

12 RADIATION PROTECTION

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12 RADIATION PROTECTION

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 12, “Radioactive Protection,” Section 12.2, “Radiation Sources,” 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.

12.2 Radiation Sources

This supplemental FSER documents the staff’s review of the applicant’s ABWR DC renewal incorporation of the condensate storage tank (CST) as a radiation source and design features associated with reducing radiation exposure and minimizing potential contamination from the CST in DCD Tier 2, Section 12.2, “Radiation Sources.” This supplement also contains updated information clarifying that the inspections, tests, analyses, and acceptance criteria (ITAAC) in DCD Tier 1, Tables 3.2a and 3.2b should have been identified as design acceptance criteria (DAC). Finally, this supplemental evaluation also documents the staff’s review of source term table errors and associated corrections in DCD Tier 2, Section 12.2.

12.2.1 Regulatory Criteria

As explained below, the CST design changes are to supply information omitted from the originally certified DCD that is necessary to meet the regulations applicable and in effect at initial certification. The clarification of the ITAAC in DCD Tier 1, Tables 3.2a and 3.2b as DAC is consistent with the original understanding of these ITAAC and is needed to correct an inconsistency with DCD Tier 2 of the originally certified ABWR DCD. The applicant’s source term table changes are to correct errors in the originally certified ABWR DCD. Therefore, the changes are “modifications,” as this term is defined in Chapter 1 of this supplement and will be evaluated using the regulations applicable and in effect at initial certification.

Incorporation of the Condensate Storage Tank as a Radiation Source

The following regulatory requirements provide the basis for the acceptance criteria for the staff’s review:

- 10 CFR 50.34(b)(3) (1997) required final safety analysis reports (FSARs) to include “[t]he kinds and quantities of radioactive materials expected to be produced in the operation and

the means for controlling and limiting radioactive effluents and radiation exposure within the limits set forth in Part 20 of this chapter.”

- 10 CFR 20.1101(b) (1997,) required that licensees use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).
- 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” Appendix A, “General Design Criteria for Nuclear Power Plants,” (GDC) 61, “Fuel Storage and Handling and Radioactivity Control” (1997), required, in part, that fuel storage and handling, radioactive waste, and other systems that might contain radioactivity be designed to assure adequate safety under normal and postulated accident conditions, including being designed with a capability to permit appropriate periodic inspection and testing of components important to safety, with suitable shielding for radiation protection, and with appropriate containment, confinement, and filtering systems.

Clarification of Inspections, Tests, Analyses, and Acceptance Criteria

The following regulatory requirement provides the basis for the acceptance criteria for the staff’s review:

- 10 CFR 52.47(a)(1)(vi) (1997), required DC applications to include the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the tests, inspections, and analyses are performed and the acceptance criteria met, a plant that references the design is built and will operate in accordance with the DC.

Correction of Source Term Tables

The following regulatory requirements provide the basis for the acceptance criteria for the staff’s review:

- 10 CFR 50.34(b)(3) (1997) required FSARs to include “[t]he kinds and quantities of radioactive materials expected to be produced in the operation and the means for controlling and limiting radioactive effluents and radiation exposure within the limits set forth in Part 20 of this chapter.”
- 10 CFR 20.1101(b) (1997) required that licensees use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.
- 10 CFR 20.1201, “Occupational Dose Limits for Adults” (1997), required, in part, that licensees control the occupational dose to individual adults to a total effective dose equivalent of 5 rems.
- 10 CFR 20.1601, “Control of Access to High Radiation Areas” (1997), and 10 CFR 20.1602, “Control of Access to Very High Radiation Areas” (1997), required, in part, that licensees adequately control access to high and very high radiation areas.

- 10 CFR 50.49, “Environmental Qualification of Electrical Equipment Important to Safety for Nuclear Power Plants” (1997) and GDC 4, “Environmental and Dynamic Effects Design Bases” (1997), required that certain components important to safety be designed to withstand environmental conditions, including the effects of radiation, associated with design basis events, including normal operation, anticipated operational occurrences, and design basis accidents.
- GDC 61, “Fuel Storage and Handling and Radioactivity Control” (1997) required, in part, that fuel storage and handling, radioactive waste, and other systems that might contain radioactivity be designed to assure adequate safety under normal and postulated accident conditions, including being designed with a capability to permit appropriate periodic inspection and testing of components important to safety, with suitable shielding for radiation protection, and with appropriate containment, confinement, and filtering systems.

12.2.2 Summary of Technical Information

Incorporation of the Condensate Storage Tank as a Radiation Source

As originally certified, the DCD Tier 2, Section 9.2.9.2 indicated that water could be sent to the CST from several sources that could potentially be contaminated, including the control rod drive system and the radwaste disposal system. However, the ABWR DCD did not contain any source term information for the CST, nor did it describe any controls to limit effluent releases or radiation exposure from the CST during normal operations or anticipated operational occurrences, as required by 10 CFR 50.34(b)(3) and 10 CFR 20.1101(b). In addition, the ABWR DCD did not provide any information regarding radiation shielding for the CST or on any necessary confinement to reduce radiation exposure or to control potential leakage, in accordance with GDC 61. Therefore, to ensure compliance with 10 CFR 50.34(b)(3), 10 CFR 20.1101(b), and GDC 61 the staff issued a request for additional information dated September 25, 2014 (RAI) 12.02-2 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14267A352), requesting the applicant to: (1) update DCD Tier 2, Chapter 12 to provide source term and shielding information for the CST; (2) update DCD Tier 2, Chapters 11 and 12 to describe any procedures or engineering controls used to control radioactive effluents and radiation exposure from the CST, such as provisions to prevent CST overflow or design features to contain radioactive material if a leak or overflow were to occur; (3) update DCD Tier 2, Chapters 11 and 12 as appropriate, to describe the locations, functions, and design features of piping routed to and from the CST in order to ensure that radioactive effluents and radiation exposure is being adequately controlled (including design features to prevent or detect leakage from outdoor piping associated with the CST); and (4) update the radiation zone drawings in DCD Tier 2, Chapter 12, to include the location and radiation zoning for the CST.

The applicant responded to the staff’s RAI and provided changes to the ABWR DCD as described below in the staff evaluation (Section 12.2.3) of this FSER supplement.

Clarification of Inspections, Tests, Analyses and Acceptance Criteria

The staff issued RAI 12.02-3, dated September 25, 2014 (ADAMS Accession No. ML14267A352), requesting the applicant to clarify that DCD Tier 1, Tables 3.2a and 3.2b contain DAC, instead of normal ITAAC. The applicant responded to the staff’s RAI and

provided changes to the ABWR DCD as requested by the staff and described below in the staff evaluation (Section 12.2.3) of this FSER supplement.

Correction of source term tables

DCD Tier 2, Table 12.2-3b "Gamma Ray Source Energy Spectra – Post Operation Gamma Sources in the Core" and Table 12.2-3c "Gamma Ray Source Energy Spectra – Gamma Ray Sources External to the Core During Operation," both appeared to contain errors. The source terms in both of these tables were approximately one million times lower than comparable source term tables in currently operating BWRs and in the comparable DCD for the Economic Simplified Boiling-Water Reactor (ESBWR). The NRC staff also noted that the text in DCD Tier 2, Sections 12.2.1.2.1.1.4 and 12.2.1.2.8 associated with the aforementioned tables contained different units than the units provided in the tables. For example, Table 12.2-3b used units of picojoule / Watts per second (pJ/W.s), while Section 12.2.1.2.1.1.4 indicated that the gamma ray energy spectrum was provided in joule per second per Watt (J/s/W) (neither of which appeared to be correct).

If the incorrect source term information in DCD Tier 2, Tables 12.2-3b and 12.2-3c, were to be used during plant design, significant design errors in the plant shielding design could result (suitable shielding is required under GDC 61). This could lead to an underestimation of area dose rates and higher worker doses. In this case, compliance with 10 CFR Part 20 would not be ensured because the potential design errors could result in a facility that would not be designed in accordance with the principles of maintaining occupational radiation doses ALARA (10 CFR 20.1101) and could also potentially result in workers receiving doses in excess of the worker dose limits (10 CFR 20.1201). Furthermore, if the incorrect source term information provided in the tables were utilized, potential high and very high radiation areas may not be properly identified (in accordance with 10 CFR 20.1601 and 10 CFR 20.1602). Finally, if the incorrect source term information were used in the equipment qualification analysis, the incorrect radiation exposure rates could be calculated for equipment; which would not be in accordance with 10 CFR 50.49 and GDC 4.

Therefore, staff issued RAI 12.02-1, dated September 25, 2014 (ADAMS Accession No. ML14267A352), requesting that the applicant: (1) correct the source term data in DCD Tier 2, Tables 12.2-3b and 12.2-3c and provide documentation demonstrating the accuracy of the revised source terms; (2) update the text in DCD Tier 2, Chapter 12 to ensure the units associated with these tables were accurate; (3) ensure that the errors in the tables did not result in any other errors or inaccuracies in any other areas of the DCD, including but not limited to facility design, shielding design, radiation zoning, dose assessment, and equipment qualification; and (4) correct any additional errors identified. The applicant responded to the staff's RAI and provided changes to the ABWR DCD as described below in the staff evaluation (Section 12.2.3) of this FSER supplement.

12.2.3 Technical Evaluation

Incorporation of the Condensate Storage Tank as a Radiation Source

In the response to RAI 12.02-2, dated January 22, 2015 (ADAMS Accession No. ML15023A016), the applicant included a combined license (COL) Information Item in DCD Tier 2, Section 12.2.3.2 to specify that the COL applicant shall determine the CST source term information (including source geometry) and provide adequate shielding to ensure the dose rate

in the area surrounding the CST is less than 6 microsieverts per hour ($\mu\text{Sv/hr}$), thus maintaining a radiation Zone A that allows for uncontrolled and unlimited access to the areas surrounding the CST. The applicant also proposed updating DCD Tier 2, Figures 1.2-25 and 12.3-70 to show the location of the CST and DCD Tier 2, Figure 12.3-50 to specify that the outside area adjacent to CST is designated as radiation Zone A (less than $6 \mu\text{Sv/hr}$). The staff finds it acceptable for the COL applicant to provide the source term and shielding information for the CST, based on the specific site, to allow flexibility in the liquid waste management system design. The staff also finds that it is appropriate for the CST to be shielded to maintain Zone A and to not have any access controls as described in the design for this area because of the very low dose rates of radiation Zone A. The staff notes that if any type of access controls were needed due to specific operating conditions under actual plant operation, they would be expected to be provided as part of the radiation protection program (the radiation protection program is to be provided by the COL applicant, and evaluated by staff, as provided by the COL Information Item in DCD Tier 2, Section 12.5.3.1, "Radiation Protection Program").

In the response, the applicant also proposed updating DCD Tier 2, Section 11.2.1.2, "Design Criteria," which already stated that the CST has liquid level monitoring and is provided with a dike around the tank, which is routed to the radwaste system. The proposed update states that the buried portion of the CST piping will be enclosed within a pipe chase or a guard pipe and monitored for leakage. The staff finds that these means are acceptable to prevent and monitor leakage to provide assurance that any radiation exposures and unintended leakage to the environment will be kept to minimal levels.

In Supplement 1 of the response to RAI 12.02-2, dated July 7, 2015 (ADAMS Accession No. ML15194A053), the applicant proposed updating DCD Tier 2, Section 11.2.1.2 to specify that the CST dike is designed to preclude rainwater from entering the CST dike area and causing the introduction of impurities into the liquid radwaste management system, to the extent possible. The supplemental response also proposed updating DCD Tier 2, Section 11.2.1.2 to state that the structure for the transfer pumps will be integrated in the dike or the turbine building (TB), as well as the interfaces with any pipe chases. It is acceptable to locate the transfer pumps in the dike or the TB because any leakage accumulated in these areas will be collected and monitored. Also, in the supplemental response, the applicant proposed updating DCD Tier 2, Section 11.2.1.2 to specify that if leakage is detected in the pipe chase for CST piping, it will alarm in the main control room allowing operators to adequately control contamination and the release of radioactive material. The staff finds that these engineering controls are effective measures for preventing and mitigating leakage of radioactive liquid; as such, they are consistent with 10 CFR 20.1101(b) and GDC 61 and are acceptable.

The staff finds that the proposed ABWR DCD changes described in the RAI responses and supplemental responses to RAI 12.02-2 satisfy the requirements of 10 CFR 50.34(b)(3), 10 CFR 20.1101(b), and GDC 61. The staff verified that the DCD changes were incorporated into the ABWR DCD Revision 6. Therefore, all expected changes regarding the responses to RAIs 12.02-2 have been incorporated into the ABWR DCD, Revision 7, and these items are closed.

Finally, in its response dated March 16, 2016 (ADAMS Accession No. ML16076A067), the applicant provided information to demonstrate that the ABWR renewal DCD meets the requirements of 10 CFR 20.1406, "Minimization of Contamination." The applicant proposed updating the ABWR DCD to include design features to ensure compliance with 10 CFR 20.1406, including updating DCD Tier 2, Section 12.3.1.5.1, "Design Considerations," to specify

areas in which epoxy-type coatings are applied, which include tunnels containing piping transporting potentially radioactive contaminated liquids (including piping associated with the CST). As described in Regulatory Guide 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," epoxy coatings help to prevent leaked fluid from penetrating the tunnels and leaking into the soil. This design feature is voluntarily provided in accordance with 10 CFR 20.1406, which did not exist at the time of initial certification. The proposed revisions associated with 10 CFR 20.1406 have been incorporated into the ABWR DCD, Revision 7. The staff's evaluation of compliance with 10 CFR 20.1406 is in supplemental FSER Section 12.3 of this safety evaluation report.

Clarification of Inspection, Tests, Analyses, and Acceptance Criteria

In RAI 12.02-3, dated September 25, 2014 (ADAMS Accession No. ML14267A352), the staff asked the applicant to clarify if DCD Tier 1, Table 3.2a, Item 4 (related to compliance with 40 CFR Part 190, "Environmental Protection Standards for Nuclear Power Operations"), was appropriately classified as an ITAAC, instead of a DAC, because DCD Tier 2, Section 12.2.2.4, "Average Annual Doses," states, "For complete evaluations for compliance to 40 CFR Part 190, gamma shine evaluations are not contained in this document, since adequate detail for skyshine evaluations from the turbine complex are required in DCD Tier 1, DAC Table 3.2." In addition, all of the items in DCD Tier 1, Tables 3.2a and 3.2b are written in the form of DAC and the original ABWR FSER, Section 12.2 refers to DCD Tier 1, Tables 3.2a and 3.2b as DAC tables. Other DAC in the ABWR DCD were clearly identified in DCD Tier 1 as being DAC; however, ABWR DCD Tier 1, Tables 3.2a and 3.2b were not. The staff informed GEH that the failure to clearly identify the ITAAC as DAC was considered an error in the initial certification and should be corrected in accordance with 10 CFR 52.57(a). In Supplement 1 of the response to RAI 12.02-3, dated July 7, 2015 (ADAMS Accession No. ML15194A053), the applicant updated ABWR DCD, Tier 1, Tables 3.2a and 3.2b to specify that all of the items in the tables are DAC. This is the appropriate classification for these tables, consistent with the information in DCD Tier 2, Section 12.2.2.4. Therefore, the staff finds this change to be acceptable. The staff verified that the proposed DCD changes were incorporated into ABWR DCD, Revision 6 and are reflected in the ABWR DCD, Revision 7.

Correction of source term tables

In the response to RAI 12.02-1, dated December 16, 2014 (ADAMS Accession No. ML14350A843), the applicant indicated that DCD Tier 2, Tables 12.2-3b and 12.2-3c contained a unit conversion error, and that the text supporting the tables in DCD Tier 2, Sections 12.2.1.2.1.1.4, "Gamma Ray Source Energy Spectra," and 12.2.1.2.8, "Radioactive Sources in the Spent Fuel," erroneously contained different units than the tables.

The applicant reviewed the data originally supporting the DCD Tier 2, Table 12.2-3b, which was initially provided in Megaelectronvolt per Watt second (MeV/W-sec) and discovered the unit conversion error in converting to the units of pJ/W-sec. The RAI response provided the initial values and converted values to show that the conversion to pJ/W-sec resulted in a conversion error of a million pJ/W-sec. The response indicated that the same error occurred in DCD Tier 2 Table 12.2-3c. Therefore, the applicant corrected the values in the tables and the supporting DCD sections to ensure that all values and units were correct. The staff verified the unit corrections and verified that the core source term values in DCD Tier 2, Tables 12.2-3b and 12.2-3c were consistent with what would be expected for a large BWR and consistent with other BWR designs. Therefore, the staff determined that the revised tables are acceptable.

In addition, GEH indicated that they reviewed the ABWR DCD to ensure that the errors did not result in any other errors or inaccuracies in the ABWR DCD.

The applicant reviewed the drywell shielding analysis supporting the ABWR DCD and the upper drywell shielding radiation dose rates with a fuel bundle on refueling bellows, shown in DCD Tier 2, Figure 12.3-74, and verified that the values in this figure were calculated using the correct source term values. The dose rates provided in DCD Tier 2 Figure 12.3-74 are comparable to dose rates for the ESBWR design, which support the applicant's conclusion that the correct source terms were used. In addition, the source term and geometry for the spent fuel pool is to be determined by the COL applicant as specified in DCD Tier 2, Tables 12.2-5a and 12.2-5b; therefore, the unit errors in the ABWR DCD source term tables did not impact the spent fuel pool design.

The applicant reviewed the worker dose estimates in DCD Tier 2, Section 12.4.1, "Drywell Dose," which provided the dose estimates for workers in the drywell. The applicant stated that these dose estimates are based on estimates of occupancy and dose rates in the drywell for typical BWRs and are not based on analytical results; therefore, the table errors had no impact on this information. The staff also reviewed the dose estimates and found them comparable to similar BWRs. In addition, radiation zoning inside containment was already labeled with the highest radiation zone designation in the ABWR DCD. Therefore, the staff determined that the table errors could not have resulted in underestimating the radiation zoning inside containment.

The applicant also indicated that there was no impact on equipment qualification. The applicant reviewed the equipment qualification dose rate values provided in DCD, Tier 2, Tables 3I-7 through 3I-11, and indicated that the unit conversion errors did not impact those tables. The staff reviewed the equipment qualification dose rates in the drywell area in DCD Tier 2, Table 3I-7 and found them to be consistent with the use of the corrected source terms. Specifically, staff performed confirmatory calculations using the MicroShield computer program to estimate the gamma dose rate through the reactor shield wall and estimated a maximum dose rate in the drywell area of approximately 12 rem/hour from the reactor core. This is less than the 20 rem per hour provided by the applicant in DCD, Tier 2, Table 3I-7. In addition, the staff reviewed the ESBWR DCD and found that the equipment qualification doses inside containment in the ABWR DCD are very similar to doses in the ESBWR DCD. As a result, the staff concluded that the correct source term information was used in the equipment qualification calculations.

The applicant and staff did not find any other information in the ABWR DCD that was impacted by the unit errors in the ABWR DCD tables or any other errors related to source term information in the ABWR DCD. As a result, the staff finds that the incorrect source term information in DCD Tier 2, Tables 12.2-3b and 12.2-3c did not have any impact on the plant design, equipment qualification analysis, plant radiation zoning, or worker dose estimates.

The staff verified that the applicant incorporated the proposed ABWR DCD changes described above into the ABWR DCD Revision 6 and these changes are reflected in the ABWR DCD Revision 7. Therefore, this issue is resolved.

12.2.4 Conclusion

Incorporation of the Condensate Storage Tank as a Radiation Source

Based on the above, the staff finds that the CST design features provided in the ABWR DCD, Revision 7, meet the requirements of 10 CFR 50.34(b)(3), 10 CFR 20.1101(b), and GDC 61. The COL applicant will provide the CST source term and shielding information, as specified by the COL Information Item in DCD Tier 2, Section 12.2.3.2, which is acceptable.

Clarification of Inspections, Tests, Analyses, and Acceptance Criteria

The correction specifying that DCD Tier 1, Tables 3.2a and 3.2b, contain DAC is consistent with 10 CFR 52.57(a) and 10 CFR 52.47(a)(1)(vi). Therefore, the responses to RAIs 12.02-2 and 12.02-3 and associated DCD revisions are acceptable.

Correction of Source Term tables

Based on the above, the response to RAI 12.02-1 is complete and meets the requirements of 10 CFR 50.34(b)(3). In addition, the table errors and subsequent correction of the errors does not invalidate any other information in the DCD and does not impact any of the staff's findings for the original ABWR certification (NUREG-1503, including Supplement 1), including those related to 10 CFR 20.1101(b), 10 CFR 20.1201, 10 CFR 20.1601, 10 CFR 20.1602, 10 CFR 50.49, GDC 4, and 61. Therefore, the response to RAI 12.02-1 and associated DCD revisions are acceptable.

References

1. 10 CFR 20.1101, "Radiation protection programs."
2. 10 CFR 20.1201, "Occupational dose limits for adults."
3. 10 CFR 20.1406, "Minimization of Contamination."
4. 10 CFR 20.1601, "Control of access to high radiation areas."
5. 10 CFR 20.1602, "Control of access to very high radiation areas."
6. 10 CFR 50.34, "Contents of applications; technical information."
7. 10 CFR 50.49, "Environmental qualification of electric equipment important to safety for nuclear power plants."
8. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."
9. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."
10. 10 CFR Part 50, Appendix A, GDC 61, "Fuel Storage and Handling and Radioactivity Control."
11. 10 CFR Part 52, Appendix A, "Design Certification Rule for the U.S. Advanced Boiling Water Reactor."
12. 10 CFR 52.47, "Contents of Applications; Technical Information."
13. 40 CFR Part 190, "Environmental Protection Standards for Nuclear Power Operations."
14. NRC, NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design," July 1994 (ADAMS Accession No. ML080670592).
15. 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).
16. NRC, RG-1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, And Components Installed In Light-Water-Cooled Nuclear Power Plants," Revision 1, October 1979.
17. GEH, ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 5, Tier 1 and Tier 2, December 2010 (ADAMS Accession No. ML110040323).
18. GEH, ABWR Standard Plant Design Certification Renewal Application Design Control Document, Revision 6, Tier 1 and Tier 2, February 2016 (ADAMS Accession No. ML16214A015).

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