

## 15.0 SAFETY ANALYSES

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## 15.0 SAFETY ANALYSES

### 15.1 Introduction

This chapter of the U.S. Nuclear Regulatory Commission's (NRC's) safety evaluation report (SER) provides the NRC staff evaluation of the North Anna 3 responses to postulated disturbances in process variables and postulated equipment failures or malfunctions, determines their consequences, and evaluates the capability of the plant to control or accommodate these events. These analyses help determine the limiting conditions for operation, limiting safety system settings, and design specifications for safety-related components and systems.

The analyses in this chapter include a discussion of: (1) the classification of the transients and accidents and their results in the context of a sufficiently broad spectrum of initiating events and postulated equipment failures, (2) the frequency of occurrence of initiating events for anticipated operational occurrences and highly unlikely accidents, (3) plant characteristics considered in the safety evaluation, (4) assumed protection system actions, (5) evaluation of individual initiating events and systems that operate to reduce the probability of occurrence of specific events, and (6) analysis of anticipated transients without scram. The safety analyses provide a significant contribution to the selection of limiting conditions for plant operation, limiting safety system settings, and design specifications for plant components and systems from the standpoint of public health and safety.

### 15.2 Summary of Application

Chapter 15 of the North Anna 3 Combined License (COL) Final Safety Analysis Report (FSAR), Revision 8, incorporates by reference Chapter 15 of the Economic Simplified Boiling–Water Reactor (ESBWR) Design Control Document (DCD), Revision 10, referenced in Appendix E, “Design Certification Rule for the ESBWR Design,” to Title 10 of the Code of Federal Regulations (10 CFR) Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.” In addition, in COL FSAR Chapter 15 the applicant provided the following additional information:

#### Supplemental Information:

- STD SUP 15.3-1 Radiological Consequences

The applicant added that procedures will detail the use of nuclear instrumentation to help in detecting a possible miss-located fuel bundle after fuel loading.

- NAPS SUP 15.3-2 Early Site Permit (ESP) Information

The applicant stated that Chapter 15 of the North Anna ESP Site Safety Analysis Report (SSAR) is incorporated by reference, except that plant parameter envelope (PPE) information in the ESP SSAR is replaced by Chapter 15 of the ESBWR DCD. This information is identified as NAPS ESP Variance (VAR) 2.0-6.

- NAPS SUP 15.4-1

The applicant provided supplemental information related to NAPS COL 2A.2 2 A, “Confirmation of Reactor Building  $\chi/Q$  [V]alues,” which discusses administrative control of certain doors or

personnel air locks during movement of irradiated fuel, as related to the design-basis accident (DBA) control room habitability dose analysis for the fuel-handling accident (FHA).

### 15.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966, “Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling-Water Reactor Standard Design,” issued April 2014, and its Supplement 1, issued September 2014.

Compliance with the non-seismic siting criteria of 10 CFR 100.21 and General Design Criterion (GDC) 19, “Control Room,” in Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” requires that the applicant show that, for a plant located at the North Anna site, the radiological consequences of postulated accidents meet the criteria set forth in 10 CFR 52.79(a)(1) and for GDC 19, that the control room provides adequate radiation protection to ensure that radiation exposures shall not exceed 0.05 sievert (Sv) (5 rem) total effective dose equivalent (TEDE) to permit access and occupancy of the control room under accident conditions for the duration of the accident. Requirements for the technical information in the FSAR in the COL application (COLA) for a combined license are given in 10 CFR 52.79. In particular, 10 CFR 52.79(a)(1)(vi) requires a description and safety assessment of the site on which the facility is to be located, including an evaluation of the offsite radiological consequences of postulated accidents to show that the site characteristics comply with 10 CFR Part 100.

Both 10 CFR 100.21, which references 10 CFR 50.34(a)(1), and 10 CFR 52.79(a)(1)(iv) have the same offsite radiological consequence evaluation factors as follows:

*An individual located at any point on the boundary of the exclusion area for any 2-hour period following the onset of the postulated fission product release, would not receive a radiation dose in excess of [0.25 Sv] 25 rem total effective dose equivalent (TEDE).*

*An individual located at any point on the outer boundary of the low population zone, who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of [0.25 Sv] 25 rem TEDE*

### 15.4 Technical Evaluation

The staff reviewed Chapter 15 of the North Anna 3 COL FSAR and the referenced DCD to ensure that the combination of the ESBWR DCD and the information in the COL FSAR, which incorporates the ESP SSAR, represents the complete scope of information relating to this review topic.<sup>1</sup> The staff’s review confirmed that the information contained in and incorporated by reference addresses the required information related to the safety analyses. The staff’s technical evaluation of the information in the ESBWR DCD related to accident analysis is documented in NUREG–1966.

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<sup>1</sup> See “Finality of Referenced NRC Approvals” in Section 1.2.2 for a discussion on the staff’s review related to verification of the scope of information to be included within a COL application that references a design certification.

In addition, the staff confirmed that the information contained in the North Anna 3 COLA, including information incorporated by reference, addresses the required information related to the DBA radiological consequence analyses. The staff's technical evaluation of the information incorporated by reference in the North Anna ESP SSAR related to the DBA radiological consequence analyses is documented in the corresponding SER (i.e., NUREG-1835, "Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site," issued September 2005).

The staff reviewed the relevant information in the COL FSAR:

Supplemental Information:

- STD SUP 15.3-1 Radiological Consequences
- NAPS SUP 15.3-2 (NAPS ESP VAR 2.0-6) ESP Information

North Anna COL FSAR, Revision 0, incorporated by reference the analysis of the radiological consequences from the ESBWR DCD, Revision 4, Section 15.4, and from Chapter 15 of North Anna ESP SSAR. The staff review of the sections that were incorporated by reference noted that the isotopic time-dependent fission product release rates to the environment for each DBA analyzed in the ESBWR DCD, Revision 4 were not bounded by the values specified in Appendix B, "Controlling Values of Parameters and Design-Basis Accident Source Term Plant Parameters," in ESP No. ESP-003 issued for the North Anna site.

Therefore, the staff requested, in request for additional information (RAI) 15.06.05-1, that if the isotopic activity releases per time period specified in the radiological consequence analyses for each DBA analyzed in the ESBWR DCD and from Chapter 15 of North Anna ESP SSAR are not bounded by those specified in Appendix B to the North Anna ESP, that the applicant provide the site-specific radiological consequence doses for the exclusion area boundary (EAB), the low population zone (LPZ), and the control room for each DBA to demonstrate that North Anna site still meets the dose evaluation factors set forth in 10 CFR 50.34(a)(1)(ii)(D), 10 CFR 52.79(a)(1)(vi), and GDC 19.

In its response to RAI 15.06.05-1, dated October 17, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML082980134), the applicant clarified that that the COL FSAR would not incorporate by reference the information in the North Anna ESP PPE that was related to the ESBWR design, but instead would show compliance with the relevant regulations by incorporating by reference the DBA radiological consequence analyses from the ESBWR DCD. Revision 1 of the COL FSAR, and subsequent revisions, included this variance (NAPS ESP VAR 2.0-6) from the North Anna ESP, as described in Chapter 15 supplemental information NAPS SUP 15.3-2.

By taking a variance from the North Anna ESP with respect to the PPE information on the ESBWR, the analyses in the ESP SSAR that show compliance with the dose evaluation factors set forth in 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1)(vi) are no longer being relied upon for the COL. Instead the COL FSAR is showing compliance with the relevant regulations by incorporating by reference the analyses from a more recent revision of the ESBWR DCD Chapter 15. Therefore, the staff agrees that it is unnecessary for the COL to show that the ESP PPE information is bounding for the COL, and the issue raised by the staff in RAI 15-06-05-1 is resolved and closed.

More specifically, the following summarizes the applicant's October 17, 2008, response to RAI 15.06.05-1 and the staff's evaluation:

- The applicant stated that, for the EAB and LPZ, North Anna 3 FSAR, Revision 0, Table 2.0-201, "Evaluation of Site/Design Parameters and Characteristics," shows that the site-specific atmospheric dispersion factor ( $\chi/Q$ ) values for Unit 3 fall within those values in DCD, Revision 5, and, therefore, North Anna 3 meets the dose evaluation factors set forth in 10 CFR 50.34(a)(1)(ii)(D) and 10 CFR 52.79(a)(1)(vi)..

The staff finds that this response is acceptable.

- For the control room, the DCD, Revision 5  $\chi/Q$ s also remain bounding except for those associated with the DCD COL Item 2A.2-2-A, "Confirmation of Reactor Building  $\chi/Q$  values." This COL item specifies administrative controls to be implemented if the  $\chi/Q$  values for a release from certain reactor building (RB) or fuel building (FB) doors are not bounded by the DCD, Revision 5  $\chi/Q$  values. The North Anna FSAR, Revision 0 did not specify this condition in its administrative controls. In the North Anna FSAR, Revision 1, Chapter 2, "Site Characteristics," NAPS COL 2A.2-2-A, the applicant stated that the North Anna administrative controls will be such that the doors and personnel air locks on the east side of the RB or FB are promptly closed under conditions indicative of a fuel handling accident.

The staff finds that this response is acceptable. The staff's evaluation of this topic, including additional supplemental information provided at a later date, is discussed in more detail below with regard to NAPS SUP 15.4-1.

- The bounding values for isotopic activity release rates to the environment for the DBAs in ESP No. ESP-003, Appendix B, were not available for inclusion in North Anna FSAR Revision 0 because the ESP was issued on the same day that the Unit 3 COLA was submitted. A subsequent review of the COLA with respect to the as-issued ESP by the applicant identified that the DBA source terms evaluated in the DCD Revision 4, Chapter 15 were not bounded by the ESP-003 source terms in all cases. Therefore, the applicant stated that it will revise the COLA to address the DCD Revision 5 source terms and will include a request for a variance to use the DCD Revision 5 source terms in lieu of the ESP values. In the North Anna FSAR, Revision 1, the applicant revised the FSAR to address the ESBWR DCD, Revision 5, Chapter 15 source terms and requested a variance, NAPS ESP VAR 2.0-6, to use the North Anna 3 source terms from the DCD Revision 5 in lieu of those values specified in the North Anna ESP.

The staff finds that this variance is acceptable because the calculated doses in the ESBWR, Revision 5 are within the regulatory limits and the site-specific  $\chi/Q$  values are lower than those values specified in the ESBWR DCD, Revision 5.

- The applicant stated that the North Anna 3 COLA Departure Report is being revised to clarify the criteria under which a variance is requested. In the North Anna COL Departure Report, Revision 1, the applicant revised the variance sections to clarify the criteria under which a variance is requested.

Therefore, the staff requested information in RAI 15.06.05-1 is resolved and closed.

- NAPS SUP 15.4-1

By letter dated September 16, 2014, the applicant provided supplemental information to clarify operator actions that are related to the analysis of the design basis fuel-handling accident (FHA) radiological consequences in the North Anna Unit 3 control room. Specifically, the applicant proposes to add the following site-specific supplemental information to the next revision of FSAR Section 15.4.1.2.3, "Identification of Operator Actions:"

During movement of irradiated fuel, those doors and personnel air locks on the plant east sides of the Reactor Building or Fuel Building that could act as a point source could result in control room  $\chi/Q$  values that are higher than the ESBWR  $\chi/Q$  values for a release in the Reactor Building or Fuel Building (See Section 2A.2.5). Therefore, those doors and personnel air locks on the plant east sides of the Reactor Building or Fuel Building that could act as a point source are administratively controlled to remain closed during movement of irradiated fuel. Administrative control of these doors and personnel air locks ensures that the control room habitability dose analysis for the fuel handling accident (FHA) incorporated by reference from DCD Section 15.4.1 is bounding for Unit 3 and control room doses do not exceed the requirements of GDC 19 in the event of an FHA.

ESBWR DCD, COL Item 2A.2-2-A, gives guidance to COL applicants that if the site-specific point source control room receptor  $\chi/Q$  values for potential releases through doors or personnel air locks on the east sides of the RB and FB are greater than those used as site parameter values in the ESBWR DCD dose analysis for the FHA, and if the values would result in a higher radiological consequence than was reported in the DCD, then the affected doors or air locks are administratively controlled during movement of irradiated fuel. The applicant did not provide either site-specific point source control room receptor  $\chi/Q$  values for releases through the doors and air locks on the east sides of the RB and FB or a comparison with the values used in the ESBWR DCD for the FHA to enable a determination of whether the dose in the control room for the FHA would be higher than reported in the ESBWR DCD. Instead, the applicant stated in NAPS COL 2A.2-2-A that those doors and personnel air locks on the plant east sides of the RB or FB that could act as a point source are administratively controlled to remain closed during movement of irradiated fuel. This statement was repeated in NAPS SUP 15.4-1 with additional information to include the relationship to the assumptions used in the FHA control room dose analysis. The staff found the supplemental information acceptable because administrative control of the doors and air locks on the east side of the RB and FB that could act as a point source during the movement of irradiated fuel provides assurance that, in the event of an FHA, releases through the doors are sufficiently prevented so that the FHA dose analysis incorporated by reference from ESBWR DCD, Section 15.4.1, is bounding for North Anna 3. The applicant committed to providing NAPS SUP 15.4-1 in a future revision of the FSAR. The staff verified that the North Anna 3 FSAR, Revision 9, includes the appropriate administrative controls to ensure that the air locks on the east side of the RB and FB would not act as a point source during the movement of irradiated fuel. Therefore, Confirmatory Item 15-1 from the staff's advanced SER for North Anna 3 is resolved and closed.

ESBWR DCD, Revision 10, Section 15.4, provides details and results of analyses of the radiological consequences for the DBAs. The following lists the DBAs analyzed for radiological consequences and the sections where the radiological consequence analyses for those DBAs are discussed in the ESBWR DCD.

<u>DCD Section</u>	<u>Design-Basis Accident</u>
15.4.1	Fuel Handling Accident
15.4.4	Loss-of-Coolant Accident Inside Containment Radiological Analysis
15.4.5	Main Steamline Break Accident Outside Containment
15.4.6	Control Rod Drop Accident
15.4.7	Feedwater Line Break Outside Containment
15.4.8	Failure of Small Line Carrying Primary Coolant Outside Containment
15.4.9	RWCU/SDC [Reactor Water Cleanup/Shutdown Cooling] System Line Failure Outside Containment
15.4.10	Spent Fuel Cask Drop Accident

The DBA radiological consequence analyses in the ESBWR DCD, Revision 10, used design reference site parameter values for the offsite atmospheric dispersion factors, in place of site characteristic (site-specific) values. The  $\chi/Q$  values are the only input to the DBA radiological consequence analyses that are affected by the site characteristics. The applicant provided and discussed the North Anna site characteristic short-term accident  $\chi/Q$  values in resolution of NAPS COL Item 2.0-10-A, "Short-Term Dispersion Estimates for Accidental Atmospheric Releases," and NAPS ESP COL Item 2.3-2, "Atmospheric Dispersion Factors for Control Room." The applicant also provided supplemental information in North Anna 3 COL FSAR Table 2.3-207, "Unit 3 Cross Unit  $\chi/Q$  Result," for evaluating the impact of a postulated DBA in North Anna 1 and 2 on the North Anna 3 control room. Table 2.3.4 1 of the North Anna COL FSAR gives site characteristic EAB and LPZ  $\chi/Q$  values.

In Section 2.3.4, "Short-Term Diffusion Estimates," of this SER, the staff discusses its review and resolution of (1) NAPS COL Item 2.0-10-A, (2) NAPS ESP COL Item 2.3-2, and (3) the supplemental information, related to the North Anna site characteristic  $\chi/Q$  values as stated above, included under Section 2.3.4 of the North Anna COL FSAR.

The estimated DBA dose calculated for a particular site is affected by the site characteristics through the calculated  $\chi/Q$  input to the analysis; therefore, the resulting dose would be different than that calculated generically for the ESBWR design in the DCD. All other inputs and assumptions in the radiological consequences analyses remain the same as in the DCD. Smaller  $\chi/Q$  values are associated with greater dilution capability, resulting in lower radiological doses. When comparing a DCD site parameter  $\chi/Q$  value and a site characteristic  $\chi/Q$  value, the site is acceptable for the design if the site characteristic  $\chi/Q$  value is smaller than the site parameter  $\chi/Q$  value. Such a comparison shows that the site has better dispersion characteristics than that required by the reactor design.

For each time averaging period, the North Anna site characteristic offsite and control room short-term  $\chi/Q$  values are less than the site parameter  $\chi/Q$  values used by the ESBWR DCD, Revision 10, radiological consequence analysis for each of the DBAs. Because the result of the radiological consequence analysis for a DBA during any time period of radioactive material release from the plant is directly proportional to the  $\chi/Q$  for that time period, and because the North Anna site characteristic  $\chi/Q$  values are less than the comparable ESBWR DCD, Revision 10, site parameter  $\chi/Q$  values for all time periods and all accidents, the North Anna site-specific

total dose for each DBA is therefore less than the ESBWR DCD, Revision 10, generic total dose for each DBA.

Because the analyses in ESBWR DCD, Revision 10, show that the offsite and control room radiological consequences meet the regulatory dose requirements of 10 CFR 100.21, 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), and GDC 19, and because, by the logic above, the North Anna site-specific DBA offsite and control room radiological consequences are less than those for ESBWR DCD, Revision 10, the applicant has sufficiently shown that the DBA radiological consequences meet the requirements of 10 CFR 100.21, 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), and GDC 19.

### **15.5 Post-Combined License Activities**

The applicant states in Supplemental Information NAPS SUP 15.4-1 that the doors and personnel air locks on the east sides of the RB and FB are administratively controlled to remain closed during movement of irradiated fuel.

### **15.6 Conclusion**

The staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this chapter. The results of the staff's technical evaluation of the DCD information incorporated by reference is in NUREG 1966. With the exception of Confirmatory Item 15-1, pursuant to 10 CFR 52.63(a)(5) and Section VI.B.1 of Appendix E, "Design Certification Rule for the ESBWR Design," to 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," all nuclear safety issues relating to safety analyses that were incorporated by reference are resolved.

In addition, the staff has compared the additional COL supplemental information within the application to the relevant NRC regulations, acceptance criteria defined in Chapter 15, "Transient and Accident Analysis," of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," issued March 2007, and other NRC regulatory guides and concludes that the applicant is in compliance with NRC regulations.

## References

1. 10 CFR 100.21, "Non-seismic siting criteria."
2. 10 CFR 50.34, "Contents of construction permit and operating license applications; technical information."
3. 10 CFR 50.34a, "Design objectives for equipment to control releases of radioactive material in effluents-nuclear power reactors."
4. 10 CFR 52.63, "Finality of standard design certification."
5. 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report."
6. 10 CFR Part 100, "Reactor Site Criteria."
7. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."
8. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."
9. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."
10. 10 CFR Part 50, Appendix A, GDC 19, "Control room."
11. 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."
12. 10 CFR Part 52, Appendix E, "Design Certification Rule for the ESBWR Design."
13. GEH ESBWR Design Control Document (DCD), Revision 10, April 2014 (ADAMS Accession No. ML14104A929).
14. NRC Staff NUREG-0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," March 2007 (ADAMS Accession No. ML070660036).
15. NRC Staff NUREG-1966, "Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling-Water Reactor Standard Design," and its Supplement 1, April 2014 (ADAMS Accession Nos. ML14099A519, ML14099A522, ML14099A532, ML14100A187, ML14100A190, ML14100A194, ML14265A084).
16. NRC Staff NUREG-1835 2006b, "Supplement to the Final Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site, September 2006 (ADAMS Accession No. ML063170371).
17. NRC Staff NUREG-1835 NRC 2005b, "Safety Evaluation Report for an Early Site Permit (ESP) at the North Anna ESP Site, September 2005 (ADAMS Accession No. ML052710305). Available at <http://pbadupws.nrc.gov/docs/ML0527/ML052710305.pdf>