotechnical engineering design parameters and the associated sections in NUREG–1503 and its Supplement 1, the FSER for the original DC. The staff's technical evaluation focused on the technical basis of the design parameters and the adequacy of associated COL Information Items.

The dynamic bearing capacity and differential settlement site parameters are important design requirements to ensure the stability of foundation and structure for a nuclear power plant, in a request for additional information (RAI) Question 02.05.04-1, dated June 9, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15160A421), the staff asked the applicant to add these site parameters to the DCD and to provide details on how the dynamic bearing capacity and differential settlement site parameters were determined, including the model(s), assumptions and input parameters used in analyses and calculations, and justifications for site parameter value determinations. In the applicant's response on July 24, 2015 (ADAMS Accession No. ML15209A561), November 13, 2015 (ADAMS Accession

No. ML15317A092) and May 31, 2016 (ADAMS Accession No. ML16152A512), GEH provided additional site parameters with detailed descriptions and justifications.

The applicant incorporated all design changes from its RAI 02.05.04-1 responses in the ABWR DCD, Revision 7. This includes clarifying DCD Tier 2, Table 2.0-1, to reflect that the 2,700 kilopascals (kPa) (392 pounds per square inch (psi)) value represents the minimum dynamic bearing capacity site parameter. As discussed below, Confirmatory Item 02.05.04-1 from the staff's advanced safety evaluation with no open items for the ABWR DC renewal is resolved and closed.

The applicant stated that since the site parameter for minimum static bearing capacity in the originally certified ABWR DCD was determined by adding a margin factor to the calculated maximum static foundation pressure value, the same approach was used in the determination of the minimum dynamic bearing capacity site parameter. The calculated maximum dynamic bearing pressure for the ABWR reactor building (the heaviest building) was 2,336 kPa (339 psi), as documented in DCD Tier 2, Section 3H.1.5.6 (unchanged from the originally certified DCD). Based on this calculation, the applicant specified the minimum dynamic bearing capacity site parameter as 2,700 kPa (392 psi) to provide some margin. The applicant further specified that the site-specific dynamic bearing capacity determined at the COL application stage should be obtained by dividing the ultimate soil bearing capacity by a factor of safety appropriate for the design load combination, which is described in its revised COL Information Item 2.3.1.2 (2) in DCD Tier 2, Section 2.3.1.2.

The staff reviewed the applicant's RAI responses and related documents. (1) the staff reviewed DCD Tier 2, Section 3H.1.5.6 and confirmed that the calculated maximum foundation bearing pressure under the combination of seismic and other loads was specified as 2,336.0 kPa (339 psi), which is the same as that in the certified ABWR DCD, Revision 4; (2) the applicant specified the minimum dynamic bearing capacity site parameter as 2,700 kPa (392 psi), which is about 15 percent higher than the calculated maximum foundation bearing pressure value; and (3) the ABWR DCD requires a factor of safety appropriate for the design load combinations to be used when determining site specific soil dynamic bearing capacity. The combination of the higher site parameter value than the calculated one and the requirement of an appropriate factor of safety to be used when determining the site-specific soil dynamic bearing capacity will provide an adequate safety margin that accounts for the variability and uncertainties of subsurface materials and dynamic/seismic loadings. The staff therefore concludes that the specified dynamic bearing capacity site parameter is adequate because it will provide a design basis for subsurface material underneath the structure foundations to withstand maximum foundation pressure generated by the structure's response to the combination of designed dynamic/seismic and dead loadings.

The applicant specified a total long term (post-construction) settlement of 75 millimeters (mm) (2.95 inches (in.)) as a site parameter based on ABWR construction experience. The staff concludes that the long term settlement limit of 75 mm (2.95 in.) is reasonable for the GEH ABWR structures because total settlements up to 125 mm (4.92 in.) can be tolerated without damage for buildings constructed on reinforced concrete mat or raft foundation according to the commonly accepted industrial guidance (e.g., engineering manual of the U.S. Army Corps of Engineers) and engineering practices.

As angular distortion, defined as the slope between two adjacent column lines, is one of the foundation differential settlement measurements that affects foundation stability, the applicant

specified the maximum angular distortion limit as 1/750. The staff considers this angular distortion limit to be acceptable because the commonly accepted limits for angular distortion are in the range of 1/500 to 1/750 according to industrial guidance and practices (e.g., engineering manual of the U.S. Army Corps of Engineers;) the staff, therefore, concludes that defining the angular distortion limit at 1/750, the lower end of this range, meets the foundation stability requirement and will not have an adverse effect on structures housing equipment sensitive to differential settlement.

For other issues related to differential settlement, such as the effect of building settlement on the connection of other components to the buildings, the applicant stated that even with an aggressive 39 month construction schedule, the mechanical and electrical components would be installed at least 12 months after the completion of the foundation basemat, which allows sufficient time for the buildings to settle. The applicant also stated that because the ABWR primary containment penetrations sleeves are fixed and some component positions cannot be adjusted after its construction, the ABWR primary containment shares a common basemat with the reactor building, and openings will be left in exterior walls to allow for the installation of components after construction of the wall and these openings are made large enough to account for expected settlement. The applicant further stated that the ABWR DCD does not need to have a design value for the differential settlement between buildings because the maximum differential settlement is the same as the building's maximum settlement value. The staff considers the applicant's statement that building settlement will not affect the connection of components to the buildings is reasonable because (1) engineering practices have shown that more than 95 percent of total building settlement will occur within 12 months of construction completion for suitable nuclear power plant foundation supporting materials (e.g., well compacted granular materials;) and (2) the design and construction procedure of the wall openings for component connections will accommodate the residual long-term settlement. The staff therefore concludes that the specified allowable foundation settlement will have no adverse effect on proper component connections to the buildings. Since the ABWR primary containment shares a common basemat with the reactor building, these two buildings will have the same settlement, and the design and sequences of building construction and component connection will ensure the proper installation of components between buildings. Therefore, the staff agrees that no other differential settlement requirement, other than the angular distortion limit, is needed for the ABWR design.

Based on the above findings, the staff concludes that the applicant adequately addressed the issues related to minimum dynamic bearing capacity and settlement limit requirements, and the modifications related to geology, seismology, and geotechnical engineering design parameters will provide additional assurance of the stability and safety of the nuclear power plant structures. The applicant provided the necessary information in the ABWR DCD, Revision 7, which incorporated the changes described in the applicant's responses to RAI 02.05.04-1. Therefore, Confirmatory Item 02.05.04-1 from the staff advanced safety evaluation with no open items for the ABWR DC renewal is resolved and closed.

2.5.4 Conclusion

Based on the review of the applicant's design modifications related to the geology, seismology, and geotechnical engineering presented in the ABWR DCD, Revision 7, and the applicant's RAI responses, the staff concludes that the applicant adequately specified additional clarification on site parameters that include minimum dynamic bearing capacity, long term settlement limits and angular distortion limit in the ABWR DCD, with associated COL Information Items. The added

site parameters were determined based on NRC approved analysis procedures and/or in conformance with the commonly accepted industrial guidance and practices, which will provide additional assurance of the foundation and structure stability. The staff also concludes that the new and revised COL Information Items associated with the added site parameters adequately direct COL applicants referencing the ABWR DC renewal to meet those site parameter requirements. Therefore, the staff concludes that the design modifications related to geology, seismology, and geotechnical engineering design parameters and associated COL application requirements meet the regulatory requirements of 10 CFR 52.47(a)(1)(iii), GDC 2, and 10 CFR Part 100, Appendix A, Section V.(d).

References

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

2. 10 CFR Part 50, Appendix A, GDC 2, “Design Bases for Protection Against Natural Phenomena,” (1997).

3. 10 CFR Part 52, Appendix A, “Design Certification Rule for the U.S. Advanced Boiling Water Reactor.”

4. 10 CFR 52.47, “Contents of Applications; Technical Information.”

5. 10 CFR Part 100, Appendix A, “Seismic and Geologic Siting Criteria for Nuclear Power Plants.”

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

7. 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).

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

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

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