3 DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT AND SYSTEMS

3.1 Conformance with NRC General Design Criteria

Section 3.1, "Conformance with NRC General Design Criteria," of the North Anna 3 Combined License (COL) Final Safety Analysis Report (FSAR) Revision 8, incorporates by reference, with no departures or supplements Section 3.1, "Conformance with NRC General Design Criteria," of the Economic Simplified Boiling-Water Reactor (ESBWR) design-control document (DCD) Revision 10, referenced in 10 CFR Part 52, Appendix E. As documented in NUREG-1966 "Final Safety Evaluation Report related to the Certification of the Economic Simplified Boiling-Water Reactor (ESBWR) Standard Design," the U.S. Nuclear Regulatory Commission (NRC) staff reviewed and approved Section 3.1 of the certified ESBWR DCD. The staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The staff's review confirmed that the applicant has addressed the required information, and there is no outstanding information related to this section that remains to be addressed in the COL FSAR. Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 52.63(a)(5) and Section VI.B.1 of Appendix E to 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," all nuclear safety issues relating to the "Conformance with NRC General Design Criteria," that were incorporated by reference have been resolved.

3.2 Classification of Structures, Systems and Components

3.2.1 Introduction

Nuclear power plant structures, systems, and components (SSCs) important to safety should be designed to withstand the effects of earthquakes without losing the capability to perform their safety functions. SSCs important to safety are defined in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," as those SSCs that "provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public." These SSCs include safety-related SSCs whose functions ensure: (1) the integrity of the reactor coolant pressure boundary (RCPB); (2) the capability to shut down the reactor and maintain it in a safe shutdown condition; and (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures. These SSCs are designed to sustain and remain functional for a design basis safe shutdown earthquake (SSE). The SSE is based on an evaluation of the maximum earthquake potential for the site and is an earthquake that produces the maximum vibratory ground motion for which SSCs are designed to remain functional. The regulatory treatment of nonsafety systems (RTNSS) process is applied to define seismic requirements for SSCs that are nonsafety-related but perform risk significant functions.

Nuclear power plant SSCs important to safety are designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. SSCs important to safety are those that provide reasonable assurance that the facility can be

[1] See "*Finality of Referenced NRC Approvals*," in SER 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 DC.

operated without undue risk to the health and safety of the public. Risk-significant nonsafety-related fluid systems that are important to safety are evaluated under the RTNSS process.

3.2.2 Summary of Application

Section 3.2, “Classification of Structures, Systems and Components,” of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 3.2, “Classification of Structures, Systems and Components,” of the ESBWR DCD, Revision 10. Section 3.2 of the ESBWR DCD includes Sections 3.2.1, “Seismic Classification,” and 3.2.2, “Quality Group Classification.”

The system seismic and quality group classifications, discussed in the ESBWR DCD, address the requirement to design nuclear power plant SSCs important to safety to withstand the effects of earthquakes without a loss of capability to perform their safety functions – that means designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

This requirement is applicable to both pressure-retaining and non-pressure-retaining SSCs that are part of the RCPB, and to other systems important to safety, when reliance is placed on these systems to (1) prevent or mitigate the consequences of accidents and malfunctions originating within the RCPB, (2) permit a shutdown of the reactor and maintain it in a safe shutdown condition, and (3) retain radioactive material.

Regulatory Guide (RG) 1.29, Revision 4, “Seismic Design Classification,” describes an acceptable method of identifying and classifying those plant features that should be designed to withstand the effects of SSEs. RG 1.26, Revision 4, “Quality Group Classification and Standards for Water, Steam, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” provides the regulatory guidance for designing safety-related SSCs to quality standards commensurate with the importance of the safety functions to be performed. Risk-significant nonsafety-related SSCs that are important to safety are evaluated under the RTNSS process described in FSAR Chapter 19 and reviewed by the staff in the DCD Safety Evaluation Report (SER) Chapter 22, “Regulatory Treatment of Nonsafety Systems,” of NUREG-1966, “Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling-Water Reactor.”

In addition, North Anna 3 COL FSAR, Section 1.9 includes the following information related to the applicable seismic classification and quality group classification:

- In FSAR Table 1.9-201, “Conformance with Standard Review Plan” (SRP), the applicant added a line stating that the North Anna 3 application conforms to Revision 2 of the SRP for Section 3.2.1. In this table, the applicant added another line stating that the North Anna 3 application conforms to Revision 2 of the SRP for Section 3.2.2.

- In FSAR Table 1.9-202, “Conformance with Regulatory Guides,” the applicant added a line stating that the North Anna 3 application conforms to RG 1.26 and 1.29. The applicant further notes that this conformance is evaluated in FSAR Appendix 17AA, “Quality Assurance Program Description” (QAPD), Part IV.

- In FSAR Table 1.9-203, "Conformance with the FSAR Content Guidance in RG 1.206," the applicant stated that the North Anna 3 application conforms to RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," Regulatory Position C.III.1 Subsection C.I.3.2.1, "Seismic Classification." The applicant also stated that there are no additional safety-related or RTNSS SSCs subject to seismic classification beyond those addressed in the DCD. In addition the applicant stated that there are no SSCs outside the referenced certified design that are required to be designed for an Operating Basis Earthquake (OBE). In this table, the applicant also stated that the North Anna 3 application conforms to RG 1.206, Position C.III.1, Subsection C.I.3.2.2, "System Quality Group Classification."

In addition, In the North Anna 3 FSAR, Revision 8, Section 3.2, the applicant provided the following supplemental information:

Site Specific Information Replacing Conceptual Design Information

- STD CDI — RTNSS Systems

The applicant stated in FSAR Section 3.2 that there are no site-specific safety related or non-safety related RTNSS systems beyond the scope of the DCD.

- STD CDI — Classification Summary-Hydrogen Water Chemistry System (HWCS)

The applicant stated that the site-specific plant design includes the HWCS. The staff reviewed the North Anna 3 HWCS in Section 9.3.9 of this SER.

- NAPS CDI — Classification Summary-Zinc Injection System

The applicant stated that the site-specific plant design includes the Zinc Injection System. The staff reviewed the North Anna 3 Zinc Injection System in Section 9.3.11 of this SER.

- NAPS CDI — Cold Machine Shop

The applicant stated that the North Anna 3 site-specific plant design does not include the cold machine shop.

3.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966, the Final Safety Evaluation Report (FSER) related to the certified ESBWR DCD.

In addition, the relevant requirements of Commission regulations for the seismic classification and quality group classification, and the associated acceptance criteria are in Section 3.2.1 and Section 3.2.2 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (LWR Edition)," the Standard Review Plan (SRP).

The applicable regulatory requirements for seismic classification of SSCs are as follows:

10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2, “Design bases for protection against natural phenomena,” which requires (in part) that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes.

The related acceptance criteria are as follows:

- RG 1.29 establishes an acceptable regulatory basis for meeting GDC 2 relative to seismic classification and classifies SSCs that are to be designed to withstand earthquakes.

- RG 1.206 states that the applicant should identify those SSCs important to safety that are outside the scope of the referenced certified design and that are designed to withstand the effects of earthquakes without loss of capabilities to perform their safety functions. The applicant should designate plant features that are outside the scope of the referenced certified design and that are designed to remain functional in the event of an SSE or a surface deformation as seismic Category I. The applicant should identify portions of SSCs outside the scope of the referenced certified design that are not required to continue to function, but whose failure could reduce the functioning of any seismic Category I plant feature to an unacceptable safety level or could result in an incapacitating injury to control room occupants. The design and construction of these SSCs should ensure that the SSE would not cause such failures. The applicant should also list or otherwise clearly identify all SSCs or portions thereof that are outside the scope of the referenced certified design and are intended to be designed for an OBE.

The applicable regulatory requirements for the quality group classification of SSCs are as follows:

- 10 CFR Part 50, Appendix A, GDC 1, “Quality standard and records,” which requires (in part) that SSCs important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be supplemented or modified as necessary to assure a quality product consistent with the required safety function.

The related acceptance criteria are as follows:

- RG 1.26 establishes an acceptable regulatory basis for meeting GDC 1 relative to quality group classification. RG 1.26 also classifies fluid systems and their supports that are important to safety, which are to be designed to quality standards commensurate with their safety function.

- RG 1.206 states that the applicant should identify those fluid systems or portions thereof that are important to safety and outside of the certified design scope, as well as the applicable industry codes and standards for each pressure-retaining component.

3.2.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.2 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.2 of the North Anna 3 COL FSAR, Revision 8, and checked the ESBWR DCD, Revision 10, to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to this Section.

The staff reviewed the information in the North Anna 3 COL FSAR, Revision 8, as follows:

Site Specific Information Replacing Conceptual Design Information

- STD CDI — RTNSS Systems
- STD CDI — Classification Summary – Hydrogen Water Chemistry
- NAPS CDI — Classification Summary – Zinc Injection System
- NAPS CDI — Classification Summary – Cold Machine Shop

Seismic Classification

NRC staff determined that the supplements, including site specific information related to the hydrogen water chemistry, zinc injection systems, cold machine shop, and RTNSS systems do not affect the seismic classifications.

The staff reviewed the COL application information to determine whether the application contains sufficient information on the seismic classification of site specific SSCs that are outside of the DCD scope. The staff issued several requests for additional information (RAIs) to determine whether the scope of SSCs considered to be site specific is essentially complete, and whether sufficient information concerning the seismic classification of those SSCs is included in the application. The staff reviewed the following technical topics:

Seismic Classification of Site Specific RTNSS SSCs

GDC 2 identifies, in part, that SSCs important to safety shall be designed to withstand the effects of earthquakes. FSAR Section 3.2.1 identifies no departures or supplements relative to the seismic classification of SSCs, and the standardization matrix identifies no site specific information that applies to Section 3.2. However, certain potential RTNSS-important SSCs, such as the plant service water system (PSWS) and makeup water system, are identified as site specific and makeup sources for the ultimate heat sink. Also, initially it was not clear whether there were non-safety-related SSCs outside of the DCD scope that may be important to safety. Therefore, in RAI 03.02.01-6 dated August 6, 2008 Agencywide Documents Access and Management System (ADAMS) Accession No. ML082190780, the staff requested that the applicant clarify whether there are any site specific, non-safety-related SSCs outside of the DCD scope that are important to safety and, if so, to identify the appropriate seismic classification of those SSCs. For example, certain site specific defense in depth RTNSS SSCs, such as the

PSWS and the intake structure, may be considered non-safety-related but may be important to safety and should be categorized as designed to withstand the effects of earthquakes. This seismic concern for RTNSS SSCs was also identified during the concurrent ESBWR design certification review at that time. The applicant decided to resolve this issue in the DCD rather than in the COL for all plant SSCs, including those that are site specific. Therefore, in response to RAI 03.02.01-6, dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that there are no non-safety-related SSCs important to safety (RTNSS SSCs) that are outside of the DCD scope. This response also clarified that the seismic classification of RTNSS SSCs is within the DCD scope, and Appendix 19A of the DCD had undergone substantial changes in DCD Revision 5. The staff concurred that the seismic classification of site specific RTNSS SSCs can be evaluated in the DCD which is reflected in the ESBWR DCD, Revision 10. Accordingly, the staff considers all issues associated with RAI 03.02.01-6 resolved and closed.

Seismic Classification of Other Site Specific SSCs

Section 1 of the DCD identifies only limited site specific SSCs that are outside the scope of the DCD, and for which the COL applicant is expected to provide site specific information. COL application Table 1.9-203 indicates that there are no safety-related or RTNSS SSCs that are not included in the DCD. It is not clear, however, whether there are any other non-safety-related SSCs that are considered important to safety but are not included in the DCD that will be addressed in the COL application.

Therefore, in RAI 03.02.01-5 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify whether there are any site specific SSCs outside of the DCD scope that are not included in DCD Table 3.2-1 and are to be seismically classified in the COL. For example, site specific structures such as the stack and miscellaneous items such as the reactor vessel insulation, which may or may not be site specific, are not included in the tables. If so, the RAI requested the applicant to identify the appropriate seismic classification of those SSCs or clarify when those SSCs will be classified. In response to RAI 03.02.01-5, dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that there are no non-safety-related SSCs important to safety (RTNSS SSCs) outside of the DCD scope, and there are no site specific SSCs not in the DCD that are to be seismically classified. In regard to the stack (changed to three stacks in DCD Revision 5) and reactor vessel insulation, the applicant clarified that these SSCs are not site specific. Because no site specific SSCs will be classified in the COL, the staff considers all issues associated with RAI 03.02.01-5 resolved and closed.

Quality Assurance for Seismic Category II SSCs

In an RAI 03.02.01-4 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify the extent to which pertinent Quality Assurance (QA) requirements of Appendix B to 10 CFR Part 50 in Regulatory Position C.4 of RG 1.29 apply to the activities affecting safety-related functions of those portions of SSCs covered under Regulatory Positions 2 and 3 of RG 1.29, including any site specific SSCs. This concern was also cited in an RAI for the ESBWR design certification review at the time. In response to RAI 03.02.01-4 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that this issue will be resolved in the ESBWR DCD, and General Electric-Hitachi (GEH) has included this information in DCD Section 3.2 and in DCD Appendix 19A for all SSCs, which is reflected in the ESBWR DCD, Revision 10. The staff concurred that this information has been reviewed in connection with the certified design, and applies to the COL applicants including North Anna 3 that reference that ESBWR design. Accordingly, the staff considers all issues associated with RAI 03.02.01-4 is resolved and closed.

Consistency with Regulatory Guidance

FSAR Table 1.9-201 points out that the seismic classification conforms to SRP Section 3.2.1, Revision 2, and that SRP Section 3.2.1 references RG 1.29 (currently Revision 4) for seismic classification. SRP Section 3.2.1 identifies that the applicant should provide a list of SSCs that are necessary for continued safe operation that must remain functional without undue risk to the health and safety of the public and within applicable stress, strain, and deformation limits during and following an OBE, if the applicant has set the OBE ground motion to the value of one-third of the SSE ground motion. The list of SSCs may be addressed either in this section or in the operational programs for pre-earthquake planning in COL FSAR Section 3.7.4. Other than the four CDIs noted above, North Anna 3 Section 3.2 of FSAR, Revision 8, does not identify any departures or supplements relative to the seismic classification in the DCD and the conformance to RG 1.29 Revision 3 in the ESBWR DCD, Revision 10.

In RAI 03.02.01-3 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify the extent to which site specific seismic classifications of SSCs are consistent with RG 1.29 Revision 4. In response to RAI 03.02.01-3 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant clarified that the FSAR is incorrect. The classification of site specific SSCs is consistent with the DCD that references RG 1.29 Revision 3, and COL FSAR Table 1.9-202 will be revised accordingly. In addition, the staff has indicated to the applicant that there are no site specific SSCs requiring classification in the COL application or changes to the methodology. Therefore, the staff finds that use of RG 1.29, Revision 3 is acceptable. The staff verified that the COL FSAR Revision 8, Table 1.9-202 is revised accordingly. Therefore, the staff considers all issues associated with RAI 03.02.01-3 is resolved and closed.

List of SSCs Necessary for Continued Safe Operation During and Following an OBE

In a RAI 03.02.01-7 dated August 20, 2009 (ADAMS Accession No. ML092360286), the staff indicated to the applicant that, in order to be consistent with the requirements and guidance of 10 CFR Part 50, Appendix S, IV(a)(2)(I) and (3), RG 1.166 and NUREG-0800, SRP Section 3.2.1 Revision 2, a list of SSCs necessary for continued operation when subjected to an OBE should be available for review if the applicant has set the OBE ground motion equal to one-third of the SSE ground motion. Since the COL applicant has not deviated from the DCD, which sets the OBE ground motion equal to one-third of the SSE ground motion, staff requested that the COL applicant provide the list of SSCs necessary for continued safe operation that must remain functional without undue risk to the health and safety of the public and within applicable stress, strain, and deformation, during and following an OBE. In response to RAI 03.02.01-7 dated December 9, 2009 (ADAMS Accession No. ML093490251), the COL applicant stated that as noted in 10 CFR Part 50, Appendix S, Section IV(a)(2)(i)(A), if the OBE ground motion is set to one-third or less of the SSE, then the requirements associated with the OBE ground motion in 10 CFR Part 50, Appendix S, Section IV (a)(2)(i)(B)(I) can be satisfied without the COL applicant performing explicit response or design analyses. Since the ESBWR has set the OBE at one-third of the SSE (as discussed in ESBWR FSAR Tier 2, Section 3.7), no further explicit response is required in accordance with 10 CFR Part 50, Appendix S, Section IV(a)(2)(i)(A). Those SSCs that are designed to withstand an SSE are classified as Seismic Category I and are given in ESBWR Tier 2, Table 3.2.2-1, "Classification Summary." This classification is in accordance with SRP Section 3.2.2-1. Based on the COL applicant's statement that the list is addressed through ESBWR FSAR Tier 2, Table 3.2.2-1 and the staff finding that the table is acceptable, the staff considers RAI 03.02.01-7 is resolved and closed.

Important to Safety SSCs

In the North Anna 3 FSAR Section 3.2 the applicant states:

> There are no site-specific safety related or non-safety related RTNSS systems beyond the scope of the DCD.

The ESBWR DCD, Section 1, Revision 10, provides for COL Item 17.4-1-A identifying site-specific SSCs outside the scope of the DCD but within the scope of the reliability assurance program. In the North Anna 3 FSAR COL Item 17.4-1-A, the applicant states:

> There are no site specific SSCs within the scope of the Reliability Assurance Program (RAP). The quality elements for all SSCs within the scope of the Design Reliability Assurance Program (D-RAP) are in accordance with the Quality Assurance Program Description (QAPD).

The staff finds that the applicant's response conforms to the guidance in RG 1.206 and the requirements in 10 CFR Part 50, Appendix A, GDC 1, and is therefore acceptable.

List of RTNSS SSCs

DCD Revision 5, Section 3.2.1 refers to Table 19A-1 for a list of RTNSS SSCs. However, Table 19A-1 in Revision 5 of the DCD has been deleted. It was not clear at that time whether this list included site specific SSCs. Therefore, in RAI 03.02.01-2 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant identify the appropriate reference for the list of site specific RTNSS SSCs. In response to RAI 03.02.10-2 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant noted the correct reference for risk-significant RTNSS SSCs is in Table 3 of NEDO-33411. The staff further verified that the list of RTNSS SSCs can be reviewed in the ESBWR DCD, Revision 10, Appendix 19A. Table 19A-3 in addition identifies the structures housing the RTNSS functions identified in DCD Table 19A-2. Accordingly, the staff considers all issues associated with RAI 03.02.01-2 resolved and closed.

RTNSS SSCs Classified as Non-Seismic

DCD Revision 4 Table 3.2-1 identified various non-safety-related potential RTNSS SSCs as either Seismic II or nonseismic (NS). DCD Section 19A.8.3 classifies RTNSS Criterion B-SSCs, as a minimum, seismic Category II, and are qualified to the Institute of Electrical and Electronics Engineers (IEEE)-344-1987. These SSCs must be available following a seismic event. In RAI 03.02.01-1 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify the basis for the Seismic II or NS classification or identify an appropriate departure. In response to RAI 03.02.01-1 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that there are no site specific, RTNSS-important SSCs beyond those identified in the DCD. The staff verified that the ESBWR DCD, Revision 10, Appendix 19A Table 19A-3 identifies the structures housing the RTNSS functions. Accordingly, the staff considers all issues associated with RAI 03.02.01-1 resolved and closed.

Summary

Based on the above evaluation of the applicant's information related to seismic classification, the staff finds that the requirements of GDC 2 are met and the information is consistent with the guidance in RGs 1.29 and 1.206 for all SSCs important to safety.

Quality Group Classification

The NRC staff's review of North Anna 3 COL FSAR, Revision 8, finds that the applicant has incorporated by reference Section 3.2.2 of the ESBWR DCD, Revision 10. The review confirms that the information in the application and the information incorporated by reference address the required information relating to the quality group classification of SSCs.

NRC staff determined that the site specific information replacing conceptual design information related to the hydrogen water chemistry and zinc injection systems does not affect the quality group classifications.

The ESBWR DCD Section 1.10 states that the COL applicant is required to provide site-specific information as COL items.

The staff reviewed the following technical topics:

Consistency with Regulatory Guidance

FSAR Table 1.9-201 shows that the quality group classification conforms to SRP Section 3.2.2, Revision 2 and that SRP Section 3.2.2 references RG 1.26 (currently Revision 4) for quality group classification. Section 3.2 of the North Anna 3 FSAR, Revision 1, did not identify any departures or supplements relative to the quality group classification identified in the DCD and compliance with RG 1.26 Revision 3 in the DCD. But FSAR Table 1.9-202 references conformance to Revision 4, dated March 2007. QA Program AR-NA-30 references Revision 4 to RG 1.26 with the DCD exception, but incorrectly references February 1976 rather than March 2007. Therefore, in RAI 03.02.02-1 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify whether classifications of site specific SSCs are consistent with RG 1.26 Revision 4.

In response to RAI 03.02.02-1 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant clarified that the FSAR is incorrect. The classification of site specific SSCs is consistent with the DCD that references RG 1.26 Revision 3. COL FSAR Table 1.9-202 and Appendix 17BB will be revised accordingly. COL applicants should supplement generic DCD information on conformance to RGs to address those that were issued since the time the standard design was approved. There are no site specific SSCs classified in the COL application, so the effective RGs are appropriately referenced in the DCD. Therefore, the staff finds that use of RG 1.26, Revision 3 is acceptable. The staff verified that the COL FSAR Revision 8, Table 1.9-202 and Appendix 17BB is revised accordingly. Therefore, the staff considers all issue associated with RAI 03.02.02-1 resolved and therefore Open Item 03.02.02-1 is closed.

Codes and Standards

The NRC staff requirements memorandum (SRM) dated July 21, 1993, concerning SECY-93-087, stated that the staff will review passive plant design applications using the newest codes and standards endorsed by the NRC, and unapproved revisions to the codes will be reviewed on a case-by-case basis. Editions of various codes and standards referenced in DCD, Revision 4, Section 3.2.6 are not current, and newer codes and standards are not referenced in COL applicant Sections 3.2 or 1.8. Therefore, in RAI 03.02.02-2 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the COL applicant clarify the specific code editions the applicant has referenced that are currently endorsed by the NRC. The applicant was also asked to clarify whether current editions of codes and standards will be applied to the detailed design and procurement of ESBWR SSCs, so that these editions may be reviewed on a case-by-case basis. If the applicant decides to resolve this issue in the DCD rather than in the COL for all plant SSCs, including those that are site specific, the staff has asked the applicant to so advise the NRC.

In response to RAI 03.02.02-2 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that DCD Table 1.8-22 identifies industrial codes and standards and adjustments that have been made to these codes and standards. The applicant also indicated that questions regarding versions of codes and standards should be addressed to GEH. COL applicants should supplement generic DCD information on compliance with RGs to address those that have been issued since the time the standard design was approved.

The staff recognizes that there are no site specific SSCs that are not classified in the DCD. However, regulatory guidance for site specific SSCs should be identified in the COL application so that the correct RG revision is applied to site specific SSCs, including those added in the future. North Anna 3 FSAR, Revision 8, Table 1.9-204 supplements the ESBWR DCD, Revision 10, Table 1.9-22 to address industrial codes and standards applicable to portions of the design that are beyond the scope of the DCD. The staff found the response acceptable because the COL applicant adequately addressed staff's concern regarding use of codes and standards. Therefore, the staff considers all issue associated with RAI 03.02.02-2 resolved and therefore Open Item 03.02.02-2 is closed.

Special Treatment for Risk-Significant SSCs

GDC 1 identifies (in part) that SSCs important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. Supplemental quality standards and the QA Program applicable to passive SSCs used in non-safety-related RTNSS systems that may be important to safety were not clearly defined in the initial North Anna 3 COL application for site specific SSCs.

Therefore, in RAI 03.02.02-3 dated August 6, 2008 (ADAMS Accession No. ML082190780), the staff requested that the applicant clarify what supplemental quality standards are applied to non-safety-related, site specific SSCs that are important to safety to ensure that all SSCs important to safety are designed, fabricated, erected, and tested to quality standards commensurate with the safety function to be performed. This concern was also identified in an RAI for the review of the ESBWR design certification at the time. In response to RAI 03.02.02-3 dated September 17, 2008 (ADAMS Accession No. ML082661075), the COL applicant stated that this issue will be resolved in the DCD. The applicant clarified that GEH has included this information in DCD Section 3.2 and Appendix 19A and that these are applicable to site specific SSCs. The staff verified that the issue was resolved in the ESBWR DCD, Revision 10. Accordingly, the staff considers all issues associated with RAI 03.02.02-3 resolved and closed.

Summary

Based on the above evaluation of the applicant's information related to quality group classification, the staff finds that the requirements of GDC 1 are met and the information is consistent with the guidance in RG 1.26 and RG 1.206.

3.2.5 Post Combined License Activities

There are no post COL activities related to this section.

3.2.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. 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 section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the additional COL information in the application to the relevant NRC regulations, the guidance in Sections 3.2.1 and 3.2.2 of NUREG–0800, and the applicable RGs. The staff's review concludes that the applicant has adequately addressed the seismic and quality group classifications. The staff notes that these classifications meet the requirements of GDC 1 and GDC 2 and the guidance of RG 1.26, RG 1.29, and RG 1.206. Therefore the staff also finds that North Anna 3 COL FSAR, Revision 8, Sections 3.2.1 and 3.2.2 are acceptable because they meet NRC regulatory requirements and acceptance criteria in Sections 3.2.1 and 3.2.2 of NUREG-0800.

3.3 Wind and Tornado Loadings

3.3.1 Introduction

Seismic Category I for the ESBWR structures are designed for tornado and extreme wind phenomena. Seismic Category II structures are designed for extreme and tornado wind. Safety-related systems and components are protected within wind-resistant structures and the remainder of plant structures and components not designed for extreme wind loads are arranged or designed such that their failures do not adversely affect the ability of any Seismic Category I SSC to perform their safety-related function.

3.3.2 Summary of Application

Section 3.3, "Wind and Tornado Loadings," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference, with a supplement, Section 3.3, "Wind and Tornado Loadings," of Revision 10 of the ESBWR DCD.

In addition, in North Anna 3 FSAR Section 3.3 the applicant provided the following:

Supplemental Information

- NAPS SUP 3.3-1 Extreme Hurricane Winds

In FSAR Table 2.0-201, the applicant provided the following supplemental information.

> Section 2.3 defines the site-specific extreme hurricane wind speed in accordance with RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants." The site-specific extreme hurricane wind speed is less than the maximum tornado wind speed listed in North Anna 3 FSAR Table 2.0-201.

3.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG-1966, the final FSER related to the ESBWR DCD. In addition, the relevant requirements of the Commission regulations for SSCs protection from natural phenomena and the associated acceptance criteria are in Section 3.3.1, “Wind Loading” and Section 3.3.2, “Tornado Loadings” of NUREG-0800 SRP.

The applicable regulatory requirements and associated guidance for wind and tornado loadings are as follows:

- 10 CFR 50, Appendix A, GDC 2 requires that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, tsunami, floods, and seiches without loss of capability to perform their safety functions as it relates to natural phenomena. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

3.3.4 Technical Evaluation

As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.3 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.3 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced DCD to ensure that the combination of the DCD and the information in the COL represent the complete scope of information relating to this review topic.[1] The staff’s review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to the wind and tornado loadings for North Anna 3.

In 2011 the NRC issued new guidance for hurricanes in RG 1.221, “Design Basis-Hurricane and Hurricane Missiles for Nuclear Power Plants.” This guidance demonstrated that hurricane missiles could be more severe than tornado missiles. In addition, the ESBWR design certification rule includes an exclusion from finality for loads on applicable systems, structures, and components (SSCs) from hurricane-generated missiles, but only to the extent that such loads are not bounded by other loads analyzed in the ESBWR DCD.

The staff reviewed the relevant information in the COL FSAR as follows:

<u>*Supplemental Information*</u>

- NAPS SUP 3.3-1 Extreme Hurricane Winds

The staff reviewed NAPS SUP 3.3-1 for extreme hurricane winds in accordance with RG 1.221, Revision 1, which was guidance that was issued following the staff approval of the ESBWR DCD Revision 10. North Anna 3 incorporated this new guidance and therefore included this supplemental COL information to address this RG revision. As stated by the applicant the North Anna 3 site specific hurricane wind speeds are bounded by the results of the DCD for wind loadings on safety related structures, and therefore the staff finds that the site specific generated hurricane wind speed and loading is acceptable for the safety related structures as defined by the ESBWR DCD.

3.3.5 Post Combined License Activities

There are no post COL activities related to this section.

3.3.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. The NRC staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information relating to the wind and tornado loadings, and no outstanding information is expected to be addressed in the COL FSAR related to this Section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference are resolved.

In addition, the staff compared the additional North Anna 3 supplemental information in the application including NAPS SUP 3.3-1 and NAPS SUP 3.5-3 from FSAR Section 3.5 to the relevant NRC regulations and regulatory guides. The staff's review concludes that the applicant has provided sufficient information in its supplemental information on wind, extreme hurricane winds and tornado loadings on safety related structures. The staff finds that the supplemental information on hurricane wind speed meets the latest guidance of RG 1.221 and the requirements of GDC 2 for SSCs important to safety that are able to withstand the effects of natural phenomena without loss of capability to perform their safety function.

3.4 <u>Water Level (Flood) Design</u>

Section 3.4, "Water Level (Flood) Design," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference, with no departures or supplements, Section 3.4, "Water Level (Flood) Design," of the certified ESBWR DCD Revision 10 referenced in 10 CFR Part 52, Appendix E. As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.4 of the certified ESBWR DCD. The staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The staff's review confirmed that the applicant has addressed the required information, and there is no outstanding information related to this section that remains to be addressed in the COL FSAR. Pursuant to 10 CFR 52.63(a)(5) and Section VI.B.1 of Appendix E to 10 CFR Part 52, all nuclear safety issues relating to the "Water Level (Flood) Design," that were incorporated by reference have been resolved.

3.5 <u>Missile Protection</u>

3.5.1 Introduction

SSCs important to safety are analyzed for and designed to be protected from a wide spectrum of internally generated missiles, such as missiles from rotating equipment, high energy fluid systems, and gravitational missiles; externally generated missiles from tornado winds and extreme winds; and missiles from proximate site sources and aircraft hazards.

Methods of protection must be provided for all SSCs that are necessary to perform functions required to attain and maintain safe shutdown or to otherwise mitigate the consequences of an accident. These methods may consist of (1) locating the system or component in a missile-proof structure, (2) separating redundant systems or components in the missile's path or range, (3) providing local shields and barriers for systems and components, or (4) designing the equipment to withstand the impact of the most damaging missile.

The specific reactor site location determines the potential for missile hazards from nearby industrial sources and the hazards from aircraft operating in the region.

3.5.2 Summary of Application

Section 3.5, "Missile Protection," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 3.5, "Missile Protection," of the ESBWR DCD, Revision 10.

In addition, in FSAR Section 3.5, the applicant provided the following:

Supplemental Information

- STD SUP 3.5-1 Site Proximity Missiles

The applicant provided the following supplemental information. The applicant referred to Section 2.2 for information regarding the site specific missile sources.

- STD SUP 3.5-2 Aircraft Hazards

The applicant provided the following supplemental information. The applicant referred to Section 2.2 for information regarding the site specific aircraft hazard analyses and site specific critical areas.

- NAPS SUP 3.5-3 Missiles Generated by Natural Phenomena

The applicant provided the following supplemental information. The applicant referred to FSAR Section 2.3 for information regarding the site specific extreme hurricane winds in accordance with RG 1.221, ""Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants."

The applicant stated the following:

> The site-specific extreme hurricane wind speed is less than the maximum tornado wind speed listed in Table 2.0-201. Table 3.5-201 lists the NA3 site hurricane missile spectrum and velocities in accordance with the guidance in RG 1.221

3.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG–1966, the FSER related to the ESBWR DCD.

In addition, the relevant requirements of the Commission regulations for turbine missiles and the associated acceptance criteria are described in Section 3.5.1.3 and the aircraft hazards and the associated acceptance criteria are described in Section 3.5.1.6 of NUREG-0800, the SRP.

The applicable regulatory requirements for protection against site proximity missiles and aircraft hazards are as follows:

- GDC 4 of Appendix A to 10 CFR Part 50, “Environmental and dynamic effects design bases.”

3.5.4 Technical Evaluation

As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.5 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.5 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD represents the complete scope of information relating to this review topic.[1] The staff’s review confirms that the information in the application and the information incorporated by reference address the required information related to missile protection.

The staff reviewed the information in the COL FSAR as follows:

Supplemental Information

- STD SUP 3.5-1 Site Proximity Missiles

The staff reviewed STD SUP 3.5-1, which states that the site specific missile sources are addressed in Section 2.2 of the North Anna 3 FSAR.

The staff’s technical evaluation of this portion of the application is limited to reviewing the supplemental information pertaining to STD SUP 3.5-1.

The staff reviewed the conformance of Section 3.5 of the North Anna 3 COL FSAR to the guidance in RG 1.206, Regulatory Position C.III.1, Section C.I.3.5.1.3, “Turbine Missiles”. The staff finds that the FSAR appropriately incorporates by reference Section 3.5.1.1.1.2 of the ESBWR DCD, Tier 2, Revision 10.

In addition the staff noted the potential for turbine missile hazard from the proposed North Anna 3 site in proximity of two existing nuclear units. Therefore, the staff requested in RAI 03.05.01.05-1, dated August 11, 2008 (ADAMS Accession No. ML082250417) that the applicant provide an assessment of the potential for the turbine missile generation for existing Units 1 and 2 to affect the safe operation of the proposed Unit 3. The applicant’s response to RAI 03.05.01.05-1 dated September 26, 2008 (ADAMS Accession No. ML082750076), that the planes-of-rotation of the turbine generators in Units 1 and 2 are oriented approximately 90 degrees relative to Unit 3 and are located approximately 1,640 feet from that unit. On the basis of the information the applicant provided the potential for impact from turbine missiles generated as a result of that particular orientation is not considered a possible threat that could affect the safe operation of the proposed North Anna 3. The staff concludes that the applicant has established that the operation of North Anna 3 on the proposed site location is acceptable in terms of the site proximity missile hazard in accordance with the guidance in SRP Section 3.5.1.3 and therefore, RAI 3.5.1.5-1 is resolved and closed

- STD SUP 3.5-2 Aircraft Hazards

The staff reviewed STD SUP 3.5-2 which states that the site specific aircraft analysis and site specific critical areas are addressed in Section 2.2 of the North Anna 3 FSAR.

The staff's technical evaluation of this portion of the application is limited to reviewing the supplemental information pertaining to STD SUP 3.5-2.

The applicant performed the aircraft hazards evaluation in the North Anna 3 Early Site Permit (ESP) SSAR because the ESP site lies within 5 miles of the edge of a military route and within 2 miles of the edge of a federal airway. The applicant in its ESP SSAR addressed and evaluated potential aircraft hazards following the approach and methodology outlined in the NUREG-0800, SRP Section 3.5.1.6, "Aircraft Hazards." The applicant simulated an aircraft crash into the effective plant areas of the safety-related structures on the site. The applicant further evaluated the probability of aircraft accidents resulting in radiological consequences greater than the 10 CFR Part 100 exposure guidelines based on the following updated analysis for the COL application:

- A third airport within 10 miles of Unit 3 opened in 2007 following the ESP evaluation. It is a private landing strip approximately 7.6 miles north-northwest of the site. The airport is not licensed for commercial use and has only three small aircraft based on the field. The expected volume of traffic is very light and would not exceed the limiting operations threshold as determined in the ESP SSAR. Therefore, no additional evaluation of potential design basis aircraft event was performed.

- One civil airway (V223) and four military training routes (IR714, IR760, VR1754, and VR1755) pass near the North Anna 3 site. The U.S. Federal Aviation Administration (FAA) at Richmond International Airport characterized civil airway V223 as "not heavily used" and estimated the traffic to be no more than 200 aircrafts per day. The U.S. Department of the Navy identified a total of 341 flight operations in the year 2006 for the four routes, compared with the ESP SSAR assumption of 6,000 flights per year. As a result, the number of military training flights assumed in the ESP SSAR remains bounding. To estimate the probability calculations, the applicant for the ESBWR design considered the ESBWR reactor building (RB) and fuel building (FB) and the control and radwaste buildings. The applicant estimated the total effective plant area at 0.024 square miles for civil airways and 0.032 square miles for the military routes and revised the probability calculations.

Utilizing the above revised data as part of the North Anna 3 COL application, the applicant determined that the total probability of an aircraft crash into the plant is 1.02×10^{-7} events per year. The staff obtained updated FAA flight data and determined that the applicant had used conservatively higher values for flight operations to determine the total aircraft hazard probability. On the basis of FAA flight data and the review of the applicant's calculations of the probability of aircraft hazards, the staff considered the applicant's approach reasonable and its conclusion acceptable.

- NAPS SUP 3.5-3 Missiles Generated by Natural Phenomena

The staff evaluated hurricane generated missiles on safety related structures in this SER for NAPS SUP 3.3-1, Section 3.3.4 as well as in the SER Chapter 19 Appendix 19A.

3.5.5 Post Combined License Activities

There are no post COL activities related to this section.

3.5.6 Conclusion

The staff's finding related to information incorporated by reference is in NUREG–1966. NRC 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 section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the COL supplemental information in the application to the relevant NRC regulations, the guidance in Section 3.5 of NUREG–0800 SRP, and other NRC RGs. The staff concluded that the supplemental information presented in the COL FSAR is acceptable and meets the requirements of GDC 4 of Appendix A to 10 CFR Part 50. The staff based this conclusion on the following:

- STD SUP 3.5-1, "Site Proximity Missiles," is acceptable because the applicant has identified potential accidents related to the generation of site proximity missiles (except aircraft) in the site vicinity that could affect a nuclear power plant or plants of the specified type that might be constructed on the proposed site. The applicant has appropriately determined those potential accidents that should be considered as design-basis events and has demonstrated that the plant is adequately protected and can be operated with an acceptable degree of safety with regard to the design-basis accidents. The staff reviewed the information in the SSAR and FSAR. For the reasons given above, the staff concluded that the applicant has established that the construction and operation of Unit 3 of the specified type on the proposed site location is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance with respect to determining the acceptability of the site.

- STD SUP 3.5-2, "Aircraft Hazards," is acceptable because the applicant has identified potential accidents related to the aircraft hazards in the site vicinity that could affect a nuclear power plant or plants of the specified type that might be constructed on the proposed site. The applicant has appropriately determined those potential accidents that should be considered as design-basis events and has demonstrated that the plant is adequately protected and can be operated with an acceptable degree of safety with regard to the design-basis accidents. The staff reviewed the information in the SSAR and FSAR. For the reasons given above, the staff concluded that the applicant has established that the construction and operation of Unit 3 of the specified type on the proposed site location is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance with respect to determining the acceptability of the site.

3.6 <u>Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping</u>

Section 3.6, "Protection against Dynamic Effects Associated with the Postulated Rupture of Piping," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference, with no departures or supplements, Section 3.6, "Protection against Dynamic Effects Associated with the Postulated Rupture of Piping," of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E. As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.6 of the certified ESBWR DCD. The staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The staff's review confirmed that the applicant has addressed the required information, and there is no outstanding information related to this section that remains to be addressed in the COL FSAR. Pursuant to 10 CFR 52.63(a)(5) and Section VI.B.1 of Appendix E to 10 CFR Part 52, all nuclear safety issues relating to the "Protection against Dynamic Effects Associated with the Postulated Rupture of Piping," that were incorporated by reference have been resolved.

3.7 Seismic Design

Safety-related structures, systems, and components (SSCs) are designed to withstand safe-shutdown earthquake (SSE) loads and other dynamic loads, including those due to reactor building vibration (RBV) caused by suppression pool dynamics. This section addresses seismic aspects of the design and analysis in accordance with RG 1.206, "Combined License Applications for Nuclear Power Plants."

3.7.1 Seismic Design Parameters

Seismic Category I SSCs are designed to withstand the effects of an SSE event and to maintain the specified design functions. Seismic Category II and non-seismic (NS) structures are designed or physically arranged so that the SSE could not cause unacceptable structural interactions with or the failure of Seismic Category I SSCs. The ESBWR standard plant SSE design ground motion is addressed in Section 3.7 of ESBWR DCD, Tier 2, Revision 10. The horizontal and vertical SSE design ground response spectra (for 5 percent damping), also termed certified seismic design response spectra (CSDRS) for the ESBWR design were developed based on enveloping RG 1.60, Revision 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants," response spectra anchored to 0.3 g peak ground acceleration (PGA) and the high-frequency hard rock spectra anchored to 0.5 g PGA. The CSDRS for the reactor and fuel building (RB/FB) and the control building (CB) are shown in ESBWR DCD, Tier 2, Revision 10, Chapter 2.0, Figures 2.0-1 and 2.0-2 for horizontal and vertical directions, respectively. The CSDRS for the firewater service complex (FWSC) is 1.35 times the values shown in DCD Tier 2, Figures 2.0-1 and 2.0-2. The CSDRS have been defined as free-field outcrop spectra at the foundation level (bottom of the base slab) for the seismic design of the Category I structures included in the design certification document. The applicant has provided the seismic design parameters for the North Anna 3 site in the North Anna 3 COL FSAR, Revision 9, Section 3.7.1, as documented below.

3.7.1.1 Introduction

The North Anna 3 FSAR, Revision 9, Section 3.7.1 addresses the site-specific design earthquake ground motion used for the seismic analysis and design of the Seismic Category I structures. This design earthquake ground motion is based on the seismic and geologic characteristics at the North Anna 3 site and is established in terms of a set of idealized and smooth curves called the design response spectra. At the North Anna 3 site, the site-specific seismic design parameters include the design ground motion in terms of the foundation input response spectra (FIRS), design ground motion time histories, percentage of critical damping values, and the characteristics of the supporting media for Seismic Category I structures.

3.7.1.2 Summary of Application

In the North Anna 3 COL FSAR Section 3.7.1, Revision 9, the applicant incorporated by reference Section 3.7.1 of ESBWR DCD, Revision 10.

In addition, in FSAR Section 3.7.1, the applicant provides the following:

Exemption

- Exemption 3 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

The North Anna 3 site-specific seismic conditions described in FSAR Chapter 2 and Section 3.7.1 indicate that certain seismic design characteristics are not bounded by the DCD seismic design parameters. Therefore, Unit 3 defines the SSE to include both the CSDRS and the site-specific FIRS for each seismically qualified structure.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

This departure is described in North Anna 3 COL FSAR Part 7, Departures Report. The site-specific horizontal and vertical seismic response spectra as shown in North Anna 3 COL FSAR Figures 2.0-201 through 2.0-204 exhibit exceedances at certain frequencies, when compared to the ESBWR CSDRS. As a result of these exceedances, the applicant performed site-specific soil-structure interaction (SSI) analyses of the RB/FB, CB, and FWSC structures and revised the SSE definition to include both the ESBWR CSDRS and the site-specific FIRS for each seismically qualified structure for use in performing seismic design, analysis, and qualification of structures, systems, and components (SSCs). In addition, FSAR Figure 3.7.1-285 provides the SSI input spectra defining site-specific ground motion for the FWSC at the bottom of the concrete fill (Elevation 220 ft) as discussed in FSAR Section 3.7.1.1.4.2.3.

Because the SSE is defined in DCD Tier 1, Table 5.1-1, this change to the site-specific definition requires the applicant to take a departure from the DCD Tier 1 information. Therefore, a request for exemption from DCD Tier 1 information is also provided in Exemption 3 described in North Anna 3 COL FSAR Part 7. The staff evaluated North Anna 3 Exemption 3 in Section 3.7.1.4 of this SER.

In addition, DCD Section 3.7 defines, as Tier 2* information, the ESBWR Operating Basis Earthquake (OBE) as one-third of the SSE ground motion. Because the site-specific SSE is being defined through this departure as consisting of both the CSDRS and FIRS for each structure, two spectra are used to define the North Anna 3 OBE design ground motion as: one-third of the CSDRS and one-third of the site-specific SSE manifestation at grade presented in FSAR Figure 3.7.1-267. The detailed criteria for plant shutdown are evaluated in this safety evaluation report (SER) in Section 3.7.1.4.

Supplemental Information

- NAPS SUP 3.7-7 Design Ground Motion

As discussed under the departure, NAPS DEP 3.7-1, the site-specific FIRS at North Anna 3 site exceed the CSDRS. For this reason, the applicant supplemented FSAR Section 3.7.1.1 to provide site-specific seismic design parameters (such as SSI input strain-compatible soil profiles, SSI input response spectra, SSI input acceleration time histories) for the site-specific SSI analyses of the RB/FB, CB, and FWSC.

- NAPS SUP 3.7-1 Site Specific Design Ground Motion Response Spectra

In FSAR Section 3.7.1.1.4, the applicant provided the following:

1. The development of the strain compatible dynamic properties (e.g., compression wave velocities, damping ratios) of the subsurface material profiles used in the site-specific SSI analyses of the RB/FB, CB, and FWSC in FSAR Section 3.7.1.1.4.1.

2. The development of a set of site-specific input response spectra for SSI analyses of the RB/FB, CB, and FWSC in FSAR Section 3.7.1.1.4.2. For each of the buildings, the applicant described how the site-specific SSI input response spectra are obtained from the corresponding FIRS and performance-based surface response spectra (PBSRS) by using the guidance in DC/COL-ISG-017. This supplement also described how the site-specific SSI input response spectra are augmented to obtain the final SSI input response spectra to meet the minimum ground motion requirements of 10 CFR Part 50, Appendix S.

- NAPS SUP 3.7-2 Site Specific Design Ground Motion Time History

In FSAR Section 3.7.1.1.5, the applicant provided information on two sets of three statistically independent acceleration time histories of motions (i.e., two horizontal and one vertical component) developed for the full column and partial column SSI analyses of the RB/FB and CB. For FWSC, one set of acceleration time histories were developed at two elevations, at the bottom of the basemat and at the bottom of the concrete fill. The SSI input acceleration time histories match the final SSI input response spectra developed in FSAR Section 3.7.1.1.4. The applicant used the guidance of SRP 3.7.1 in developing these time histories.

- NAPS SUP 3.7-3 Supporting Media for Seismic Category I Structures

This supplement provided information on the supporting media of Seismic Category I structures in FSAR Section 3.7.1.3. The Seismic Category I structures for North Anna 3 have concrete mat foundations on rock or concrete fill on rock.

3.7.1.3 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". In addition, the relevant requirements of the Commission regulations for the seismic design, and the associated acceptance criteria, are in Section 3.7.1 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the seismic design basis to reflect the appropriate consideration of the most severe earthquakes historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated; and SSCs important to safety be designed to withstand the effects of earthquakes without a loss of capability to perform their intended safety functions.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it relates to the SSE ground motion in the free-field at the foundation level of the structures to be an appropriate response spectrum with a PGA of at least 0.1 g; and if the OBE is chosen to be less than or equal to one-third of the SSE ground motion, it will not be necessary to conduct explicit response or design analyses in accordance with Section IV.(2)(i)(A) of 10 CFR Part 50, Appendix S.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.1 include the following:

- SRP Section 3.7.1 for reviewing seismic design parameters to ensure that they are appropriate and contain a sufficient margin so that seismic analyses (reviewed under other SRP sections) accurately and/or conservatively represent the behavior of SSCs during postulated seismic events.

- RG 1.60, Revision 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants," to determine the acceptability of design response spectra for input into the seismic analysis of nuclear power plants.

- RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants," to determine the acceptability of damping values used in the dynamic seismic analyses of Seismic Category I SSCs.

- RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," to review acceptability of the input FIRS.

- Design Certification/COL–Interim Staff Guidance (DC/COL-ISG)-01, "Interim Staff Guidance on Seismic Issues of High Frequency Ground Motion."

- Design Certification/COL–Interim Staff Guidance (DC/COL-ISG)-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses."

- NUREG/CR-6728, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines,” to determine the acceptability of the site-specific FIRS used in the site-specific seismic analysis.

3.7.1.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 3.7.1 of the ESBWR DCD. The staff reviewed Section 3.7.1 of the North Anna 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff’s review confirms that the information in the application and the information incorporated by reference address the required information relating to this Section.

The staff reviewed the following information in the COL Part 7, “Departures Report” and the North Anna 3 COL FSAR, Revision 9:

Exemption

- Exemption 3 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

The North Anna 3 horizontal and vertical FIRS for the RB/FB, CB, and FWSC structures are not bounded by the CSDRS at all frequencies. Therefore, the applicant made a Tier 1 Departure from the DCD to accommodate the site specific seismological and geological conditions for North Anna 3. The applicant’s definition of the SSE for North Anna 3 has therefore been revised to include both the DCD CSDRS and the site-specific FIRS for each seismically qualified structure. Site-specific SSI analyses have been performed for the North Anna 3 Seismic Category I structures, and the staff evaluation of the results has confirmed the standard design to be adequate with the DCD modifications as outlined in Section 3.7 and 3.8 of the COL FSAR Revision 9. The site-specific definition of SSE will be applied in the ITAAC for ensuring seismic capability of the plant.

The applicant provided the following in its description of this Tier 1 change to the DCD:

> The Unit 3 horizontal and vertical foundation input response spectra for the RB/FB, CB, and FWSC structures are not bounded by the CSDRS at all frequencies. The definition of the SSE for Unit 3 has therefore been revised to include both: 1) the CSDRS, as described in DCD Tier 1, Table 5.1-1, Footnote (4), and DCD Tier 1 Figures 5.1-1 and 5.1-2; and 2) the site-specific FIRS and the SSI input response spectra for the FWSC at the average elevation of the bottom of the concrete fill (Elevation 220 ft NAVD88, 220.86 ft NGVD29), representative of the Unit 3 site seismological and geological conditions. DCD Tier 1, Section 5.1, provides for site-specific soil structure interaction analyses to be performed to confirm the seismic adequacy of the certified design using approved methods and acceptance criteria. Site-specific soil structure interaction (SSI) analyses have been performed for Unit 3 Seismic Category I structures and evaluation of the results has confirmed the standard design to be adequate. The site-specific definition of SSE will be applied in the ITAAC for ensuring seismic capability of the plant.

In the North Anna 3 COL application, Revision 7, Part 7, “Departures Report,” June 2016, the applicant requested an exemption from the provisions of 10 CFR Part 52, Appendix E, Section III.B, “Design Certification Rule for the ESBWR Design, Scope and Contents,” which requires an applicant referencing a certified design to incorporate by reference Tier 1 information.

Specifically, in North Anna Part 7, Exemption 3, the applicant proposed to depart from the ESBWR DCD, Tier 1, SSE definition from Table 5.1-1, Footnote (4) of the DCD. This exemption represents the Tier 1 changes that relate to Departure NAPS DEP 3.7-1 for Tier 2 and Tier 2* information regarding site-specific CSDRS partial exceedances. Part 10 of the North Anna 3 COL application reflects these changes to the DCD Tier 1 information regarding the site specific SSE. This change of the SSE definition is reflected in the revisions to site-specific ITAAC. The site-specific definition of SSE will be applied in the ITAAC for ensuring seismic capability of the plant as designed, as constructed and for any future potential plant modifications.

Regulations

- 10 CFR Part 52, Appendix E, Section VIII.A.4 states that exemptions from Tier 1 information are governed by the requirements of 10 CFR 52.63(b) and 10 CFR 52.98(f). 10 CFR Part 52, Appendix E, Section VIII.A.4 also states that the Commission will deny such a request if it finds that the design change will result in a significant reduction in the level of safety otherwise provided by the design.

- 10 CFR 52.63(b)(1) allows an applicant to request NRC approval for an exemption from one or more elements of the certification information. The Commission may only grant such a request if it determines that the request complies with the requirements for specific exemptions in 10 CFR 52.7and 10 CFR 50.12, and if the special circumstances that 10 CFR 52.7 requires to be present outweigh the potential decrease in safety due to reduced standardization. Therefore, any exemption from the Tier 1 information certified by 10 CFR Part 52, Appendix E must meet the requirements of 10 CFR 50.12, 10 CFR 52.7, and 10 CFR 52.63(b)(1).

Evaluation of Exemption

As stated in 10 CFR Part 52, Appendix E, Section VIII.A.4, an exemption from Tier 1 information is governed by the requirements of 10 CFR 52.63(b)(1) and 52.98(f). Additionally, the Commission will deny an exemption request if it finds that the requested change to Tier 1 information will result in a significant decrease in safety. Pursuant to 10 CFR 52.63(b)(1), the Commission may, upon application by an applicant or licensee referencing a certified design, grant exemptions from one or more elements of the certification information, as long as the criteria given in 10 CFR 50.12 and required by 10 CFR 52.7 outweigh any potential decrease in safety due to reduced standardization.

Applicable criteria for when the Commission may grant the requested specific exemption are provided in 10 CFR 50.12(a)(1) and (a)(2). 10 CFR 50.12(a)(1) provides that the requested exemption must be authorized by law, not present an undue risk to the public health and safety, and be consistent with the common defense and security. The provisions of 10 CFR 50.12(a)(2) list six special circumstances for which an exemption may be granted. It is necessary for one of these special circumstances to be present in order for NRC to consider granting an exemption request. The applicant stated that the requested exemption meets the special circumstances of 10 CFR 50.12(a)(2)(ii). That subsection defines special circumstances as when "[a]pplication of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule." The staff's analysis of each of these findings is presented below. Although the applicant requested an exemption from 10 CFR Part 52, Appendix E, Section III.B, the NRC is treating the requested exemption as one from ESBWR DCD Tier 1, Table 5.1-1, Footnote (4) to define the North Anna 3 SSE.

Authorized by Law

This exemption would allow the applicant to implement approved changes to Tier 1 information. This is a permanent exemption limited in scope to particular Tier 1 information, and subsequent changes to this Tier 1 information or any other Tier 1 information would be subject to full compliance by the applicant as specified in 10 CFR Part 52, Appendix E, Section VIII.A.4. As stated above, 10 CFR 52.63(b)(1) allows the NRC to grant exemptions from one or more elements of the certification information, namely, Tier 1. The staff determined that granting of the applicant's proposed exemption will not result in a violation of the Atomic Energy Act of 1954, as amended, or NRC regulations. Therefore, as required by 10 CFR 50.12(a)(1), the exemption is authorized by law.

No Undue Risk to Public Health and Safety

The purpose of Exemption 3 to ESBWR DCD Tier 1, Table 5.1-1, Footnote (4),for the North Anna 3 COL is to define the site specific SSE, due to the exceedances of the ESBWR standard plant SSE at certain seismic frequencies. The site specific SSE is then employed for the purpose of performing site-specific seismic inspections, tests, and analyses. The seismic design and qualification of structures, systems, and components are done in accordance with the methods of the standard design in conjunction with the site-specific results of the FIRS and which is then compared to the standard design. The applicant indicated that the exemption changes will augment the North Anna 3 site specific ESBWR standard design attributes to ensure that the North Anna 3 site-specific seismic conditions are adequate and meet regulatory requirements. The North Anna 3 seismic design and analyses are verified through the appropriate ITAAC. The proposed exemption which defines the site-specific SSE ensures that the as-built plant will be seismically designed, analyzed, and qualified for meeting both the standard design and the site-specific conditions. The plant-specific Tier 1 DCD will continue to reflect the approved licensing basis for the applicant and will maintain a level of detail consistent with that which is currently provided elsewhere in Tier 1 of the plant-specific DCD. The affected design description in the plant-specific Tier 1 DCD will continue to provide the detail necessary to support the performance of the associated ITAAC. The staff has evaluated the related departure NAPS DEP 3.7-1 in applicable sections of this SER, and concluded that this departure has been addressed adequately in the North Anna 3 site-specific seismic design evaluation of the ESBWR standard design. Therefore, the staff finds Exemption 3 presents no undue risk to public health and safety as required by 10 CFR 50.12(a)(1).

Consistent with Common Defense and Security

The proposed exemption would allow the applicant to implement modifications to the Tier 1 information requested in the applicant's submittal. This is a permanent exemption limited in scope to particular Tier 1 information. Subsequent changes to this Tier 1 information or any other Tier 1 information would be subject to full compliance by the applicant as specified in 10 CFR Part 52, Appendix E, Section VIII.A.4. This change is not related to security issues. Therefore, as required by 10 CFR 50.12(a)(1), the staff finds that the exemption is consistent with the common defense and security.

Special Circumstances

Special circumstances, in accordance with 10 CFR 50.12(a)(2)(ii), are present whenever application of the regulation in the particular circumstances would not serve the underlying purposes of the rule or is not necessary to achieve the underlying purpose of the rule. The underlying purpose of the North Anna 3 COL Exemption 3 to the ESBWR DCD Tier 1, Table 5.1-1, Footnote (4) is to define the North Anna 3 SSE which will ensure that the safety-related structures that must withstand the effects of earthquakes are designed to the relevant requirements of GDC 2 and comply with Appendix S to 10 CFR 50 concerning natural phenomena. Standardized plants such as the ESBWR are designed to envelop the most severe earthquakes that affected a great number of sites where a nuclear plant may be located, with sufficient margin considering the limits of accuracy, quantity and period of time during which historical data have been accumulated. In the case of North Anna 3 the site-specific horizontal and vertical foundation input response spectra for the RB/FB, CB, and FWSC structures are not bounded by the CSDRS at all frequencies. Therefore the applicant proposed a change to the Tier 1 definition of the SSE to include both the CSDRS and the site specific FIRS which ensures that the North Anna 3 seismic structures are appropriately qualified and applied to the site specific ITAAC. In addition, site specific seismic analysis and design as described in FSAR Revision 9, Sections 3.7 and 3.8, show that the ESBWR standard design with necessary changes is adequate for the North Anna 3 site specific seismological and geological conditions. Accordingly, special circumstances are present because the certified design information in ESBWR DCD Tier 1, Table 5.1-1, Footnote (4), is not necessary to achieve the underlying purpose of the rule in view of the site specific seismological and geological conditions. Therefore, the staff finds that special circumstances exist, as required by 10 CFR 50.12(a)(2)(ii) for the granting of an exemption from the DCD Tier 1 information..

Special Circumstances Outweigh Reduced Standardization

This exemption would allow the applicant to change certain ESBWR DCD Tier 1 information proposed in the North Anna 3 COL application in view of site-specific seismological and geological conditions. The key design functions of seismically qualified structures will nonetheless be maintained, based on the nature of the proposed changes to the generic ESBWR DCD Tier 1 Table 5.1-1, Footnote (4) to define the North Anna 3 SSE, and the understanding that this change ensures that the as-built plant will be seismically designed, analyzed, and qualified for meeting both the standard design and the site-specific seismic conditions. However, this exemption request and the associated changes to North Anna 3 COL Tier 1 information demonstrate that there is a minimal change from the standard information provided in the ESBWR DCD. This change augments the ESBWR DCD for the North Anna 3 site-specific seismic conditions to ensure that the adequacy of the North Anna 3 seismic design and analyses are verified through the appropriate ITAAC. Consequently, the decrease in safety due to reduced standardization would also be minimal. For this reason, the staff determined that even if other ESBWR licensees and applicants do not request a similar exemption, the special circumstances outweigh the potential decrease in safety due to reduced standardization of the ESBWR design, as required by 10 CFR 52.63(b)(1).

No Significant Reduction in Safety

The proposed exemption would not modify the function of the North Anna 3 seismically qualified structures and SSCs. This change will ensure that the adequacy of the Unit 3 seismic design and analyses are verified through appropriate ITAAC. Therefore, the staff finds that granting the exemption would not result in a significant decrease in the level of safety otherwise provided by the design, as required by 10 CFR Part 52, Appendix E, Section VIII.A.4.

Conclusion

For the reasons set forth above, the staff has concluded that pursuant to 10 CFR Part 52, Appendix E, Section VIII.A.4, the exemption: (1) is authorized by law; (2) presents no undue risk to the public health and safety; (3) is consistent with the common defense and security; (4) has special circumstances that outweigh the potential decrease in safety due to reduced standardization; and (5) does not significantly reduce the level of safety at the licensee's facility. Therefore, the staff finds that the applicant's request to depart from the information in ESBWR DCD Tier 1 Table 5.1-1, Footnote (4) is acceptable, and the applicant's request for an exemption from these Tier 1 requirements is granted.

Departure

- NAPS DEP 3.7-1 Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

Seismic Design Parameters

The staff reviewed the information presented in NAPS DEP 3.7-1 submitted in North Anna 3 COL FSAR Section 3.7 and in Part 7 of the COL application. This departure described that the site-specific FIRS exceeded the CSDRS at certain frequencies and as such, revised the SSE definition to include the site-specific FIRS in addition to the CSDRS for seismic analyses of Seismic Category I and Category II SSCs. Since this departure involves changes to ESBWR DCD Tier 1, Table 5.1-1, the applicant also requested an exemption (Exemption 3 in Part 7) from the DCD Tier 1 information. This departure also includes redefinition of the OBE for the plant shutdown.

The applicant has developed the site-specific seismic design parameters (FIRS, input acceleration time histories, etc.) using the guidance in SRP Section 3.7.1. Comparisons of site-specific FIRS with the CSDRS are presented in FSAR Figures 2.0-201 through 2.0-204 for RB/FB, CB, and FWSC. These Figures indicate that site-specific FIRS exceed the CSDRS for all these structures. As such, the applicant has performed site-specific SSI analyses consistent with the guidance in SRP Section 3.7.2 to determine the site-specific seismic demand for evaluation of the acceptability of the ESBWR standard plant design at the North Anna 3 site. The applicant also indicated that North Anna 3 seismic design, analyses, and qualification of the

SSCs use both the CSDRS and the site-specific FIRS as the SSE. Details of the applicant's development of site-specific FIRS and ground motion time histories are described in the supplementary information to COL FSAR Sections 3.7.1.1.4 and 3.7.1.1.5 (NAPS SUP 3.7-1 & 3.7-2).

Two spectra are used to define the North Anna 3 OBE design ground motion as: (1) one-third of the CSDRS presented in the FSAR Figures 2.0-201 and 2.0-202 and (2) one-third of the 5 percent damped site-dependent SSE spectra manifested at grade as presented in the FSAR Figure 3.7.1-267. Exceedance of the response spectra (1) & (2) is evaluated independently (not through the envelope of these two). Staff's evaluation of the plant shutdown criteria due to OBE exceedance is discussed in Section 3.7.4 of this SER. The staff finds the use of both the CSDRS and the site-specific SSE as the basis of defining the OBE to be acceptable since: (1) safety related SSCs are designed and qualified to meet both the CSDRS and site-specific FIRS consistent with the PBSRS, (2) the OBE is defined as one-third of the SSE, as such meets the requirement of 10 CFR Part 50 Appendix S, and (3) PBSRS and corresponding FIRS were developed using the guidance in SRP 3.7.1 and RG 1.208.

FSAR Section 3.7.2.4 discusses the site-specific SSI analyses of the ESBWR standard plant structures. FSAR Section 3.8 discusses design evaluation of the ESBWR standard plant structures for the site-specific seismic demand. The staff's evaluation of the site-specific FIRS and ground motion time histories is provided below under "Site-Specific Design Ground Motion Response Spectra" and "Site-Specific Design Ground Motion Time History." Staff's evaluation of the plant shutdown criteria is provided in Section 3.7.4.4 of this SER. The staff's evaluation of the site-specific RB/FB, CB, and FWSC SSI analyses and the applicant's assessment of the ESBWR standard plant design adequacy at North Anna 3 site is provided in Sections 3.7.2.4 and 3.8 of this SER.

Since the applicant incorporates both the CSDRS and the site-specific FIRS as the SSE for North Anna 3 seismic design, analyses, and qualification of Category I SSCs, the staff concludes that the seismic design parameters used in site-specific seismic analyses and evaluation of the ESBWR standard design to address FIRS exceedance of the CSDRS at the North Anna 3 site are acceptable.

Single Envelope Ground Motion

DCD Section 3.7.1.1.3 provides information regarding the single envelop ground response spectra which is referred to as the CSDRS. The CSDRS is used for the design of the ESBWR standard plant structures. NAPS DEP 3.7-1 noted that the site parameter comparison indicates exceedance of the CSDRS by the North Anna 3 FIRS and thus a site-specific SSI analysis is performed as presented in COL FSAR Section 3.7.2. The applicant also clarified that SSCs are seismically designed, analyzed, and qualified to both CSDRS and FIRS as described in FSAR Sections 3.7.1, 3.7.2, 3.7.3, and 3.10. The staff finds this clarification in FSAR Section 3.7.1.1.3 to be acceptable. For staff's evaluation of acceptability of the site-specific SSI analysis, refer to this SER in Section 3.7.2.4.

Percentage of Critical Damping Values

NAPS DEP 3.7-1 in COL FSAR Section 3.7.1.2 clarifies that OBE structural damping values consistent with RG 1.61 Revision 1 are used for site-specific SSI analyses unless SSE damping in DCD Table 3.7-1 is justified by stress demand. FSAR Section 3A.13.2 further describes the damping values used in the site-specific SSI analyses. FSAR Section 3A.15 and Tables 3A.15-201 through 3A.15-206 provide details of the use of SSE damping values in specific analyses cases. The staff evaluated the acceptability of the damping values used in the site-specific SSI analyses during its review of the site-specific design basis models as discussed in this SER in Section 3.7.2.4 under the heading "*SSI Analysis Structural Models*." The staff found the applicant's method of assigning the damping values for site-specific SSI analyses acceptable per the guidance in RG 1.61, Revision 1. In addition, the maximum soil damping ratio as specified in the FSAR Tables 3.7.1-201 through 3.7.1-206 is below 15 percent in all cases and is therefore acceptable per the guidance in SRP Acceptance Criterion 3.7.2.II.4.

<u>*Supplemental Information*</u>

- NAPS SUP 3.7-7 Design Ground Motion

Design Ground Motion

ESBWR CSDRS are discussed in DCD Section 3.7.1.1 and are shown in DCD Figures 2.0-1 and 2.0-2. This supplement to COL FSAR Section 3.7.1.1 describes that the site-specific SSI analysis is carried out using the site-specific seismic design parameters. The site-specific design parameters are developed as described in COL FSAR Sections 3.7.1.1.4 and 3.7.1.1.5. These design parameters include the SSI strain compatible soil profiles, SSI input response spectra, and SSI input acceleration time histories for the Category I structures. The development of the site-dependent SSE manifestation at-grade is discussed in FSAR Section 3.7.1.1.6, which is used to define OBE. The staff's evaluation of the supplementary information is provided below under review of NAPS SUPs 3.7-1 and 3.7-2 in this SER.

- NAPS SUP 3.7-1 Site Specific Design Ground Motion Response Spectra

Site-Specific Design Ground Motion Response Spectra

The applicant in FSAR Section 3.7.1.1.4.2 stated that, for all Seismic Category I structures FIRS are presented in FSAR Section 2.5.2.6. The applicant used the results of site response analyses as input to the development of the ground motion response spectra (GMRS), FIRS, and PBSRS. FIRS were developed for both full column outcrop motions and partial column outcrop motions for the RB/FB and CB. The final SSI input response spectra for the RB/FB are shown in the FSAR Figures 3.7.1-218 through 3.7.1-220 and for the CB are shown in the FSAR Figures 3.7.1-229 through 3.7.1-231. For the FWSC, two sets of site-specific SSI input response spectra were developed: one with the control motion defined at the bottom of the FWSC foundation mat (Elevation 282 ft.), and the other with the control motion defined at the elevation corresponding to the bottom of concrete fill (Elevation 220 ft.) supporting the FWSC foundation mat. The final FWSC SSI input response spectra at the Elevation 282 ft. are shown in the FSAR Figures 3.7.1-232 through 3.7.1-234, and those at the Elevation 220 ft. are shown in the FSAR Figures 3.7.1-283 through 3.7.1-285.

The applicant used the performance-based methodology as described in the FSAR Sections 2.5.2.5 and 2.5.2.6 in developing the GMRS, FIRS, and PBSRS following the guidance in RG 1.208. The applicant first developed the GMRS, FIRS, and PBSRS for the horizontal component of the motions. In accordance with the guidance in NUREG/CR-6728, Appendix J the applicant used the frequency dependent vertical-to-horizontal (V/H) response spectral ratios appropriate for the North Anna 3 site to obtain the corresponding vertical GMRS, FIRS, and PBSRS from the horizontal spectra.

For the RB/FB and CB, the applicant developed site-specific SSI input response spectra from the corresponding FIRS and PBSRS using the method described in Section 5.2.1 of DC/COL-ISG-017 to ensure hazard-consistent seismic inputs for the deterministic site-specific SSI analyses. For the FWSC, the applicant used the envelope of the results of the two SSI analyses – one with the SSI input response spectra applied at the bottom of the FWSC foundation mat (Elevation 282 ft.) and the other input response spectra applied at the bottom of the concrete fill (Elevation 220 ft.) – to ensure adequate consideration of the hazard-consistent SSI input for the deterministic SSI analyses.

Development of the SSI input response spectra consists of establishing the three strain compatible deterministic soil profiles for the SSI analyses, adjusting the FIRS to ensure that these three soil profiles will result in PBSRS being bounded by the envelope of the FIRS propagating to the ground surface, and verifying that the seismic input meets the minimum requirement of 10 CFR Part 50, Appendix S. The staff found the applicant's process of developing the SSI input response spectra for the Seismic Category I structures acceptable, because the method and procedure used are consistent with the guidance in DC/COL-ISG-017 and SRP 3,7.1.II.4.A. For the FWSC, the staff found the use of one set of input control motion defined at the bottom of the FWSC foundation mat and one set at the bottom of the concrete fill to be acceptable as discussed in this SER below under *"SSI Input Response Spectra for the FWSC*".

Details of the staff's evaluation of the development of the SSI strain compatible soil profiles, SSI input response spectra from the FIRS, and the applicant's method of satisfying the minimum design ground motion requirements of 10 CFR Part 50, Appendix S are discussed as follows in this SER.

SSI Strain Compatible Soil Properties

In accordance with DC/COL-ISG-017, the applicant developed from the in-situ soil profiles three deterministic strain compatible soil profiles for the SSI analyses as follows: Best Estimate (BE), Lower Bound (LB), and Upper Bound (UB). These soil profiles were used by the applicant to adjust the FIRS to ensure that the PBSRS is bounded by the envelope of the FIRS propagating to the ground surface, as well as to account for potential effects of the variation of the soil parameters on the site-specific SSI analyses. FSAR Section 3.7.1.1.4.1 describes the methodology used by the applicant to develop these profiles. The methodology follows the guidance in RG 1.208, SRP Acceptance Criterion 3.7.2.II.4, and DC/COL-ISG-17. The methodology is based on the statistics of the strain-iterated soil properties obtained from the probabilistic site response analyses using the randomized full soil column profiles as described in FSAR Sections 2.5.2.5 and 3.7.1.1.4.1. In addition in response to staff RAI 03.07.01-8, dated

February 23, 2015 (ADAMS Accession No. ML15056A047), the applicant addressed the following:

- From the probabilistic full column site response analyses of the soil columns described in FSAR 2.5.2.5, a set of 60 strain-compatible soil properties is obtained for each of the 4 input rock cases of 10^{-4} and 10^{-5} annual-frequency-of-exceedance level of low frequency (LF) and high frequency (HF) seismic events. The mean and standard deviation for each of the 4 sets of shear wave velocity (Vs) and damping ratios are calculated. These values are used to establish the mean and standard deviation of the strain compatible soil properties that are consistent with the FIRS motions.

- The UB and LB values of the soil parameters (shear wave velocity and damping ratios) are calculated as ± one log-standard deviation from the log-mean values. Maximum strain compatible damping ratios were below 15 percent in all cases and are thus consistent with SRP Acceptance Criterion 3.7.2.II.4.

- The UB and LB shear wave velocity profiles were adjusted where necessary to satisfy the minimum variation criteria of SRP 3.7.2. According to this criteria, LB shear wave velocity profiles should be less than or equal to (V_S) / ($\sqrt{1.5}$) and the UB shear wave velocity profile should be greater than or equal to (V_S) x ($\sqrt{1.5}$) where V_S is the BE strain compatible shear wave velocity corresponding to the FIRS level of motion. This approach is consistent with the guidance in SRP Acceptance Criterion 3.7.2.II.4 for a site with well investigated subsurface material properties.

- The compression wave velocity profiles were based on the corresponding shear wave velocity profiles and the site-specific Poisson's ratios identified in FSAR Table 2.5.4-208. In the layers below water table, a minimum Primary wave (P-wave) was first set to a velocity of 4800 ft/sec. The Poisson's ratio is adjusted to obtain the minimum P-wave velocity. The maximum value of Poisson's ratio used is 0.48. In the layers of bedrock below the groundwater table, the compression wave velocities exceeded 4800 ft./sec in all cases and no adjustment was necessary.

FSAR Tables 3.7.1-201, 3.7.1-203, and 3.7.1-205 present the values of strain compatible in-situ subsurface material properties used for fully embedded site-specific SSI analyses for the RB/FB, CB, and FWSC, respectively. The top 7 layers (17 ft.) of the RB/FB profile corresponding to saprolite are removed in the partially embedded SSI analysis of the RB/FB. The top 10 layers (25 ft.) of the CB profile representing the saprolite are removed in the partially embedded SSI analysis of the CB. In these tables, a combination of the lower shear wave velocity and P-wave velocity along with the higher damping values constitute the LB profile. Similarly, the higher shear and P-wave velocities along with the lower damping values constitute the UB profile.

FSAR Tables 3.7.1-202, 3.7.1-204, and 3.7.1-206 present the UB, BE, and LB shear wave velocity, P-wave velocity, and the damping values for the structural fill and concrete fill materials for the RB/FB, CB, and FWSC, respectively. The concrete fill is considered as linear elastic material for the purpose of SSI analyses. These strain compatible (i.e., compatible with the FIRS) fill material properties were also calculated following the same methodology discussed above for the in-situ soil profile. The strain-compatible structural fill and concrete fill materials are used for the near-field finite elements as part of the structural models.

The staff finds the above approach for developing the strain compatible soil properties for the in-situ material, structural backfill material, and the concrete fill material acceptable because these were developed using the guidance in SRP Acceptance Criterion 3.7.2.II.4 and DC/COL-ISG-17.

SSI Input Response Spectra for the RB/FB and CB

- *Nuclear Energy Institute (NEI) Check[2] per DC/COL-ISG-017*

As discussed in FSAR Sections 3.7.1.1.4.2.1 and 3.7.1.1.4.2.2, the site-specific SSI input response spectra are calculated for SSI analyses of the RB/FB and CB structure as fully embedded structure and as partially embedded (i.e., only considering embedment in the rock) structure. FSAR Section 2.5.2.6 described the development of full column and partial column FIRS and the corresponding PBSRS. The corresponding full column FIRS and partial column FIRS for RB/FB are shown in FSAR Figures 2.5.2-307 and 2.5.2-309 and for the CB in FSAR Figures 2.5.2-308 and 2.5.2-310. The corresponding full column PBSRS are shown in FSAR Figure 2.5.2-311. The partial column PBSRS are included in FSAR Figures 3.7.1-216 and 3.7.1-217 for the RB/FB and in FSAR Figures 3.7.1-227 and 3.7.1-228 for the CB.

The applicant used the method described in Section 5.2.1 of DC/COL-ISG-017 to adjust the FIRS to yield SSI input response spectra for the RB/FB and the CB. FSAR Figures 3.7.1-212 and 3.7.1-213 present the envelope of the ground surface response spectra obtained from the horizontal and vertical full column FIRS propagated to the ground surface through the LB, BE, and UB profiles for the RB/FB. Also presented in FSAR Figures 3.7.1-212 and 3.7.1-213 are the corresponding PBSRS and FIRS. As shown from the Figures 3.7.1-212 and 3.7.1-213, the envelope of the LB, BE, and UB ground surface response spectra does not bound the PBSRS at all frequencies. For this reason, the applicant used an adjustment factor to modify the FIRS to develop the SSI input response spectra. The frequency dependent adjustment factor is either unity where the PBSRS is bounded or the ratio of the PBSRS to the envelope of LB, BE, and UB surface response spectra. This conservative bounding adjustment factor is then applied to the corresponding FIRS to obtain the SSI input response spectra.

The applicant also used the same method described in Section 5.2.1 of DC/COL-ISG-017 for developing the input spectra for the partially embedded case for the RB/FB and for the fully embedded and partially embedded cases for the CB. For the RB/FB, the FSAR Figures 3.7.1-212 and 3.7.1-213 include the SSI input response spectra for the full column case and Figures 3.7.1-216 and 3.7.1-217 for the partial column case. For the CB, Figures 3.7.1-223 and 3.7.1-224 show the SSI input response spectra for the fully embedded case and Figures 3.7.1-227 and 3.7.1-228 show those for the partially embedded cases.

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[2] The NEI New Reactor Seismic Issues Resolution Program undertook several studies producing industry white papers. The guidelines developed in ISG-01, the NEI white paper, and the development of the criteria associated with this ISG result from the coordination of the industry initiative, U.S. Nuclear Regulatory Commission (NRC) studies, and other stakeholder inputs through interactions in public meetings. In particular, the meeting of September 25–26, 2008, was instrumental in establishing a framework of common understanding (see meeting summary, ADAMS Accession No. ML082950476)

The applicant performed the above NEI check based on the random vibration theory (RVT) method, which did not use the synthetic acceleration time histories. To confirm whether the envelope of the response spectra of the spectrally matched design acceleration time histories also envelops the PBSRS at the ground surface, the applicant, as discussed in the FSAR Sections 3.7.1.1.5.1.1 and 3.7.1.1.5.1.2, performed additional comparisons of the envelope of the response spectra of the spectrally matched design acceleration time histories to the PBSRS for RB/FB and CB respectively. These comparisons in FSAR Figures 3.7.1-295 through 3.7.1-306 show that, except at a few locations, the enveloped response spectra at the surface exceeds the PBSRS. In a few instances as discussed below, the raw envelopes of response spectra of the acceleration time histories at the ground surface for the LB, BE, and UB soil cases were below the PBSRS for some frequencies.

For the instances in the horizontal direction, the dips were generally small and occurred in very narrow frequency ranges. These dips correlate to the dips shown on the spectrally matched response spectra, which are still consistent with the SRP 3.7.1 guidance. However, since the structural demands were calculated using the design time histories (not directly using the FIRS) in the SSI analysis, the staff requested during Audit 1 (ADAMS Accession No. ML16064A271) that the applicant assess the effect of these dips on the structural response. The applicant performed a sensitivity study as referenced in the North Anna 3 FSAR Section 3.7.1.1.5.1.1, using the time history for the CB partial column in the horizontal (H1) direction, and the staff also confirmed the results during the North Anna 3 Audit 1. This time history was modified slightly so that its response spectrum was above the final SSI input response spectra around the affected frequency. The in-structure response spectra (ISRS) calculated using this modified time history did not show significant changes over the ISRS calculated using the original time history and those changes did not affect the enveloped and broadened ISRS used in the design. Therefore based on this sensitivity study, the staff concluded that the small dips which occurred in a very narrow frequency range in the raw envelop do not affect the broadened ISRS in the horizontal direction and thus, found the NEI check in the horizontal direction acceptable.

For the instance of RB/FB fully embedded condition in the vertical direction (FSAR Figure 3.7.1-297), where the enveloped response spectrum falls below the PBSRS between 16.6 Hz and 20.4 Hz, the applicant explained during Audit 1 and also in the FSAR Section 3.7.1.1.5.1.1 that the RB/FB structural response transfer functions relative to the outcrop SSI input motion show this dip is outside of the structural frequencies of the RB/FB in the vertical direction so its effect on structural response is negligible. The staff found this justification acceptable because, as also reflected in the FSAR, the vertical input motion to the structure and the load transfer from the building primarily occur at the mat foundation and the surrounding rock interface and consequently the effects of vertical ground motion near the ground surface are insignificant for structural responses in the vertical direction.

The applicant also indicated in the FSAR Section 3.7.1.1.5.1.1 that this dip reflects a difference in the method to calculate the vertical PBSRS (by applying the frequency-dependent V/H ratio) and the method to calculate the acceleration response (through P-wave propagation). In order to understand the effect of this difference, the staff reviewed the pertinent information in DC/COL-ISG-17, FSAR Section 3.7.1.1.5.1.1, and NUREG/CR-6728. The staff confirmed this information during the North Anna 3 Audit 1. The same frequency-dependent V/H ratio was used to obtain the vertical FIRS and PBSRS from the horizontal FIRS and PBSRS, respectively, regardless the difference in the elevations of FIRS (at foundation level) and PBSRS (at ground surface).In addition, the application of V/H ratios is independent of the vertical soil profiles (LB, BE, and UB) that are used to propagate the vertical FIRS up to the ground surface. Therefore, for comparison purposes in the vertical direction, the two methods may not be consistent. The staff also concluded that while the observed difference between the vertical PBSRS and the enveloped response spectra at the ground surface is possible, the effects of these dips on the structural response are considered insignificant since: (1) FSAR Figures 3.7.1-295 through 3.7.1-306 show that, except at a few instances, the enveloped response spectra at surface exceed the PBSRS (for some cases by large margins) and (2) the seismic load transfer in the vertical direction primarily occurs at the foundation-rock interface and not at the free ground surface. For this reason, the staff found the NEI check for the SSI input spectra for the RB/FB and CB to be acceptable.

- *Meeting the Minimum Requirement of 10 CFR Part 50 Appendix S*

10 CFR Part 50, Appendix S, requires that the horizontal component of the SSE ground motion in the free-field at the foundation levels of structures must be an appropriate response spectrum with a PGA of at least 0.1 g. In FSAR Section 3.7.1.1.4.2.1, the applicant described how the final SSI input response spectra were developed from the performance-based input response spectra to meet the minimum requirement of 10 CFR Part 50 Appendix S. The applicant stated that for the full soil column analyses, the final SSI input response spectra are determined by enveloping the full column SSI input response spectra and the minimum required response spectra defined in RG 1.60 anchored at 0.1 g. Similarly, for the partial soil column analyses the final SSI input response spectra are determined by enveloping the partial column SSI input response spectra and the minimum required response spectra defined in RG 1.60 anchored at 0.1 g. The development of final horizontal and vertical SSI input response spectra for RB/FB is shown in FSAR Figures 3.7.1-218 and 3.7.1-219 and for the CB in Figures 3.7.1-229 and 3.7.1-230.

The staff reviewed the results, and notes that the initially adjusted FIRS as discussed above under "*NEI Check"* were further enhanced to ensure that the final input spectra envelop the RG 1.60 spectrum anchored at 0.1 g. For this reason, the staff concluded that the final SSI input response spectra meet the 10 CFR Part 50, Appendix S minimum horizontal ground motion requirement at the foundation level.

The staff found the applicant's final SSI input response spectra for the RB/FB and the CB SSI analyses acceptable because: (a) the method and the procedure used are consistent with the guidance in DC/COL-ISG-017 and SRP 3.7, (b) the envelope of the surface response spectra based on the three deterministic soil columns bounds the corresponding PBSRS for the two embedment configurations (i.e., fully embedded and partially embedded) with a few minor exceptions that were determined to be insignificant to structural responses, and (c) the final SSI input spectra meet 10 CFR Part 50, Appendix S minimum 0.1 g horizontal ground motion requirement.

SSI Input Response Spectra for the FWSC

In the initial submittal of FSAR Section 3.7.2, the site specific SSI analyses considered the FWSC as a surface founded structure at Elevation 282 ft. The control motion used in the SSI analysis was applied at the bottom of the basemat and not at the bottom of the concrete fill at Elevation 220 ft. The applicant did not need to use the methodology in Section 5.2.1 of

DC/COL-ISG-017 for ensuring that the SSI input spectra specified at Elevation 282 ft would envelop the PBSRS because FWSC is considered as surface-founded.

The staff, however, noted that the concrete fill below the FWSC basemat was represented as an integral part of the structural model used in the SSI analyses. Staff notes that, from the point of view of the SSI analysis, the combined FWSC-concrete fill is similar to an embedded structure and as such, the control motion for SSI analysis could also be defined at the bottom of the concrete fill. In addition, the control motion specified at the foundation level (Elevation 282 ft.) may include the effect of potential de-amplification of the high frequency content of the earthquake motion through the in-situ soil material. For this reason, the staff in RAI 03.07.01-11**,** requested the applicant to provide the technical justification for defining the control motion used in the SSI analysis at the bottom of the basemat and not at the bottom of the concrete fill.

In the response to RAI 03.07.01-11 (ADAMS Accession No. ML15056A047), the applicant supplemented the FSAR Section 3.7.1.1.4.2.3 to include a new control motion at the bottom of concrete fill (Elevation 220 ft.). The applicant used two sets of site-specific SSI input response spectra defined at the bottom of the FWSC basemat (Elevation 282 ft) and at the bottom of the concrete fill (Elevation 220 ft). The FIRS corresponding to the control motion applied at the bottom of the FWSC basemat (Elevation 282 ft) represent the PBSRS for the FWSC soil column as shown in FSAR Figure 2.5.2-312. The final SSI input response spectra at Elevation 282 for FWSC are the envelope of the FIRS for FWSC and the RG 1.60 spectra anchored at 0.1 g to meet the minimum requirement of 10 CFR Part 50, Appendix S. Similarly, the final SSI input response spectra at Elevation 220 ft. are the envelope of the design response spectra (DRS) at Elevation 220 ft. for FWSC and the RG 1.60 spectra anchored at 0.1 g to meet the minimum requirement of 10 CFR Part 50, Appendix S. The applicant calculated the DRS at Elevation 220 ft. using the same method as described in FSAR Section 2.5.2.5 and 2.5.2.6. The final SSI input response spectra at Elevation 282 ft. and at Elevation 220 ft. are respectively presented in FSAR Figures 3.7.1-232 through 3.7.1-234 and in Figures 3.7.1-283 through 3.7.1-285.

The staff reviewed the information provided in the FSAR and found the applicant's final SSI input response spectra for the FWSC SSI analyses acceptable because: (a) the applicant in addition to using the guidance in DC/COL-ISG-017 to apply SSI input response spectra at the foundation level of the FWSC, used another set of site-specific SSI input response spectra applied at the bottom of the concrete fill; (b) the results of the two sets of SSI analyses are enveloped to develop the site-specific seismic demand of the FWSC and as such, the analyses bound any potential effect of de-amplification resulting from a single input analysis with the control motion applied only at the foundation level; and (c) the final input spectra meet the 10 CFR Part 50, Appendix S minimum 0.1 g horizontal ground motion requirement.

Consideration of Backfill Material in RB/FB and CB SSI Analyses

FSAR Section 3.7.1.1.4 indicates that the in-situ saprolite is replaced by structural fill and Zone III rock is replaced by concrete fill. As discussed earlier in this SER the applicant has also developed the engineering properties of the granular fill and concrete fill. However, the applicant did not consider the backfill material (granular structural fill and concrete fill) in developing the FIRS and PBSRS. The staff therefore requested the applicant in RAI 03.07.01-7 to provide a technical basis for computing the FIRS and PBSRS which only considers the in-situ soil/rock columns and not the backfill material that would exist surrounding the Seismic Category I structures.

In the response to RAI 03.07.01-7 (ADAMS Accession No. ML15056A047), the applicant stated that the backfill material that is placed below and around the Seismic Category I structures is limited in extent. In order to capture the effects of the limited extent of the backfill material on the response of the RB/FB and CB, the dynamic models for the seismic response analyses use near-field elements as part of the SSI structural model representing the dynamic properties of concrete and structural fill materials. LB, BE, and UB dynamic properties of the structural fill materials compatible to strain generated by the design ground motion are developed from the results of the site response analyses as discussed in the FSAR Section 3.7.1.1.4.1. The dynamic properties used for the concrete fill are linear and independent of the strain. The site-specific seismic demand is obtained from the envelope of responses from the SSI analyses of two different embedment configurations: partial column and full column subgrade profiles representing dynamic properties of the far-field in-situ subgrade materials. The applicant used the minimum value of lateral extent of backfill for the RB/FB SSI model as one-half of the distance between the RB/FB and the adjacent Turbine Building (TB) and for the CB SSI model as one-half of the distance between the CB and the adjacent Service Building (SB). The partial and full embedment configurations bound the effect of subgrade stiffness variations related to the lateral extent of the backfill (partial columns also account for the effects of soil separation) and groundwater table variations. The partial column models provide a lower bound stiffness representation whereas the full column models represent the upper bound subgrade stiffness.

The staff reviewed the response and found the response acceptable for the RB/FB and the CB because (a) the effect of the subgrade stiffness variations on the seismic demand due to consideration of limited lateral extent of the backfill material in the SSI model is bounded by the two embedment configurations used in the SSI analyses; and (b) use of the minimum value of the lateral extent of the backfill material in the full column model which conservatively maximizes the subgrade lateral stiffness and minimizes the subgrade damping values.

Consideration of Backfill Material in FWSC SSI Analyses

The applicant in the response to RAI 03.07.01-7 (ADAMS Accession No. ML15056A047) indicated that in the structural part of the SSI model, the concrete fill placed below the FWSC foundation basemat (down to the top of the Zone III/IV rock) was modeled as solid finite elements. While the in-situ soil surrounding the concrete fill was modeled in the SSI analyses of the FWSC, the model did not include the near field structural backfill material surrounding the concrete fill. The applicant justified the backfill material not being explicitly modeled on the basis that the differences between the dynamic properties of the structural backfill and the in-situ soil are small and are not expected to significantly affect the response. This is also because the FWSC is founded on concrete fill which is supported by the in-situ rock material.

The staff reviewed the comparison of the dynamic properties of the structural fill and in-situ material for the FWSC provided in the response to RAI 03.07.01-7. However based on the information provided, the staff could not determine conclusively the potential effect on the SSI response of not including the backfill material as part of FWSC structural model. The applicant subsequently performed additional SSI analyses considering soil separation from the concrete fill, which effectively represent the cases of the lower bound of the structural fill effect. The depths of the soil separation were estimated from static and dynamic lateral soil pressures and are in the range of 4.75 m to 8.83 m, which are close to the range of the partial embedment for RB/FB and CB. The depths of the soil separation are also close to 6 m as per the ASCE 4-98 soil separation guidance. These analyses found some exceedances in structural demands and ISRS, and these exceedances are appropriately considered in the applicant's design evaluation of the ESBWR standard design for the North Anna 3 site. More detailed evaluation of exceedance consideration is provided in this SER in Section 3.7.2. The staff also performed a confirmatory analysis of the FWSC SSI model and confirmed the applicant's conclusions. A summary of this confirmatory analysis is provided in this SER in Section 3.7.2. As discussed in that Section of this SER, the staff found the applicant's analyses and conclusions acceptable because the effect of the structural fill is adequately considered.

Supplemental Information

- NAPS SUP 3.7-2 Site Specific Design Ground Motion Time History

Site-Specific Design Ground Motion Time History

In the North Anna 3 FSAR Section 3.7.1.1.5, the applicant describes that for each set of horizontal and vertical final SSI input response spectra presented in FSAR Section 3.7.1.1.4.2, a set of three spectrally matched acceleration time histories (two horizontal and one vertical component) were generated. The seed time histories used are those of the 1984 M6.2 Morgan Hill earthquake recorded at the station Gilroy–Gavilan College chosen from the CEUS database of acceleration time histories in NUREG/CR–6728. FSAR Section 3.7.1.1.5.1.1 describes the selection process of the seed time histories and the methodology to develop the spectrally matched time histories.

One set for each elevation of three statistically independent acceleration time histories of motions (i.e., two horizontal and one vertical component) are developed for each of the full column and partial column final SSI input response spectra for the RB/FB and the CB, respectively. For the FWSC, one set of three statistically independent acceleration time histories of motions (i.e., two horizontal and one vertical component) are developed for the final SSI input response spectra applied at each of the foundation level of the FWSC and at the bottom of the concrete fill below the FWSC.

The applicant used SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 2 in developing the time histories. FSAR Figures 3.7.1-235 through 3.7.1-240 provide comparison between the response spectra of the spectrally matched time histories with the target response spectra and the lower and upper target spectra band (90% and 130% of the target response spectra). The staff reviewed these comparisons. The comparison indicates that while the response spectra for the time histories are within 90 percent to 130 percent of the target spectra for the frequency range between 0.2 and 100 Hz, under-predictions were observed approximately below a frequency of 0.2 Hz. As such in RAI 03.07.01-12, the staff requested the applicant to provide numerical results of the spectral matching checks specified in SRP 3.7.1 acceptance criteria II.1.B.ii (Option 1, Approach 2) and provide a technical justification for the under predictions below 0.2 Hz. The staff also requested the applicant to provide power spectral density (PSD) functions of the time histories to verify that there are no significant gaps in the frequency content of the acceleration time histories.

The staff reviewed the applicant's response to RAI 03.07.01-12 (ADAMS Accession No. ML15056A047) and verified the following aspects of the spectrally matched time histories as discussed below:

- The cross-correlation coefficients between the three components are less than 0.16, as listed in FSAR Tables 3.7.1-210, 3.7.1-212, 3.7.1-214, and 3.7.1-218 which indicates statistical independence.

- The strong motion durations as defined in SRP Acceptance Criterion 3.7.1.II.1.B as listed in FSAR Table 3.7.1-211, 3.7.1-213, 3.7.1-215, and 3.7.1-219 are longer than the minimum value of 6 seconds.

- The time step of the time histories is 0.005 s, which corresponds to an acceptable Nyquist frequency of 100 Hz. The duration of the time histories is 30 s, which is greater than the 20 s criterion.

- The 5-percent damped response spectra of the time histories were compared with the target spectra in FSAR Figures 3.7.1-235 through 3.7.1-240 for RB/FB, 3.7.1-247 through 3.7.1-252 for the CB, 3.7.1-259 through 3.7.1-261 for FWSC at Elevation 282 ft, and 3.7.1-286 through 3.7.1-288 for FWSC at Elevation 220 ft. The comparison indicates that the response spectra for the time histories are within 90 percent to 130 percent of the target spectra for the frequency range between 0.2 and 100 Hz.

Based on the above review the staff finds that the cross-correlation coefficients, time step, and the duration of the strong motion portion of the time histories meet the guidance in the SRP 3.7.1 and thus are acceptable.

Concerning the under-prediction below 0.2 Hz, the applicant identified the sloshing of the water in the Gravity Driven Cooling System Pool and the Isolation Condenser/Passive Containment Cooling Expansion Pools located in the RB/FB are the only responses characterized by frequencies lower than the 0.2 Hz. No other SSCs fall in the frequency range below 0.2 Hz. The applicant also indicated that below the frequency of 0.2 Hz, CSDRS bounds the target spectrum and as such any potential under prediction of the response from site-specific analyses will be bounded by the ESBWR standard plant design. The applicant also indicated that seismic-induced hydrodynamic pressures on the pools associated with convective (sloshing) and impulsive (rigid) modes will be taken to be the larger of the standard design pressures or the North Anna 3 site-specific pressures.

The staff reviewed the Figures 1 through 6 provided in the response to RAI 03.07.01-12 and determined that significant margin exists between the CSDRS and the site specific target spectrum for RB/FB in the frequency range below 0.2 Hz. Therefore, the staff concludes that the use of time histories which are matched to the site-specific target spectrum in the frequency range between

0.2 Hz to 100 Hz and are under-predicted below the target spectrum at frequencies less than 0.2 Hz is acceptable because (a) at the North Anna 3 site the target response spectra (i.e., final SSI input spectra) is bounded by the CSDRS by a significant margin in the low frequency range and as such (b) seismic-induced hydrodynamic load demands for the Gravity Driven Cooling System Pool and the Isolation Condenser/Passive Containment Cooling Expansion Pools will be bounded by the ESBWR standard plant design envelopes.

The applicant in the FSAR Section 3.7.1.1.5.1.1 described that the characteristics values, i.e., PGV/PGA and PGA*PGD/PGV^2 ratios for the matched time histories, do not fall within the bin values reported in NUREG/CR-6728. The PGA, PGV, and PGD refer to the peak ground acceleration, peak ground velocity, and peak ground displacement, respectively. Since the target spectra used in the spectral matching procedure is a composite of both the high frequency and low frequency earthquakes, the applicant concludes that this difference is acceptable because the time histories are spectrally matched to the final SSI input response spectra, which represent a combination of hazards from both large, distant earthquakes and smaller, closer earthquakes.

The staff further reviewed FSAR Tables 3.7.1-211, 3.7.1-213, 3.7.1-215, 3.7.1-219, and 3.7.1-220, which provided the characteristic values of the matched time histories and the corresponding bin values of the selected seed time histories reported in NUREG/CR-6728. The comparison of the PGV/PGA values of the seed earthquake and the design time histories shows that the design time histories have higher energy content (a greater maximum velocity) and are therefore conservative. The staff further determined that the design input time histories have higher energy content than the FIRS and 0.1 g RG 1.60 spectra. On this basis, the staff found the peak ground motion parameter values associated with the design time histories acceptable.

In response to RAI 03.07.01-12, the applicant performed additional verifications to demonstrate that there are no significant gaps in power for the spectrally matched time histories. To do this, power spectral densities (PSDs) were calculated for the frequency range of 0.3 to 50 Hz. The PSD plots for the suite of 18 time histories are shown in FSAR Figures 3.7.1-268 through 3.7.1-282 and 3.7.1-292 through 3.7.1-294. The applicant concludes that the PSD functions do not show any significant dip in the frequency content of the input time histories. However, this conclusion was drawn without performing comparison of the estimated PSD functions with some properly developed target PSD. To gain additional confidence on the power adequacy of the time histories, the staff conducted a confirmatory analysis of the 18 time histories by comparing their estimated PSD functions with the target PSDs developed to be compatible with the final SSI input response spectra. Some estimated PSD functions were found to have dips below the 70% target PSDs; however, those dips were determined to not significantly affect structural response because they occur outside of the fundamental frequencies of the SSI models. Based on the results of the staff confirmatory analysis, the staff concluded that the spectrally matched time histories are acceptable.

As described in the FSAR Section 3.7.2.4.1.2, based on the method described in DC/COL-ISG-017, the applicant developed in-column motions at the foundation levels of the RB/FB and the CB, and at the bottom of the concrete fill under the FWSC foundation. The in-column motions were developed from the time histories that were spectrally matched to the final SSI input response spectra defined as free-field outcrop response spectra at the foundation levels for the RB/FB and the CB and at the bottom of the concrete fill under the FWSC foundation. In addition, the deterministic SSI strain compatible subsurface profiles (BE, LB, and UB) as discussed before in this SER were used in developing the in-column motions. These in-column motions were used as inputs into the North Anna 3 site-specific SSI analyses described in FSAR Section 3.7.2. This approach is acceptable to the staff because it is consistent with the method described in DC/COL-ISG-17.

Site-Dependent SSE Manifestation At-Grade and OBE Response Spectra

The applicant in the FSAR Section 3.7.1.1.6 established site-dependent SSE manifestation at grade as the envelope of the following two spectra:

1. PBSRS calculated at grade (Elevation 290 ft) from full soil column analyses for RB/FB and CB and,

2. The minimum required response spectra defined as the RG 1.60 broadband horizontal and vertical response spectra at 5 percent damping anchored to 0.1 g.

The site-dependent OBE at grade is defined as one-third of the site-dependent SSE manifestation at grade. The site-dependent SSE manifestation and OBE spectra at grade are shown in the FSAR Figure 3.7.1-267. The staff found the site-dependent SSE manifestation and OBE established at the grade level to be acceptable since (a) they were derived from the PBSRS which is developed following the guidance in RG 1.208 and (b) they meet the requirement of 10 CFR Part 50 Appendix S.

Supplemental Information

- NAPS SUP 3.7-3 Supporting Media for seismic Category I Structures

Supporting Media for Seismic Category I Structures

The applicant stated that the Seismic Category I structures for North Anna 3 have concrete mat foundations founded on rock or concrete fill placed on top of rock. FSAR Section 2.5.4.2 describes the static and dynamic engineering properties of the subsurface material at the North Anna 3 site. The dynamic properties used in the SSI analyses are discussed in FSAR Section 3.7.1.1.4.1. The minimum shear wave velocity of the supporting foundation material is greater than 1000 ft/sec. The staff determined that this information together with the ESBWR standard plant structural data in the ESBWR DCD, Revision 10, is sufficient per SRP Acceptance Criterion 3.7.1.II.3. The applicant has considered the potential variability of the properties of the subsurface material in the SSI analyses. The staff's review of this information is discussed above in this SER under "*SSI Strain Compatible Soil Properties.*" The staff's evaluation of the site-specific seismic analysis of the Seismic Category I structures using the site characteristics described in FSAR Section 3.7.1.1.4.1 is discussed in Section 3.7.2 of this SER.

3.7.1.5 Post Combined License Activities

There are no post COL activities related to this section.

3.7.1.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC 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 North Anna 3 FSAR related to this section. All nuclear safety issues relating to the seismic design parameters that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.1 of NUREG–0800, other NRC RGs, and the Interim Staff Guidance. The staff finds that the applicant has addressed seismic design parameters in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.7.1.3 of this SER.

3.7.2 Seismic System Analysis

3.7.2.1 Introduction

This section addresses the seismic analysis methods and acceptance criteria used for the ESBWR seismic Category I structures. Seismic Category I structures are designed to withstand the effects of the SSE event and to maintain the specified design functions. This section applies to building structures that constitute primary structural systems. The reactor pressure vessel (RPV) is not a primary structural component, but it is considered as part of the RB/FB model for the purpose of dynamic analysis because of its dynamic interaction with the supporting structure. Non-seismic Category I structures (seismic Category II and nonseismic) are designed or physically arranged (or both) to prevent the SSE from causing unacceptable structural interactions with or the failure of seismic Category I SSCs. The ESBWR method for a standard plant seismic analysis of the Category I structures is in Section 3.7.2 of ESBWR DCD, Tier 2, Revision 10.

3.7.2.2 Summary of Application

Section 3.7.2 and Appendices 3A and 3C of the North Anna 3 COL FSAR, Revision 9, incorporate by reference Section 3.7.2 and Appendices 3A and 3C of ESBWR DCD, Revision 10. In addition, in FSAR Section 3.7.2 and Appendices 3A and 3C, the applicant provides the following departure and supplemental information:

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

In North Anna 3 FSAR Section 3.7.2.2, the applicant described that the natural frequencies of the ESBWR standard plant structures and SSI analyses to develop the seismic demand for the seismic design of the ESBWR standard plant are presented in DCD Appendix 3A Sections 3A.1 through 3A.9. The site-specific SSI analyses used to develop the site-specific seismic demand for the RB/FB, CB, and FWSC are presented in FSAR Sections 3.7.2.4 and 3A.10 through 3A.19. In FSAR Sections 3C.7.4, 3C.7.6, and 3C.7.7, the applicant describes, respectively, the computer codes SASSI2010, ACS SASSI, and SHAKE2000 used for the North Anna 3 site-specific SSI analysis. The staff reviewed the SSI analyses and the computer programs used in the site-specific analyses as part of its review of FSAR Section 3.7.2.4. The site-specific SSI analysis considers the North Anna 3 site conditions and follows an approach that is consistent with those used for the standard design. The structural models used for the site-specific SSI analyses have the same configuration, stiffness, and the inertia properties as the standard design basis structural models presented in DCD Appendix 3A.

As discussed earlier in this SER, the site-specific horizontal and vertical seismic response spectra as shown in North Anna 3 COL FSAR Figures 2.0-201 through 2.0-204 exceed the ESBWR CSDRS at certain frequencies. As a result, the applicant has performed site-specific SSI analyses of the RB/FB, CB, and FWSC structures using input ground motion defined by the site-specific FIRS and strain compatible soil properties to establish the site-specific seismic demand. The resulting site-specific seismic demand (e.g., accelerations, enveloping structural loads, and in-structure response spectra) is used to demonstrate the applicability of the seismic design of the ESBWR standard design for the North Anna 3 site conditions. This departure is also applicable to the FSAR Section 3.7.2.8 wherein the applicant addressed site-specific seismic considerations for all non-seismic Category I structures that are within the scope of the standard design.

Supplemental Information

- NAPS SUP 3.7-5 — Interaction of Non-Category I Structures with Seismic Category I Structures

The applicant stated that the locations of structures around the North Anna 3 power block area are depicted in the plant layout provided in FSAR Figure 2.1-201 and DCD Figure 1.1-1. In FSAR Section 3.7.2.8, the applicant addresses the requirements for site-specific SSI and seismic structure-soil-structure interaction (SSSI) analyses of non-seismic Category I structures both within and outside the scope of the DCD and including the TB, SB, ADB, and RWB.

- NAPS SUP 3.7-8 — Interaction of Non-Category I Structures with Seismic Category I Structures – Radwaste Building

In FSAR Section 3.7.2.8.2, the applicant describes that the RWB exterior walls have a static wall pressure capacity of at least 3 psi. For the RWB, a pressure capacity of 3 psi for the external walls is required to ensure that the safe separation distance of the RWB from the liquid hydrogen storage tanks is maintained.

3.7.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic system analysis, and the associated acceptance criteria, are in Section 3.7.2 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the seismic design basis to reflect appropriate consideration of the most severe earthquakes historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated. In addition, SSCs important to safety should be designed to withstand the effects of earthquakes without losing the capability to perform their intended safety functions.

- 10 CFR Part 50, Appendix S, as it relates to the horizontal component of the SSE ground motion in the free-field at the foundation level of the structures to be an appropriate response spectrum with a peak ground acceleration of at least 0.1 g; and if the OBE is chosen to be less than or equal to one-third of the SSE ground motion, it is not necessary to conduct explicit response or design analyses in accordance with Section IV.(2)(i)(A) of 10 CFR Part 50, Appendix S, and the requirement of taking into account SSI effects.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.2 include the following:

- SRP Section 3.7.2 guidance to review methods for site-specific seismic analysis and modeling of structures to ensure that they accurately and/or conservatively represent the behavior of SSCs during postulated seismic events.

- DC/COL-ISG-1, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion" and DC/COL-ISG-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses" in reviewing the seismic input and the SSI dynamic model acceptability for the North Anna 3 site.

- RG 1.61 to determine the acceptability of the damping values used in the structural model.

- RG 1.122 to determine acceptability of development of floor design response spectra for seismic design.

3.7.2.4 Technical Evaluation

As documented in NUREG –1966, NRC staff reviewed and approved Section 3.7.2 and Appendices 3A and 3C of the ESBWR DCD. The staff reviewed Section 3.7.2 and Appendices 3A and 3C of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this section. The staff reviewed the information in the COL FSAR as follows:

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to soil-structure interaction analyses included under FSAR Section 3.7.2, Appendix 3A, and 3C of the North Anna 3 COL FSAR as follows:

Natural Frequencies and responses

The applicant presented information on natural frequencies and SSI responses of seismic Category I buildings under the CSDRS and generic site conditions in DCD Sections 3A.1 through 3A.9, which are incorporated by reference in North Anna 3 COL FSAR. The SSI responses for site-specific conditions are provided in North Anna 3 COL FSAR Sections 3.7.2.4 and 3A.10 through 3A.19. The results of staff's evaluation of the site-specific SSI analyses are discussed below in this SER.

Soil-Structure Interaction (SSI)

The methodology and the results of the SSI analyses for the ESBWR standard plant seismic Category I buildings are presented in the DCD Section 3.7.2, Appendix 3A and Appendix 3C for a range of soil conditions selected for the ESBWR standard plant design. The CSDRS have been applied as the input ground motion at the building foundation level for the seismic design of the Category I structures included in the design certification document. The site-specific horizontal and vertical seismic response spectra as presented in North Anna 3 COL FSAR Figures 2.0-201 through 2.0-204 exhibit exceedances at certain frequencies, when compared to the ESBWR CSDRS. As a result of these exceedances, the applicant in accordance with the requirement of DCD Tier 1, Section 5.1 performed site-specific SSI analyses of the RB/FB, CB, and FWSC structures to establish the site-specific seismic demands. FSAR Section 3.7.2.4 and Sections 3A.10 through 3A.19 present the site-specific SSI analyses of the seismic Category I RB/FB, CB, and FWSC. The staff's evaluation of the site-specific SSI analyses is discussed below:

The staff used the guidance of SRP Section 3.7.2, DC/COL-ISG-1, and DC/COL-ISG-017 in reviewing the site-specific seismic analyses. The applicant used the standard design methodology presented in the DCD to perform the North Anna 3 site-specific SSI/SSSI analyses using the computer programs SASSI2010 and ACS SASSI. The coupled soil-structure models for the SSI analyses are based on the structural models developed from the standard design structural model coupled with site-specific strain compatible dynamic subsurface properties. Specifically, the staff reviewed the methods used in the site-specific seismic analysis to account for SSI and SSSI effects including the verification and validation (V&V) of the computer programs used in the site-specific analysis.

For the RB/FB and the CB, site-specific SSI analyses were performed for two different embedment configurations representing: (1) the RB/FB and CB as being partially embedded (PE) up to the Zone III rock nominal top elevation, and (2) the RB/FB and CB being fully embedded (FE) up to the finished grade elevation accounting for the site-specific SSI effects of the soil above the Zone III rock. In addition, for each embedment configuration, the applicant used BE, LB, and UB soil column profiles resulting in a total of six subgrade profiles to account for the effects of the potential variability in subgrade properties and the potential soil separation from the foundation walls during an SSE event at the North Anna 3 site. The base case site-specific SSI analyses used RB/FB and CB models with uncracked reinforced concrete properties for the concrete members and 100 percent in-fill concrete stiffness contribution considered for the concrete filled steel internal structures. The envelope of responses obtained from these six analyses represent the base case North Anna 3 site-specific seismic demand. The applicant used the DCD structural models for the RB/FB and CB analysis. The applicant has also performed site-specific sensitivity evaluations of the effects of structural stiffness variations and SSSI on the North Anna 3 site-specific demands. These analyses are documented in FSAR Sections 3.7.2.4, and 3A.10 through 3A.19, and in General Electric Hitachi (GEH) Reports WG3-U71-ERD-S-0001 Rev. 4, “Reactor/Fuel Building Complex Seismic Analysis Report,” (ADAMS Accession Nos. ML16097A203 and ML16097A204); and WG3-U73-ERD-S-0001 Rev. 2, “Control Building Seismic Analysis Report,” (ADAMS Accession Nos. ML15357A305, ML15357A312, and ML15357A313). The applicant has used the envelope of the base case analyses and the results of the sensitivity analyses for site-specific structural analysis and design evaluation of the ESBWR standard plant structures at North Anna 3 site.

For the SSI analysis of the FWSC, the applicant used two analyses configurations representing: (1) the FWSC as a surface founded structure with the input control motions applied at the bottom of the FWSC foundation (Elevation 282 ft), and (2) the FWSC together with the concrete fill below the FWSC foundation basemat as an embedded structure with the input control motions applied at the bottom of the concrete fill (Elevation 220-ft). The base case site-specific SSI analyses used FWSC model with uncracked reinforced concrete properties for the concrete members. The applicant used the DCD structural model for this analysis. The applicant has also performed site-specific sensitivity evaluations of the effects of structural stiffness variations and soil separation. The SSSI effect on the FWSC was included in the North Anna site-specific seismic demand. The staff’s evaluation of the two SSI inputs for the FWSC is presented earlier in this SER in Section 3.7.1.4 under heading, *“SSI Input Response Spectra for the FWSC.”* FWSC SSI analysis method and results are documented in FSAR Sections 3.7.2.4, and 3A.10 through 3A.19 and in GEH Reports WG3-U63-ERD-S-0001 Rev. 4, “Firewater Service Complex Seismic Analysis Report,” (ADAMS Accession No. ML16148A131).

The staff conducted two on-site seismic audits at the applicant’s contractor GEH office in Wilmington, North Carolina. In the first audit during the week of September 28, 2015 (hereinafter referred to as North Anna 3 Audit 1), the staff reviewed the North Anna 3 seismic demand evaluation including the supporting calculations (ADAMS Accession No. ML16064A271). In the second audit held during the week of March 21, 2016 (hereinafter referred to as North Anna 3 Audit 2), the staff reviewed the applicant’s evaluation of the structural design for North Anna 3 site specific seismic demand (ADAMS Accession No. ML16193A047). During North Anna 3 Audit 1, the staff also reviewed calculations pertaining to the V&V of the computer program used in the site-specific SSI and SSSI analyses. The staff’s evaluation of the computer program V&V documents are described later in this SER Section 3.7.2.4 under the heading of *“Verification and Validation of SASSI 2010 and ACS SASSI and Bench marking of the MSM.”*

Based on its review, the staff confirmed that the applicant addressed the site-specific effects of the SSSI between the ESBWR Seismic Category I structures on the site-specific seismic demand obtained from the SSI analysis. The staff reviewed the site-specific SSSI sensitivity evaluations between the RB/FB and CB as well as between the FWSC and CB. The site-specific SSSI evaluations are performed on combined models of the two buildings considering the presence of the structural and concrete fill materials in the interspace between the buildings. Site-specific evaluations of the effects of SSSI between the RB/FB and CB and between the FWSC and CB are documented respectively in GEH Reports, WG3-U73-ERD-S-0005 Rev. 3, “Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A271) and WG3-U73-ERD-S-0002 Rev. 6, “Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A270).

The various SSI and SSSI case analyses performed by the applicant are summarized in the FSAR Tables 3A.15-201 through 3A.15-206. In these tables, DM and MSM refer to the “Direct Method” and “Modified Subtraction Method” of the SASSI2010/ACS SASSI program, respectively (See the discussion below in this SER Section 3.7.2.4 under “*SSI Analysis Method.*”). The staff finds the applicant’s consideration of the SSI and SSSI analyses cases acceptable because as shown in these FSAR Tables cited above, in establishing the site-specific seismic demand, the applicant has considered analysis cases to account for the effects of the potential variabilities in the properties of the soil and rock at the site, soil separation, potential stiffness variation of the structures, and SSSI in accordance with SRP Section 3.7.2.II.4.

Strain Compatible Dynamic Subsurface Material Properties

The site-specific SSI analyses considered the three site-specific subsurface material profiles (BE, LB, and UB) for the in-situ materials, structural fill and concrete fill, which are documented in FSAR Tables 3.7.1-201 through 3.7.1-206. The staff finds these profiles acceptable because they are determined to be consistent with design ground motion based on the staff-approved 2013 Ground Motion Model (GMM) and also properly account for the effects of the potential variability in the properties of the soils and rocks at the NA3 site. The development of three deterministic site-specific soil profiles are consistent with the SRP Acceptance Criterion 3.7.2.II.4. The staff further reviewed selected portions of the North Anna 3 calculations and reports pertaining to the development of strain compatible dynamic subsurface material properties during North Anna 3 Audit 1 and confirmed that the approach used by the applicant is consistent with the staff guidance. The staff’s detailed review of the above information is in Section 3.7.1.4 of this SER.

The staff also performed a confirmatory analysis to assess the adequacy of the method that the applicant used for calculating the log-standard deviations from the simulated low frequency profiles and the high frequency profiles. These simulated profiles were results of the applicant’s probabilistic site response analysis. The log-standard deviations are used to determine the LB and UB soil profiles. The staff confirmatory analysis showed that the results were very similar to those the applicant provided. The staff also determined that the reason for this good agreement in the results from the two different methods is that the low frequency soil profiles and the high frequency profiles are very similar. As such, the staff found that the method used by the applicant to determine the standard deviation for use in calculating the LB and UB soil profiles is acceptable.

The staff finds the strain compatible dynamic subsurface material properties acceptable based on the conclusion in Section 3.7.1.4 of this SER and the conclusion of the staff confirmatory evaluation described above.

Ground Motion Time Histories

As discussed earlier in this SER in Section 3.7.1, for the RB/FB and CB, two sets of three statistically independent acceleration time histories (i.e., two horizontal and one vertical component) are developed for the full column and partial column final SSI input response spectra. For the FWSC, two sets of three statistically independent acceleration time histories (i.e., two horizontal and one vertical component) are developed for the final SSI input response spectra applied at the foundation level of the FWSC (Elevation 282 ft) and at the bottom of the concrete fill below the FWSC (Elevation 220 ft). The staff finds that these ground motion time histories are acceptable for the site-specific SSI analyses performed by the applicant since they were developed in accordance with the guidance in SRP Section 3.7.1 and were confirmed through a staff confirmatory analysis regarding their power adequacy for the frequencies of interest to the structural responses. The staff's detailed review of the above information is in Section 3.7.1.4 of this SER.

SSI Analysis Method

The applicant performed site-specific SSI analyses following the methodology in ESBWR DCD, Tier 2, Section 3A.5.2, which is based on the frequency domain complex response approach using the SASSI 2000 program. Structural responses were computed in terms of maximum absolute accelerations, relative displacements, maximum forces and moments, and in-structure response spectra (ISRS) at the key locations in the structures identified in ESBWR DCD, Tier 2, Appendix 3A, as well as seismic lateral soil pressures acting on below-grade exterior walls (seismic soil pressures are reviewed in Section 3.8.4.4 of this SER). The use of the frequency domain complex response approach for site-specific SSI analysis is acceptable to the staff because it is the same methodology applied in the ESBWR DCD and is consistent with SRP Acceptance Criterion 3.7.2.II.4.

The staff, however, noted that the applicant used the SASSI 2010 and ACS SASSI programs in the North Anna 3 site-specific SSI analysis instead of the SASSI 2000 program that was used for the ESBWR DCD. The applicant performed V&V analyses to ensure the acceptability of the SASSI 2010 and ACS SASSI programs for use in the site-specific SSI analyses for the North Anna 3 site. The staff's review of the applicant's V&V of the SASSI programs is described below under the heading, *"Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM."* As concluded there, the use of the SASSI 2010 and the ACS SASSI programs is acceptable for the North Anna 3 site-specific application.

To perform the SSI analysis of embedded structures such as the RB/FB and the CB, the SASSI programs may use the DM ("Direct Method," also known as the "Flexible Volume Method"), the MSM (Modified Subtraction Method), or the SM ("Subtraction Method"). The DM is the numerically accurate but also the most computationally intensive method. The SM, if not implemented properly, could potentially result in erroneous and non-conservative SSI responses when compared to the DM.

FSAR Section 3A.14 indicates that the site-specific SSI analyses were performed using either the DM or the MSM, but not the SM. Current staff guidance regarding the use of the DM versus the MSM is provided in SRP Section 3.7.2, Revision 4 and Acceptance Criterion 3.7.2.II.4. Although the guidance states that the DM should be used to the extent practical, the MSM is also identified as an alternative for very large computer models where it is not feasible to use the DM. The guidance recommends the use of reduced-size computer models (e.g., half/quarter models) to perform direct comparisons between the MSM and the DM solutions and to draw conclusions that can be extrapolated to the full-size models.

For this reason, the staff in RAI 03.07.02-26, requested the applicant to demonstrate the adequacy of the MSM for the North Anna 3 application. In response to RAI 03.07.02-26 (ADAMS Accession No. ML15222A240), the applicant performed additional benchmark studies to include both LB and UB North Anna 3 soil profiles. The result of the bench marking analyses is contained in SER-DMN-011 Rev. 1, “Benchmarking of SASSI2010 MSM Results from NA3 Site-Specific Analysis” (ADAMS Accession No. ML15222A283). During North Anna 3 Audit 1, the staff reviewed the Benchmarking and other relevant technical reports and confirmed that the analyses results obtained from the MSM are essentially identical to those obtained from the DM analysis for the frequency range of interest to the North Anna 3 site conditions. Based on the review of the results of the Benchmark studies performed by the applicant, the staff concluded that the use of the MSM is acceptable for site-specific SSI analyses at the North Anna 3 site.

SSI Analysis Structural Models

Site-Specific Design Basis RB/FB SSI model

FSAR Section 3A.16 describes the SSI models used for the site-specific SSI analyses. Details of the site-specific design basis SSI model of the RB/FB are described in the GEH Report WG3-U71-ERD-S-0001 Rev. 4, “Reactor/Fuel Building Complex Seismic Analysis Report,” (ADAMS Accession Nos. ML16097A203 and ML16097A204). The site-specific RB/FB SSI model is shown in FSAR Figures 3A.16.3-201 through 3A.16.3-209. It is based on the three-dimensional lumped-mass stick model that was used for the standard design seismic response analysis in the DCD, which considers shear, bending, torsion, and axial deformations of the building. Single-degree-of-freedom (SDOF) oscillators connected to the stick models are used to represent the significant out-of-plane modes of flexible slabs and walls in the building. The RB/FB lumped-mass stick model is shown in the DCD Figure 3A.7-4. The stick models and the SDOF oscillators used in the site-specific base case SSI models are therefore acceptable because they are the same as those used in the ESBWR DCD for the same purpose and they are consistent with SRP Acceptance Criterion 3.7.2.II.3.C.iii.

The coupled soil-structure SASSI 2010 models used for the site-specific SSI analysis of the RB/FB are shown in the FSAR Figures 3A.16.3-201 through 3A.16.3-204 for the PE model and in Figures 3A.16.3-205 through 3A.16.3-209 for the FE model. The site-specific SSI model of the RB/FB differs from the standard design model in that: (a) the meshing of the below grade portion of the model is modified to match the layering and stiffness properties of the North Anna 3 subgrade, (b) near-field subgrade elements are included in the structural model to represent the structural fill and concrete fill materials surrounding the RB/FB, (c) the lower OBE damping value is used to conservatively reflect the dissipation of energy in the structures, and (d) the rigid massless outriggers are installed at each floor elevation to facilitate calculation of ISRS and displacements at floor edges. A minimum value of 3.13 m is used for the lateral extent of the near-field concrete and structural fill elements for the RB/FB model. Because of the limited lateral extent of the fill material, the staff found the applicant’s method of modeling the concrete and structural fill as the near-field structural elements acceptable. Detailed staff evaluation of the item (b) above concerning lateral extent of the near-field elements used in the SSI model is provided in Section 3.7.1.4 of this SER.

The site-specific base case model for the structural portion of the RB/FB consists of the DCD RB/FB stick model based on the uncracked concrete properties, which represents the upper bound stiffness properties of the structural elements. Along with these upper bound stiffness properties, the applicant also assigned lower OBE damping values for the structural members. The use of the OBE damping values reflects lower dissipation of energy in the structures resulting in conservative seismic response determination. Sensitivity analysis to consider concrete cracking was also performed by the applicant and is evaluated later in this section. Therefore, per guidance in SRP Sections 3.7.1 and 3.7.2, and in RG 1.61, the use of uncracked section properties and OBE damping is conservative and thus acceptable for RB/FB base case model.

The exterior walls below grade and the foundation basemat are modeled using plate elements similar to the SASSI model used for the standard design RB/FB SSI analysis except that the vertical and horizontal spacing of the elements were adjusted to closely match the site-specific subsurface profile layers and to address model passing frequencies. Brick elements were used to model the near-field structural fills and the excavated soil volume for the fully and partially embedded structures. To ensure that the dynamic response of the site-specific SSI model is adequate for the frequency range of interest, the applicant adjusted the mesh size of the below-grade portion of the model to ensure that both the horizontal and vertical mesh dimensions do not exceed 20 percent of the length of the shear wave passing through the soil material at the highest frequency of interest. In addition, the aspect ratio of the plate and brick finite elements used in the mesh should not exceed 1:4, which is validated by the applicant in V&V of SASSI 2010 program documented in GE-Hitachi report SER-DMN-020, Rev. 1, "Validation Summary Report for SASSI 2010 and Appendix with Validation Problems for RAI 03.07.02-10/RAI 03.07.02-26 Response," (ADAMS Accession No. ML15222A280). Per the Interim Staff Guidance DC/COL-ISG-1, the passing frequency of the SSI models should be at least 50 Hz.

As stated in the FSAR Section 3A.16.3.1 and GEH Report WG3-U71-ERD-S-0001 Rev. 4, the maximum aspect ratio of the finite element mesh in the RB/FB embedded models is 1:3.5. The staff finds that this ratio to be acceptable since it does not exceed the aspect ratio limit (1:4) validated in the SASSI 2010 V&V analysis. The staff's evaluation of the SASSI 2010 V&V for North Anna 3 is provided in this SER under the heading *"Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM."* The staff reviewed the finite element meshes of the RB/FB excavated volumes depicted in FSAR Figures 3A.16.3-203 and 3A.16.3-207 and the corresponding passing and cut-off frequencies shown in FSAR Table 3A.15-201. The passing frequencies are calculated based on both the maximum horizontal and vertical dimensions of the excavated volume elements and the near-field elements. The staff concluded that the mesh sizes meet the 50 Hz criteria identified above except for the SSI analysis cases corresponding to the LB full column subsurface profile. For these LB full column cases, the staff found that the passing frequency of the SSI models is 33 Hz and thus deviates from the guidance in DC/COL-ISG-1.

The staff's assessment, however, concluded that the deviation from the guidance identified above is not a concern for the following reasons:

1. The site-specific seismic responses computed for the UB subsurface profile are more susceptible to the higher frequency content of input motions above 33 Hz. These are accurately captured in the analyses because they are based on SSI models that have the required 50 Hz passing frequency.

2. The reduced passing frequency for the SSI analyses with LB full column subsurface profile reflects an insufficient mesh/layer refinement in the soil layers and near-field structural backfill elements of the model only—the mesh/layer dimensions in the rock portions below the soil layers are adequate.

3. The review of site-specific seismic responses in the structures computed from the SSI analyses of the LB full column cases indicates that these cases only bound results for the ISRS envelopes at frequencies below 9 Hz, which is 24 Hz lower than the passing and cutoff frequency 33 Hz, as stated in FSAR Section 3A.15.

4. The reduced passing frequency for the LB full column SSI analyses does not affect the seismic lateral soil pressures computed for these cases because the soil pressures are mainly the result of the low frequency responses (i.e., below 33 Hz).

According to the SRP Acceptance Criterion 3.7.2.II.4, for deep soil sites, the subsurface profile model depth generally should be at least twice the base dimension below the foundation level, which should be verified by parametric studies. For the RB/FB, the staff noted that the model depth below the foundation level is approximately two times the footprint dimension of the RB/FB. Since the computed seismic response may be sensitive to the location of the half-space interface selected, further justification was needed for the model depth selected. As discussed in FSAR Section 3A.16.3.1 and further documented in Appendix H of the GEH Report WG3-U71-ERD-S-0001 Rev. 4, the applicant performed sensitivity studies to demonstrate that the lower boundary of the RB/FB site/rock model does not affect the results of SSI analysis. The staff reviewed the results of the sensitivity analysis and confirmed that the selected total depths of the site models used for the site-specific SSI analyses are appropriate and achieve sufficient accuracy of the site-specific SSI analysis results.

The applicant performed site-specific foundation uplift evaluation of RB/FB to show that the ground contact ratio is equal to or greater than 80 percent so that the linear SASSI SSI analyses are acceptable. The 80 percent criterion is provided in SRP 3.7.2. The analyses included four combinations of the possible directions of the input motion to consider the non-symmetric effect of the RB/FB model in the EW direction. The minimum base contact ratio was determined to be associated with the case of the UB full column subgrade profile. During North Anna 3 Audit 1, the staff reviewed the methods for calculation of basemat uplift, and noted that the stress contours of the basemat showed that uplift occurred only along the exterior walls for RB/FB, which did not appear to be realistic for reinforced concrete structures with a thick base mat and interior walls. A further review of this issue revealed that the RB/FB SSI model does not have interior walls connected to the basemat shell model. This modeling simplification is considered to be adequate for determining the SSI responses (e.g., structural response, ISRS, etc.) because there are rigid beams connecting the super structure (lumped mass stick model) to the exterior walls (shell elements) at all basement floor levels above the top of the basemat. However, because the basemat was modeled as shell elements without the interior walls, which would have increased the out-of-plane stiffness of the basemat, the shell model representation of the basemat is much more flexible than the real basemat construction. Therefore, the staff requested the applicant to perform uplift evaluation to consider the effect of the interior walls.

As discussed in FSAR Section 3A.17.12.5, the applicant performed additional uplift analyses of RB/FB by assuming a rigid foundation as a bounding case. The analyses were based on a closed-form solution from the theory of elasticity using the results of the vertical base reaction and overturning moments obtained from the SSI analyses. The UB partial column and UB full column profiles were identified as critical cases based on results shown in Table 3A.17.12.5-201. The results show that a rigid foundation assumption leads to a minimum base contact ratio of 97.2 percent which is larger than those estimated based on flexible foundation models. The staff finds that the method for the additional uplift evaluation is acceptable and the linear SASSI

SSI analyses are acceptable because the potential uplift of the RB/FB was found to be within the 80 percent ground contact ratio limit as recommended in SRP 3.7.2, Rev. 4.

For the RB/FB, the applicant has performed site-specific sensitivity evaluations of the effects of structural stiffness variation. In addition, potential soil separation from the RB/FB structure is considered through the SSI analysis of partial soil column cases which do not include the softer in-situ Saprolite and structural fill material above the Zone III rock. The evaluation considers the effect of concrete cracking on the response of the reinforced concrete members and the out-of-plane vibrations of the flexible slabs and walls. The staff's evaluation of the sensitivity studies including the models used in the analyses are discussed later in this SER Section 3.7.2.4 under the headings of "*Effect of Structural Stiffness Variations on Site-Specific Results"* and *"Soil Separation Analysis."*

Based on the above evaluation, the staff finds that the site-specific design basis SSI model of RB/FB described in FSAR Section 3A.16.3.1 meets the SRP Acceptance Criteria 3.7.2.II.3 and 3.7.2.II.4 and is therefore acceptable.

Site-specific Design Basis CB SSI model

The site-specific design basis CB SSI model is shown in FSAR Figures 3A.16.3-210 through 3A.16.3-213 for the PE model and in FSAR Figures 3A.16.3-214 through 3A.16.3-217 for the FE model. The connection between CB stick model and foundation is shown in the FSAR Figure 3A.16.3-218. Details of the site-specific design basis SSI model of the CB are described in the FSAR Section 3A.16.3.2 and in GEH Report WG3-U73-ERD-S-0001, Rev. 2, "Control Building Seismic Analysis Report," (ADAMS Accession Nos. ML15357A305, ML15357A312, and ML15357A313). The CB lumped-mass stick model used in the site-specific CB SSI model is the same model used for the standard design seismic response analysis in the ESBWR DCD, which considers shear, bending, torsion, and axial deformations of the CB. This model is shown in the ESBWR DCD Figure 3A.7-6 and designated in the ESBWR DCD Table 3A.6-1 as the "base" model. SDOF oscillators connected to the stick models are used to represent the out-of-plane seismic response of flexible slabs in the buildings. The lumped-mass stick model and the SDOF oscillators used in the site-specific CB SSI models are therefore acceptable because they are the same as those used in the ESBWR DCD for the same purpose and they are consistent with SRP Acceptance Criterion 3.7.2.II.3.C.

The site-specific SSI model of the CB differs from the standard design model in that: (a) the meshing of the below grade portion of the model is modified to match the layering and stiffness properties of the North Anna 3 subgrade, (b) near-field subgrade elements are included in the structural model to represent the fill materials (structure and concrete fills) surrounding and below the CB, (c) the lower OBE damping value is assigned to the uncracked concrete members for the purpose of generating site-specific design basis ISRS, and (d) the rigid massless outriggers are installed at each floor elevation to facilitate calculation of ISRS and displacements at floor edges. The staff's evaluation of the above differences between the DCD and the site-specific CB model is discussed below:

The staff reviewed the coupled soil-structure SSI base model of the CB and agreed with the applicant that the adjustment of the meshing of the below-grade portion of the model would be necessary to match the site-specific subsurface profile layers and to address model passing frequencies. A minimum value of 3.13 m is used for the lateral extent in representing the near-field subgrade elements (concrete and structural fill elements) for the CB model. Because of the limited extent of the fill material, as discussed in Section 3.7.1.4 of this SER, the staff found the applicant's method of modeling the concrete and structural fill as the near-field structural elements acceptable. The applicant assigned OBE damping values for the CB model for developing the site-specific ISRS and assigned the SSE damping value for determining the site-specific seismic demand for the CB. The staff finds the method of assigning the OBE and SSE damping values to the CB model to be acceptable since the method is in accordance with the guidance in SRP Sections 3.7.1 and 3.7.2 and in RG 1.61.

SASSI2010 CB model included approximately 4.91 m of fill concrete below the CB foundation bottom as part of the structural model. The input control motion for the CB, however, was established at the bottom of CB foundation instead of the bottom of the fill concrete. To address the potential impact of defining the SSI input control motion at the CB foundation bottom, the applicant in response to RAI 03.07.02-11 (ADAMS Accession No. ML15056A047) presented a comparison of Design Response Spectra for the CB full column and partial column profile at two different elevations (CB foundation bottom and the bottom of fill concrete). The staff reviewed the comparison provided in the response to RAI 03.07.02-11 and concluded that the results do not show any shift in the frequency content of the input or reductions of the high frequency amplitudes during upward propagation of the seismic waves. Therefore, the staff found application of the CB SSI input control motion at the CB foundation bottom acceptable.

The exterior walls below-grade and the foundation basemat are modeled using plate elements similar to the SASSI model used for the standard design CB SSI analysis except that the vertical and horizontal spacing of the elements were adjusted to closely match the site-specific subsurface profile layers and to address model passing frequencies. Solid brick elements were used to model the excavated soil volume for the fully and partially embedded structures. To ensure that the dynamic response of the site-specific SSI model is adequate for the frequency range of interest, the applicant adjusted the mesh size of the below grade portion of the model to ensure that both the horizontal and vertical mesh dimensions do not exceed 20 percent of the length of the shear wave passing through the soil material at the desired frequency of interest. In addition, the aspect ratio of the plate and brick finite elements used in the mesh should not exceed 1:4 for both the plate and brick elements as validated by the applicant in their V&V of SASSI2010 program documented in the GE-Hitachi report SER-DMN-020, Rev 1. In accordance with the Interim Staff Guidance DC/COL-ISG-1, the passing frequency of the SSI models should be at least 50 Hz.

As stated in the FSAR Section 3A.16.3.2 and GEH Report WG3-U73-ERD-S-0001 Rev. 2, "Control Building Seismic Analysis Report," (ADAMS Accession Nos. ML15357A305, ML15357A312, and ML15357A313) the maximum aspect ratio of the finite element mesh in the CB embedded models is 1:1.9. The staff finds this ratio to be acceptable since it did not exceed the aspect ratio limit (1:4) validated in the SASSI2010 V&V analysis.

The staff reviewed the finite element meshes of the CB excavated volumes depicted in FSAR Figures 3A.16.3-212 and 3A.16.3-216 and the corresponding passing and cut-off frequencies shown in FSAR Table 3A.15-202. The passing frequencies are calculated based on both the maximum horizontal and vertical dimensions of the excavated volume mesh and the near-field meshes. The staff concluded that the mesh sizes meet the 50 Hz criteria identified above except for the SSI analysis cases corresponding to the LB full column subsurface profile. For these LB cases, the staff found that the passing frequency of the SSI models is approximately 34 Hz and thus deviates from the guidance in DC/COL-ISG-1.

The staff's assessment, however, concluded that the deviation from the guidance identified above is not a concern and does not affect the results for the following reasons:

1. The site-specific seismic responses computed for the UB subsurface profile are more susceptible to the higher frequency content of input motions above 34 Hz. These are accurately captured in the analyses because they are based on SSI models that have the required 50 Hz passing frequency.

2. The reduced passing frequency for the SSI analyses with LB full column subsurface profile reflects an insufficient mesh/layer refinement in the soil layers and near-field structural backfill elements of the model only; the mesh/layer dimensions in the rock portions are adequate.

3. The review of site-specific enveloping ISRS responses in the structures computed from the SSI analyses of the LB and BE full column cases indicates that above 18 Hz, these cases are bounded by the other case analyses that have the required 50 Hz passing frequency, as stated in FSAR Section 3A.15. This is because SSI effects at the North Anna 3 site are dominated by the interaction between the structures and the rock in which they are embedded.

4. The reduced passing frequency for the LB SSI analyses does not affect the seismic lateral soil pressures computed for these cases because the soil pressures are mainly the result of the low frequency responses (i.e., below 34 Hz).

The site-specific base model for the structural portion of the CB consists of the ESBWR DCD CB stick model based on the uncracked concrete properties which represents the upper bound stiffness properties of the concrete structural elements. Along with these upper bound stiffness properties, the applicant also assigned lower OBE structural damping values for the development of the ISRS. The use of the OBE damping values reflects lower dissipation of energy in the structures and ensures that the ISRS peaks envelope the condition when the corresponding stresses in the structure are lower. For development of the site-specific seismic structural load demands, foundation uplift, and stability evaluations, the applicant used the CB base model (with uncracked concrete properties) with the SSE structural damping values. In accordance with the guidance in the RG 1.61 and SRP 3.7.2, the staff found the applicant's use of OBE structural damping values for developing ISRS and use of the SSE damping values for developing the structural seismic demand for the CB acceptable. The staff also found the use of SSE damping values for evaluating the potential of foundation uplift and seismic stability acceptable because these cases represent the limiting stress conditions associated with large seismic demand and the resulting foundation reactions are consistent with the structural load demand.

According to the SRP Acceptance Criterion 3.7.2.II.4, the model depth generally should be at least twice the base dimension below the foundation level which should be verified by parametric studies. For the CB, the staff found that the model depth below the foundation level of the CB is more than 88 m, which exceeds two times the maximum footprint dimension (about 30.3 m) of the CB. Based on staff's review earlier of the sensitivity studies performed by the applicant for the RB/FB as documented in Appendix H of the GEH Report WG3-U71-ERD-S-0001 Rev. 4, the staff agreed with the applicant's conclusion that the selected total depths of the CB site models used for the site-specific SSI analyses does not affect the results.

The applicant performed site-specific foundation uplift evaluation of CB to show that the ground contact ratio is greater than 80 percent so that the linear SASSI SSI analyses are acceptable. The 80 percent criterion is specified in SRP Section 3.7.2. During North Anna 3 Audit 1, the staff reviewed the methods for calculation of basemat uplift, and as discussed in Section heading, "*Site-Specific Design Basis RB/FB SSI model,"* of this SER, the staff identified a similar issue regarding the appropriateness of the CB foundation model for the uplift calculation.

Therefore, the applicant performed alternative uplift calculations for the CB foundation in Appendix H of the GEH Report WG3-U73-ERD-S-0001 Rev. 2. The applicant performed two sets of analyses of the CB partially embedded model by: (1) adding rigid beams in the middle of the CB basemat to account for the effect of the in-plane stiffness of the interior wall on the CB foundation overall stiffness, and (2) assuming a rigid foundation. Appendix H of WG3-U73-ERD-S-0001, Rev. 2, also indicates that adding rigid beams to the SSI model had no effect on the critical time that the maximum uplift occurred in the analysis and had very small effect on the estimate of eccentricity, but significantly affected the base stress distribution. The alternative foundation uplift calculations indicated that models with higher overall stiffness for the foundation predicted a reduction in the minimum base contact area, which is less than 80 percent. In particular, the analysis of the more realistic model that accounted for the effect of interior wall showed that the minimum contact ratio was 73 percent for a very short duration of 0.02 seconds. Since the calculation predicted a minimum contact ratio less than the guidance of SRP 3.7.2, the applicant provided further justification of the acceptability of the linear CB SSI analysis in the FSAR Section 3A.17.13.5. The applicant stated that the alternative uplift calculations were based on very conservative assumptions which considered the groundwater buoyancy pressure applied uniformly at the bottom of the CB foundation. The actual permeability of the concrete fill supporting the CB foundation is very small and insufficient to generate the assumed uniform buoyancy pressure. In addition, the uplift calculation based on PE configuration neglected the effect of subgrade located above the Zone III rock. Under a more realistic FE condition, additional analysis showed that the CB rigid foundation remained in full contact. In addition, the analysis based on the conservative assumptions showed that the larger uplifts (greater than 20 percent) of the CB base mat are infrequent with very short duration to have an effect on the seismic response of the CB structure.

The staff reviewed the results of alternative analyses performed by the applicant and found the applicant's justification for accepting CB SSI analyses results based on linear elastic SSI model acceptable because: (1) the assumed full permeability of the concrete to result in the full upward ground water buoyancy pressure at the interface between the CB basemat and underlying concrete fill would be unlikely, (2) the applicant's analysis of more realistic, fully embedded conditions indicated that the CB rigid foundation remained in full contact for the entire duration of the ground motion, and (3) the larger uplift (greater than 20 percent) of the CB basemat based on conservative assumptions were infrequent within a very short duration to have any effect on the seismic response.

For the CB, the applicant has performed site-specific sensitivity evaluations of the effects of structural stiffness variation and the site-specific effects of SSSI. The evaluation considers the effect of concrete cracking on the response of the reinforced concrete members and the out-of-plane vibrations of the flexible slabs. The staff's evaluation of the sensitivity studies including the models used in the analyses are discussed in this SER under the headings of "*Effect of Structural Stiffness Variations on Site-Specific Results," "SSSI Analysis,"* and *"Soil Separation Analysis."*

Based on the above evaluations, the staff finds that the site-specific design basis SSI model of CB described in FSAR Section 3A.16.3.2 meet the SRP Acceptance Criteria 3.7.2.II.3 and 3.7.2.II.4 and is therefore acceptable.

Site-specific Design Basis FWSC SSI model:

The coupled soil-structure SASSI2010 models used for site specific SSI analysis of the FWSC are shown in the FSAR Figures 3A.16.3-219 through 3A.16.3-221. Details of the site-specific design basis SSI model of the FWSC are described in the FSAR Section 3A.16.3.3 and in the GEH Report WG3-U63-ERD-S-0001 Rev. 4, "Firewater Service Complex Seismic Analysis Report," (ADAMS Accession No. ML16148A131). The FWSC SSI model is a half model with symmetric and antisymmetric boundary conditions based on the lumped-mass stick model shown in DCD Figure 3A.7-7 which considers shear, bending, torsion, and axial deformations of the structural members and is designated in the DCD Table 3A.6-1 as the "base" model. SDOF oscillators connected to the stick models are used to represent the out-of- plane seismic response of flexible slabs. The stick models and the SDOF oscillators used in the site-specific SSI models are therefore acceptable because they are the same as those used in the ESBWR DCD for the same purpose and they are consistent with SRP Acceptance Criterion 3.7.2.II.3.C.iii

The site-specific SSI model of the FWSC differs from the standard design model in that: (a) The model is modified to add the meshing of the below grade portion that matches the layering and stiffness properties of the North Anna 3 subgrade, (b) a block of near-field solid elements embedded in the in-situ soil and rock is used to model the concrete fill placed below the FWSC basemat, (c) the lower OBE damping value is assigned to the uncracked concrete members for the purpose of generating site-specific design basis ISRS, and (d) rigid outriggers are installed at each floor elevation to facilitate calculation of ISRS and displacements at floor edges. The staff's evaluation of the above differences between the DCD and the site-specific FWSC model is discussed below:

As discussed in Section 3.7.1.4 under "*SSI Input Response Spectra for the FWSC"* of this SER, the staff found the representation of the concrete fill below the FWSC basemat as an integral part of the structural model acceptable because the applicant used two sets of site-specific SSI input with control motions defined at the bottom of the FWSC foundation (Elevation 282 ft) and at the bottom of the concrete fill (Elevation 220 ft). The applicant assigned OBE damping values for the FWSC model for developing the site-specific ISRS. The SSE damping values were assigned for determining other site-specific seismic demand for the FWSC. The staff finds the method of assigning the OBE and SSE damping values to the FWSC model to be acceptable since it is in accordance with the guidance in SRP Sections 3.7.1 and 3.7.2 and in RG 1.61.

The foundation basemat is modeled using plate elements similar to the SASSI model used for the standard design SSI analysis. Solid brick elements were used to model the excavated soil volume as well as the concrete fill for the embedded portion. To ensure that the dynamic response of the site-specific SSI model is adequate for the frequency range of interest, the applicant adjusted the mesh size of the below grade portion of the model to ensure that both the horizontal and vertical mesh dimensions do not exceed 20 percent of the length of the shear wave passing through the soil material at the highest frequency of interest. In addition, the aspect ratio of the plate and brick finite elements used in the mesh should not exceed 1:4 for both the plate and brick elements as validated by the applicant in their V&V of SASSI2010 program documented in the GE-Hitachi report SER-DMN-020, Rev 1, Validation Summary Report for SASSI 2010 (ADAMS Accession No. ML15222A280). Per the Interim Staff Guidance DC/COL-ISG-1, the passing frequency of the SSI models should be at least 50 Hz.

As stated in the FSAR Section 3A.16.3.3 and GEH Report WG3-U63-ERD-S-0001, Rev. 4, the maximum aspect ratio of the plate elements for the basemat mesh in the FWSC SSI model is 1:1.4 and the maximum aspect ratio of the 3-D solid brick elements is 1:2.9. The staff finds that these ratios are acceptable since they do not exceed the aspect ratio limit (1:4) validated in the SASSI2010 V&V analysis.

The staff reviewed the finite element mesh of the FWSC excavated soil volume depicted in FSAR Figure 3A.16.3-220 and the corresponding passing and cut-off frequencies shown in FSAR Table 3A.15-203. The passing frequencies are calculated based on both the maximum horizontal and vertical dimensions of the excavated volume. The staff concluded that the mesh sizes meet the 50 Hz criteria identified above except for the SSI analysis cases corresponding to the LB subsurface profiles as shown in FSAR Table 3A.15-203. For these LB cases, the staff found that the passing and cut-off frequency of the SSI models is 36 Hz and thus deviates from the guidance in DC/COL-ISG-1.

The staff's assessment of this deviation from the guidance, however, concluded that this deviation identified above is not a concern and does not affect the results for the following reasons:

1. The site-specific seismic responses computed for the UB subsurface profile are more susceptible to the higher frequency content of input motions above 36 Hz. These are accurately captured in the analyses because they are based on SSI models that have the required 50 Hz passing frequency.

2. The reduced passing frequency for the SSI analyses with LB subsurface profile reflects an insufficient mesh/layer refinement in the soil layers of the model only; the mesh/layer dimensions in the rock portions are adequate.

3. The review of site-specific seismic responses in the structures computed from the SSI analyses of the LB cases indicates that these cases only bound the ISRS envelopes for certain frequency ranges below 25 Hz, which is 11 Hz lower than the passing and cutoff frequency of 36 Hz, as stated in FSAR Section 3A.15. This is related to the fact that SSI effects at the North Anna 3 site are dominated by the interaction between the structures and the rock in which they are embedded.

The site-specific base model for the structural portion of the FWSC consists of the DCD FWSC stick model based on the uncracked concrete properties, which represents the upper bound stiffness properties of the concrete structural elements. Along with these upper bound stiffness properties, the applicant also assigned lower OBE structural damping values for the development of the ISRS. The use of the OBE damping values reflects lower dissipation of energy in the structures and ensures that the ISRS peaks envelope the condition when the corresponding stresses in the structure are lower. For development of the site-specific seismic structural load demands, foundation uplift, and stability evaluations, the applicant used the FWSC base model (with uncracked concrete properties) with the SSE structural damping values. In accordance with the guidance in the SRP Sections 3.7.1 and 3.7.2 and in RG 1.61, the staff found the applicant's use of OBE structural damping values for developing ISRS and use of the SSE damping values for developing the structural seismic demand for the FWSC acceptable. The staff also found the use of SSE damping values for evaluating the potential of foundation uplift and seismic stability acceptable because these cases represent the limiting stress conditions associated with large seismic demand and the resulting foundation reactions are consistent with the structural load demand.

According to the SRP Acceptance Criterion 3.7.2.II.4 for deep soil sites, the subsurface profile model depth generally should be at least twice the base dimension below the foundation level, which should be verified by parametric studies. For the FWSC, the staff found that the model depth below the foundation level of the FWSC (about 123 m) is greater than two times the maximum footprint dimension (about 52 m) of the FWSC basemat. Based on staff's review earlier of the sensitivity studies performed by the applicant for the RB/FB as documented in Appendix H of the GEH Report WG3-U71-ERD-S-0001 Rev. 4, the staff agreed with the applicant's conclusion that the selected total depth of the FWSC site models used for the site-specific SSI analyses does not affect the results.

Unlike the RB/FB and the CB, the structural fill around the concrete block below the FWSC basemat was considered as part of the in-situ soil and not included as the near-field element in the FWSC SSI model. The staff found this representation to be acceptable because: (a) the properties of the in-situ soil and structural fill around the FWSC are similar as shown in the FSAR Figure 3A.12.2-203, (b) any potential effect of this representation has been captured by the FWSC-CB SSSI analysis since the structural fill is included in the combined FWSC-CB SSSI model, and (c) the FWSC site-specific design basis seismic demand is developed based on the envelope of the results obtained from site-specific SSI analyses of FWSC stand-alone model and SSSI analyses of FWSC-CB combined model.

As discussed in FSAR Section 3A.17.14.4, the applicant performed site-specific foundation uplift evaluation of FWSC to show that the ground contact ratio is equal to or greater than 80 percent so that the linear SASSI SSI analyses are acceptable. The 80 percent ground contact ratio criterion is recommended in SRP Section 3.7.2. During North Anna 3 Audit 1, the staff reviewed supporting calculations related to the FWSC uplift evaluation and confirmed that the SSI model used for the FWSC uplift evaluation is acceptable because the basemat is modeled in a manner that represents the actual structure.

For the FWSC, the applicant has performed site-specific sensitivity evaluations which consider the effect of concrete cracking, soil separation along the upper portion of the concrete block below the FWSC foundation, and SSSI on the response of the FWSC and the out-of-plane vibrations of the flexible slabs. The staff's evaluation of the sensitivity studies including the models used in the analyses are discussed in this SER later under the headings of "*Effect of Structural Stiffness Variations on Site-Specific Results,*" *"SSSI Analysis,"* and *"Soil Separation Analysis."*

Based on the above evaluations, the staff finds that the site-specific design basis SSI model of FWSC described in FSAR Section 3A.16.3.3 meet the SRP Acceptance Criteria 3.7.2.II.3 and 3.7.2.II.4 and is therefore acceptable.

SSI Analyses Cases

The SSI analyses cases for the North Anna 3 site, performed by the applicant, are summarized in FSAR, Revision 9, Tables 3A.15-201 through 3A.15-206 for the RB/FB, CB, and the FWSC. In addition, the FSAR Tables include the North Anna 3 site-specific sensitivity analyses cases which evaluate the effect of structural stiffness variation, soil separation, and SSSI on the site-specific seismic demand. These analysis cases account for the potential variability in the site-specific soil/rock properties by considering three (LB, UB, and BE) subsurface material properties. For the RB/FB and the CB, the site-specific effect of subgrade stiffness variation related to embedment, ground water, and the layering effect of in-situ soils were accounted for by considering two embedment configurations: (1) full soil column subgrade profile and (2) partial soil column subgrade profile as discussed earlier in this SER. For the FWSC, two sets of SSI analyses were performed; one with the control motion applied at the bottom of the basemat and the other with the control motion applied at the bottom of concrete fill below the FWSC foundation, were performed. Finally sensitivity studies were performed to account for, in the SSI analysis results, the effects of the potential stiffness variation in the structural members, soil separation, and SSSI. For the FWSC, the FWSC-CB SSSI together with FWSC SSI analysis cases form the basis for the site specific seismic demand.

The staff concludes that the SSI and SSSI cases summarized in FSAR Tables 3A.15-201 through 3A.15-206 provide sufficient information for the staff to determine the acceptability of the site-specific seismic demand at the North Anna 3 site for the Category I structures.

SSI Analysis Results – Transfer Functions

GEH Reports WG3-U71-ERD-S-0001 Rev. 4, Reactor/Fuel Building Complex Seismic Analysis, WG3-U73-ERD-S-0001 Rev. 2, Control Building Seismic Analysis, and WG3-U63-ERD-S-0001 Rev. 4, Firewater Service Complex Seismic Analysis, document the transfer functions computed for the site-specific SSI analyses. These reports present results for the following key locations as identified in DCD Appendix 3A:

- RB/FB: top of basemat, refueling floor, reinforced concrete containment vessel (RCCV) top slab, top of vent wall, top of reactor shield wall (RSW), top of RPV.
- CB: top of basemat and top of roof slab.
- FWSC: FWS wall top, FWS base, FPE top, FPE base

The staff reviewed the transfer function plots and found them to be generally smooth, with a sufficient density of calculated frequency points in the frequency range of interest. Although some isolated sharp spikes were noted in a few of the plots because of the interpolation scheme used by the SASSI 2010 program, these spikes had no observable impact on the ISRS or other seismic responses as described in FSAR Section 3A.14.2. During North Anna 3 Audit 1, the staff further reviewed supporting calculations for assessing the effect of the spurious peaks in some of the SASSI transfer functions on structural responses as discussed below:

To address the issue, as described in FSAR Section 3A.14.2, the applicant performed additional SASSI analyses with frequencies added near the numerical anomalies for the following cases:

- For RB/FB: UC100 model for LB, BE, UB partial columns; UC100 model LB, BE, UB full columns; CR00 and CR50 models for LB full column
- For CB: UC_OBE full columns
- For FWSC: UC_OBE full columns with input at Elevation 220 ft.
- For CB-FWSC: UB full column

The staff confirmed the additional frequencies in the SASSI analyses did not result in any significant effect on the seismic responses during North Anna 3 Audit 1. Therefore, the staff concludes that the interpolated transfer functions are acceptable and the site-specific SSI analyses performed by the applicant with the SASSI 2010 program were implemented in a manner consistent with the frequency domain complex response method described in ESBWR DCD, Tier 2, Appendix 3A.

SSI Analysis Results – Maximum Structural Loads

FSAR Section 3A.17 describes the North Anna 3 site-specific SSI analysis results for the various SSI analyses cases presented in the FSAR Tables 3A.15-201 through 3A.15-206 for the RB/FB, CB, and the FWSC. This FSAR section also describes the results of the site-specific sensitivity studies to address the effects of structural stiffness variation, SSSI, and soil separation from the foundation walls or concrete fill. The applicant compared the results of the site-specific SSI and SSSI analysis of the RB/FB, CB, and FWSC with the standard seismic design envelopes presented in DCD Section 3A.9. The applicant followed the DCD method to develop the site specific seismic demands for the RB/FB, CB, and FWSC. The applicant provided these comparisons of site-specific enveloping seismic demand for North Anna 3 Category I structures with the DCD envelope in the FSAR Section 3A.18.1.

RB/FB Site-Specific Seismic Load Demand

FSAR Tables 3A.18.1.1-201a through 3A.18.1.1-201f present the envelope of the maximum site-specific seismic forces and moments in the various stick models of the RB/FB complex obtained from the site-specific SSI analysis cases as tabulated in FSAR Table 3A.15-201 and compare these to the corresponding values in the ESBWR DCD. The adequacy of these analysis cases is evaluated above in this SER under the heading of, "*SSI Analyses Cases.*" FSAR Tables 3A.18.1.1-203 and 3A.18.1.1-204 present the site-specific enveloping out-of-plane seismic load demands on the RB/FB flexible slabs and walls obtained from the site-specific SSI analyses and the staff compared these to the corresponding values in the ESBWR DCD. FSAR Section 3A.18.1.1 also includes the envelope of the maximum accelerations in the different stick models of the RB/FB complex and the staff compared these to the corresponding design values used in the standard design. The staff reviewed these results and the supporting calculations during North Anna 3 Audit 1 and concluded that the method used in establishing the site-specific seismic demand is consistent with the DCD methodology and is in accordance with the SRP Section 3.7.2 guidance. The SASSI computer programs used to develop the site-specific seismic demand were verified and validated. The staff also determined that site-specific seismic load demands in some instances for the RB/FB exceeded the corresponding loads used for the standard design of the RB/FB structures. The applicant has performed a site-specific evaluation of RB/FB structures using the site-specific seismic demands presented in FSAR Section 3A.18.1.1 that bound the effects of full/partial soil columns and structural stiffness variations to address the exceedances in seismic loads. The staff's assessment of the effect of structural stiffness variations on the site-specific seismic demand is discussed later in this SER Section 3.7.2.4 under the heading of "*Effect of Structural Stiffness Variations on Site-Specific Results.*" The staff's assessment of the site-specific evaluation of the standard design of the RB/FB is documented in this SER in Section 3.8.4.

CB Site-Specific Seismic Load Demand

The applicant followed the method used to develop the standard design enveloping maximum structural loads in developing the structural loads representative of the site-specific seismic demands on the CB. FSAR Table 3A.18.1.2-201 presents the the maximum site-specific seismic forces and moments in the stick model of the CB obtained from the site-specific SSI analyses with the upper bound stiffness properties and SSE damping and compare these enveloping loads to the corresponding values in the ESBWR DCD. FSAR Table 3A.18.1.2-203 presents the site-specific out-of-plane seismic load demands on the CB flexible slabs and compare these to the corresponding values in the ESBWR DCD. The staff reviewed and confirmed these results and the supporting calculations during the North Anna 3 Audit 1 and concluded that the method used in establishing the site-specific seismic demand is consistent with the ESBWR DCD methodology and the SRP Section 3.7.2 guidance. The staff also determined that the site-specific seismic load demands for the CB exceeded the corresponding loads used for the standard design of the CB structures. As stated in the FSAR Section 3A.18.1.2, the applicant has performed a site-specific evaluation of the CB structures using the site-specific seismic demands presented in FSAR 3A.18.1.2 that bound the effects of full/partial soil columns and structural stiffness variations. The staff's assessment of the effect of structural stiffness variations on the site-specific seismic demand is discussed later in this SER Section 3.7.2.4 under the heading of "*Effect of Structural Stiffness Variations on Site-Specific Results.*" The staff's assessment of site-specific evaluation of the standard design of the CB is documented in this SER in Section 3.8.4.

FWSC Site-Specific Seismic Load Demand

The applicant followed the method used to develop the standard design enveloping maximum structural loads in developing the structural loads representative of the site-specific seismic demands on the FWSC. The site-specific North Anna 3 enveloping seismic demand on the FWSC are developed as an envelope of the results for maximum member forces and moments from the SSI and SSSI analyses of the FWSC standalone and the FWSC-CB combined SSSI models with uncracked stiffness properties and SSE damping using deep control motion applied at the bottom of the concrete fill at Elevation 220 ft. The analysis with deep control motion yields maximum responses that envelope the results with input motion applied at the surface.

FSAR Table 3A.18.1.3-201 presents the North Anna 3 enveloping seismic demand (member forces and moments) for the FWSC. This FSAR Table also presents the comparison of site-specific seismic demand with standard design enveloping maximum member forces for the FWSC. Table 3A.18.1.3-202 presents the maximum site-specific accelerations at different

FWSC lumped mass locations and compare them to the corresponding design values used in the standard design. FSAR Tables 3A.18.1.3-203 and 3A.18.1.3-204 present, respectively, a comparison of the site-specific maximum accelerations of FWSC SDOF oscillators and site-specific out-of-plane load on FWS roof with those of the ESBWR standard plant design. Table 3A.18.1.3-205 presents the site-specific lateral loads on the FWSC shear keys as well as a comparison of these loads with the corresponding standard design values. The staff reviewed and confirmed these results and the supporting calculations during North Anna 3 Audit 1 and concluded that the method used in establishing the site-specific seismic demand is consistent with the DCD methodology and is in accordance with the SRP 3.7.2 guidance. The staff also determined that the site-specific seismic load demands in some instances for the FWSC exceeded corresponding loads used for the standard design of the FWSC structures. The applicant has performed a site-specific evaluation of the FWSC structures using the site-specific seismic demands presented in FSAR 3A.18.1.3 that bound the effects of structural stiffness variations, the effect of soil separation, and the SSSI effect of the CB on FWSC. The staff's assessment of site-specific evaluation of the standard design of the FWSC is documented in this SER in Section 3.8.4.

SSI Analysis Results – Site-Specific Design ISRS

The site-specific SSI analyses cases are summarized in FSAR Table 3A.15-201 for the RB/FB, Table 3A.15-202 for the CB, and 3A.15-203 for the FWSC. To account for the variability in the subsurface material properties, BE, LB, and UB profiles were considered. Each analysis case consists of input motions in three orthogonal directions. The site-specific acceleration response spectra (ARS) are developed for responses at the edges of the building by taking into account coupling effects between the three directional input motions. The ARS for nodal responses due to the three input motions are combined using the SRSS method. Floor ISRS are obtained for particular floor elevations as the envelope of ARS at the four outrigger locations. FSAR Figures 3A.17.12.3-201 through 3A.17.12.3-204 present the site-specific ISRS for RB/FB, FSAR Figures 3A.17.13.3-201 through 3A.17.13.3-203 present the site-specific ISRS for CB, and FSAR Figures 3A.17.14.3-201 through 3A.17.14.3-203 present the site-specific ISRS for FWSC at the key locations of the buildings. The ISRS presented in the referenced figures of FASR 3A.17 above are obtained from the site-specific design basis SSI analyses of models with upper bound stiffness properties. Also presented there are comparisons of the site-specific ISRS with the corresponding standard design ISRS. The individual ISRS obtained from the SSI analyses cases are then enveloped. The final site-specific ISRS is calculated by (+)15 percent and (-)15 percent broadening the enveloped ISRS. Details of the development of the ISRS are provided in GEH Reports WG3-U71-ERD-S-0001 Rev. 4 for the RB/FB, GEH Report WG3-U73-ERD-S-0001 Rev. 2 for the CB, and GEH Report WG3-U63-ERD-S-0001 Rev. 4 for the FWSC. The applicant presented the enveloping site-specific design ISRS in the FSAR Figures 3A.18.2-201 through 3A.18.2-203 for RB/FB, CB, and the FWSC.

For the RB/FB and CB, the site-specific design ISRS represent the ISRS results from site-specific SSI analyses of RB/FB and CB model with upper bound stiffness properties and OBE damping (analysis cases 1 to 6 in Table 3A.15-201 for RB/FB and Table 3A.15-202 for CB). These site-specific ISRS are peak broadened and valley filled, and enhanced to bound effects of structural stiffness variations and SSSI as described in FSAR Section 3A.18.2.

Site-specific ISRS for the FWSC represent the envelope of ISRS results from: (1) the site-specific SSI analyses of the FWSC standalone model with uncracked stiffness properties and

OBE damping (analysis cases 1 to 6 in FSAR Table 3A.15-203) and (2) site-specific SSSI analysis of the FWSC-CB combined model with uncracked stiffness properties and OBE damping (cases FC1 to FC6 in FSAR Table 3A.15-206). The staff noted that these site-specific design ISRS for the FWSC already include the site-specific SSSI effects of the CB on FWSC response. The FWSC ISRS are also enhanced to bound effects of structural stiffness variations and soil separation as described in FSAR 3A.18.2.

The staff reviewed and confirmed the method of development of the site-specific ISRS and the site-specific ISRS results as presented in the FSAR Sections 3A.17 and 3A.18 and supporting calculations presented during North Anna 3 Audit 1. Based on staff's review of the comparisons provided in the FSAR, the staff concludes that the site-specific ISRS exceed the corresponding standard design ISRS at some frequencies. The applicant stated that the exceedances are addressed in the site-specific evaluation of the standard design. The staff found the method of developing the site-specific ISRS to be acceptable because the method is in accordance with the guidance in the SRP Section 3.7.2 and the RG 1.122.

The applicant has performed sensitivity studies to evaluate the effect of structural stiffness variations, SSSI, and soil separation on the site-specific design envelope ISRS. The site-specific design ISRS for the RB/FB, CB, and FWSC in general envelope the results of the various sensitivity analyses with few exceedances. The staff reviewed the methodology used to address exceedances in the site-specific design ISRS due to the sensitivity studies including the acceptance criteria in FSAR sections 3A.17 and 3A.18, and found them acceptable. The staff's evaluation of the effect of sensitivity studies are discussed below in this SER.

Effect of Structural Stiffness Variations on Site-Specific Results

RB/FB Structural Stiffness Variation Sensitivity Studies

The applicant in the response to RAI 03.07.02-14 (ADAMS Accession No. ML15222A240), stated that site-specific sensitivity evaluations of the effects of structural stiffness variation on the SSI response of the RB/FB have been performed. They are described in the FSAR Section 3A.17.9.1 and in the Appendix B of the GEH Report WG3-U71-ERD-S-0001, Rev. 4, "Reactor/Fuel Building Complex Seismic Analysis Report," (ADAMS Accession Nos. ML16097A203 and ML16097A204). As discussed earlier, the site-specific SSI analysis used a RB/FB model with uncracked reinforced concrete properties for the concrete members and 100 percent stiffness contribution of the concrete inside the steel plates for steel internal structures (referred in this report as UC100 model). The analysis was performed for three subsurface profiles and two embedment configurations (analysis cases 1 through 6 in FSAR Table 3A.15-201). The analyses used OBE damping values. The envelope of responses obtained from these six analyses cases constitutes the North Anna 3 site-specific base case seismic demand used for site-specific design and design evaluation of the RB/FB at North Anna 3 site. To evaluate the effect of potential concrete cracking, the applicant performed site-specific sensitivity SSI analyses of models with reduced stiffness properties and SSE damping (analysis cases S1 through S12 in FSAR Table 3A.15-201) and compared the results with those of the North Anna 3 site-specific demand.

The applicant performed the sensitivity analyses of the following two reduced stiffness models:

- CR00: fully cracked reinforced concrete structures with 50 percent reduced shear and bending stiffness along with no (0 percent) contribution of in-fill concrete to the stiffness of the concrete-filled steel structures (VW and D/F); and

- CR50: fully cracked reinforced concrete structures with 50 percent reduced shear and bending stiffness along with 50 percent contribution of in-fill concrete to the stiffness of the concrete-filled steel structures (VW and D/F).

The analyses of CR00 and CR50 models were performed for LB, BE, and UB soil profiles for the two embedment configurations (PE and FE). The CR00 and CR50 models used SSE damping values to be consistent with the cracked concrete assumption. The applicant has used the guidance in ASCE 43-05 to establish the stiffness reduction factors for cracked concrete members, which are in accordance with the SRP Section 3.7.2 guidance.

The staff reviewed Appendix 3A of the FSAR for the modeling approach for the cracked and uncracked cases and the models used by the applicant in the sensitivity analyses for the stiffness variations and found them acceptable because: (a) the method is consistent with the approach used for the standard design, (b) the method is consistent with the guidance in SRP Section 3.7.2, (c) the sensitivity analyses accounted for concrete cracking with the combined effects of the potential variation of the subsurface soil profiles along with the two embedment configurations, and (d) the use of SSE damping for the cracked models is consistent with the high stress conditions that the RB/FB structure would be subjected to during a fully cracked concrete condition.

SDOF oscillators connected to the stick models are used to represent the out-of-plane seismic response of flexible slabs and walls in the buildings. The staff confirmed that SDOF oscillators used in the UC100 model described in the FSAR Section 3A.16 are identical to those of the standard design models. Therefore, the staff finds these models used to capture the out-of-plane vibration mode up to 50 Hz for models with uncracked concrete are acceptable.

Since cracking of the concrete reduces the out-of-plane bending stiffness of the walls and slabs, the frequencies of out-of-plane vibration would be lowered due to cracking. Therefore, the staff requested the applicant in RAI 03.07.02-14(f) to confirm that the frequency ranges of the oscillators selected for the UC100 model are still adequate to capture the out-of-plane seismic response of the walls and slabs for the North Anna 3 site conditions. In the response to RAI 03.07.02-14(f) (ADAMS Accession No. ML15222A240), the applicant, besides applying the 50 percent reduction to the stiffness of all existing SDOF oscillators in the UC100 model, added additional oscillators to the CR00 and CR50 models to capture the modes of out-of-plane vibration of the cracked slabs and walls up to a frequency of 50 Hz. The FSAR Figure 3A.16.2-201 shows the configuration of the CR00 and CR50 stick models with the additional SDOF oscillators shown in red. The development of these additional SDOF oscillators under fully cracked conditions is described in the GEH Report SER-DMN-014, Rev. 1, "Additional Oscillators for Fully Cracked Model for RAI 3.7.2-14(f)," (ADAMS Accession No. ML15170A188).

The staff reviewed the information provided in the FSAR Section 3A.17.9 and the GEH Report SER-DMN-014 and found the site-specific representation of the out-of-plane flexibilities of walls and slabs under a cracked condition acceptable because: (a) the applicant added additional oscillators to represent all modes of vibration up to 50 Hz under fully cracked condition, and (b) the additional SDOF oscillators were developed using the same method and eigenvalue analysis that were used for standard design.

In FSAR 3A.17.9.1, Rev 9, the applicant concluded that the site-specific design basis SSI analyses of the UC100 Model with uncracked concrete stiffness and OBE damping provide site-specific seismic demand (loads and ISRS) that envelope concrete cracking effects with few exceptions (e.g., see FSAR Table 3A.17.9.1-201 and Figure 3A.17.9.1-201). The applicant also indicated that the enveloping base case site-specific seismic load demands and site-specific design ISRS are adjusted to bound effects of structural stiffness variations as described in FSAR Section 3A.18.1 and 3A.18.2, respectively. The staff found the applicant's approach to address any exceedances in the site-specific seismic demand (structural load) due to sensitivity studies for the concrete cracking acceptable because the site-specific seismic demand is enhanced where necessary to address the observed exceedances.

For the site-specific design ISRS, the applicant, however, stated that the North Anna 3 site-specific design and qualification of equipment and components will use enhanced ISRS that envelope all significant (>10 percent) peak exceedance of the site-specific design ISRS observed in the results of the sensitivity analysis cases for concrete cracking at frequencies below 50 Hz. The staff requested the applicant to provide a technical justification for establishing a significance level of 10 percent exceedance in developing the enhanced site-specific design ISRS for equipment and component in the pre-audit public meeting dated September 10, 2015 (ADAMS Accession No. ML15267A062).

The applicant in FSAR Section 3A.17.9 provided justification of using the 10 percent criteria. The applicant stated that sensitivity analysis for concrete cracking is very conservative since the analysis used 50 percent reduction in flexural and shear stiffness for all concrete elements throughout the entire structure. If the SSE were to occur, cracking will be limited in the vicinity of the highly stressed elements only and many concrete elements will not crack. Therefore the use of a significance level of 10 percent for enhancing the ISRS is justified. Staff found this basis acceptable because the use of the 50 percent reduction in flexural and shear stiffness for all concrete elements is very conservative since the cracking will be limited only to highly stressed elements. Therefore, the staff found the applicant's approach to address any exceedances (>10 percent) in the site-specific ISRS due to sensitivity studies for the concrete cracking acceptable because the site-specific ISRS is modified where necessary to address the observed exceedances greater than 10 percent.

The NRC staff reviewed the results of the North Anna 3 site-specific evaluation presented in the responses to RAIs 03.07.02-14 and 03.07.02-17 as well as the supporting documents during North Anna 3 Audit 1 and North Anna 3 Audit 2 (ADAMS Accession No. ML16193A047) to verify that the effect of the stiffness variation studies on the North Anna 3 site-specific demand for the RB/FB has been considered. The North Anna 3 site-specific seismic demands including the effects of base case, concrete cracking, and soil separation are described in FSAR Section 3A.18. FSAR Section 3A.18.1.1 presented the site-specific seismic load demand for the RB/FB structures that are based on the envelope of the base case analyses results further adjusted to bound the effect of stiffness variation. Also presented there are the comparison of the site-specific demand with the standard design. Specifically, the staff verified during North Anna 3 Audit 2 that the applicant used the enveloping site-specific seismic demand in evaluating the ESBWR standard plant structures for acceptability at the North Anna 3 site. Staff's evaluation of the ESBWR standard plant structures for the site-specific demand is described in this SER in Section 3.8.

CB Structural Stiffness Variation Sensitivity Studies

The applicant in response to RAI 03.07.02-14 (ADAMS Accession No. ML15222A240) stated that site-specific sensitivity evaluations of the effects of structural stiffness variation on the SSI response of the CB have been performed. They are described in the FSAR Section 3A.17.9.2 and in the Appendix B of the GEH Report WG3-U73-ERD-S-0001, Rev. 2, “Control Building Seismic Analysis Report.” The site-specific SSI analysis used a CB model with uncracked reinforced concrete properties for the concrete members using the OBE damping values (referred here as the UC_{OBE} model) for determining the North Anna 3 site-specific ISRS demand and SSE damping values (referred here as the UC_{SSE} model) for determining the North Anna 3 site-specific structural load demand. These analyses cases are shown in the FSAR Table 3A.15-202 as analysis cases 1 to 12. The analysis was performed for three subsurface profiles and two embedment configurations. The envelope of responses obtained from these analyses cases constitutes the North Anna 3 site-specific base case seismic demand used for site specific design and design evaluation of the CB at the North Anna 3 site. To evaluate the effect of potential concrete cracking, the applicant performed site-specific sensitivity SSI analyses of models with reduced stiffness properties and SSE damping (referred here as CR_{SSE} model). These sensitivity analysis cases are shown in the FSAR Table 3A.15-202 as analysis cases S1 through S6. The effect of the concrete cracking on the CB site-specific structural load demand is evaluated by comparing the enveloping seismic load demand obtained from the analysis of the UC_{SSE} models with those obtained from the analysis of the CR_{SSE} models. The effect of concrete cracking on the CB site-specific ISRS is evaluated by comparing the 5 percent damped ISRS results obtained from the analysis of the UC_{OBE} models with those obtained from the analysis of the CR_{SSE} models.

The analyses of CR_{SSE} models were performed for LB, BE, and UB soil profiles for the two embedment configurations (PE and FE). The applicant has used the guidance in ASCE 43-05 to establish the stiffness reduction factors for cracked concrete members which is in accordance with the SRP Section 3.7.2 guidance.

The staff reviewed the modeling approach for the cracked and uncracked cases and the models used by the applicant in the sensitivity analyses for the stiffness variations and found them acceptable because: (a) the method is consistent with the approach used for the standard design (b) the method is consistent with the guidance in SRP 3.7.2, (c) the sensitivity analyses accounted for concrete cracking with the combined effects of the potential variation of the subsurface soil profiles along with the two embedment configurations, and (d) the use of SSE damping for the cracked models is consistent with the high stress conditions that the CB structure would be subjected to during a fully cracked concrete condition.

SDOF oscillators connected to the stick models are used to represent the out-of- plane seismic response of flexible slabs and walls in the buildings. In accordance with the ESBWR DCD, use of the SDOF oscillators in the UC_{OBE} and UC_{SSE} models described in the FSAR Section 3A.16 is acceptable to capture the out-of-plane vibration mode up to 50 Hz. Since cracking of the concrete reduces the out-of-plane bending stiffness of the walls and slabs, the frequencies of out-of-plane vibration would be lowered due to cracking. Therefore, the staff requested in RAI 03.07.02-14(f) that the applicant confirm that the frequency ranges of the existing oscillators are still adequate to capture the out-of-plane seismic response of the walls and slabs for the North Anna 3 site conditions. In the response to RAI 03.07.02-14(f) (ADAMS Accession No. ML15222A240), the applicant, besides applying the 50 percent reduction to the stiffness of all existing SDOF oscillators in the UC_{OBE} and UC_{SSE} models, added additional oscillators to the CR_{SSE} models to capture the modes of out-of-plane vibration of the cracked slabs up to a frequency of 50 Hz. FSAR Figure 3A.16.2-202 shows the configuration of the CR_{SSE} stick models for the CB with the additional SDOF slab oscillators shown in red. The development of these additional SDOF oscillators under fully cracked conditions is described in the GEH Report SER-DMN-014, Rev. 1. No SDOF oscillators are added to the CR_{SSE} models to represent the out-of-plane vibrations of cracked wall since the fully cracked wall frequencies are above the 50 Hz range.

The staff reviewed the information provided in the FSAR Section 3A.17.9 and the GEH Report SER-DMN-014 and found the site-specific representation of the out-of-plane flexibilities of the slabs under a cracked condition for the CB acceptable because: (a) the applicant added additional oscillators to represent all modes of slab vibration up to 50 Hz under fully cracked condition, and (b) the additional SDOF oscillators were developed using the same method and eigenvalue analysis that were used for the standard design.

In FSAR 3A.17.9.2, Rev 9 the applicant concluded that the site-specific design basis SSI analyses of the CB Model with uncracked concrete stiffness and SSE damping provide site-specific seismic load demand that envelope concrete cracking effects with few exceptions of local out-of-plane loads on some CB slabs (e.g., see FSAR Table 3A.17.9.2-201). The applicant indicated that the enveloping site-specific seismic load demands and site-specific design ISRS are adjusted to bound effects of structural stiffness variations. The applicant also stated that North Anna 3 site-specific design and qualification of equipment and components will use enhanced ISRS that envelope all significant (>10 percent) peak exceedance of site-specific design ISRS observed in the results of the sensitivity analysis cases at frequencies below 50 Hz. As discussed earlier in this SER, the staff found the use of 10 percent criteria for enhancing the design ISRS to be acceptable. The staff found the applicant's approach described in FSAR 3A.18.1.2 and 3A.18.2 to address any exceedances in the site-specific seismic demand due to sensitivity studies for the concrete cracking acceptable because the site-specific seismic demand is modified where necessary to address the observed exceedances.

The NRC staff further reviewed the results of the North Anna 3 site-specific evaluation presented in the responses to RAI 03.07.02-14 as well as the supporting documents during North Anna 3 Audit 1 and North Anna 3 Audit 2 to verify that the effect of the stiffness variation studies on the North Anna 3 site-specific demand for the CB has been considered. The site-specific demand based on the upper bound stiffness and OBE and SSE damping values provide site-specific seismic demands on the CB that in general envelope the effect of structural stiffness variations with some exceedances. Only the local out-of-plane loads on some of the CB slabs exceed the loads obtained from the analyses of the CB model with full stiffness and SSE damping as shown on FSAR Table 3A.17.9.2-201. There are small sharp peak exceedances observed in some of the SDOF oscillator ISRS. The staff reviewed the methodology of addressing ISRS exceedances as discussed above and found them acceptable.

The North Anna 3 site-specific seismic demands including the effects of base case, SSSI, concrete cracking, and soil separation are described in FSAR Section 3A.18. FSAR Section 3A.18.1.2 presented the site-specific seismic load demand for the CB structures that are based on the envelope of the base case analyses results further adjusted to bound the effect of stiffness variation. Also presented, is a comparison of the site-specific demand with that of the standard design. Specifically, the staff verified during North Anna 3 Audit 2 that the applicant used the enveloping site-specific seismic demand in evaluating the ESBWR standard plant CB structures for acceptability at the North Anna 3 site. The staff's evaluation of the ESBWR standard plant CB structures for the site-specific demand is described in this SER in Section 3.8.4.

FWSC Structural Stiffness Variation Sensitivity Studies

The applicant in the response to RAI 03.07.02-14 (ADAMS Accession No. ML15222A240) stated that site-specific sensitivity evaluations of the effects of structural stiffness variation on the SSI response of the FWSC have been performed. They are described in the FSAR Section 3A.17.9.3 and in the Appendix B of the GEH Report WG3-U63-ERD-S-0001 Rev. 4, "Firewater Service Complex Seismic Analysis Report," (ADAMS Accession No. ML16148A131). The site-specific SSI analysis used a FWSC model with uncracked reinforced concrete properties for the concrete members using the OBE damping values (referred here as UC_{OBE} model) for determining the North Anna 3 site-specific ISRS demand and SSE damping values (referred here as UC_{SSE} model) for determining the North Anna 3 site-specific structural load demand. These analyses cases are shown in the FSAR Table 3A.15-203 as analysis cases 1 to 9. The analysis was performed for three subsurface profiles with the two input control motions, one applied at the bottom of the FWSC basemat at Elevation 282 ft and the other applied at the bottom of the concrete fill located at Elevation 220 ft. The UC_{SSE} model was analyzed only for the deep control motion applied at the bottom of the concrete fill because the use of UC_{SSE} with EL. 220' motion was based on comparison of results of the UC_{OBE} models with motion applied at the two different elevations. The envelope of responses obtained from appropriate combinations of these analyses cases constitutes the North Anna 3 base case for the site-specific seismic demand of the FWSC. The ISRS envelopes are based on six UC_{OBE} cases and load demand envelopes are based on three UC_{SSE} cases.

To evaluate the effect of potential concrete cracking, the applicant performed site-specific sensitivity SSI analyses of models with reduced stiffness properties and SSE damping (referred to here as CR_{SSE} model). These analysis cases are shown in the FSAR Table 3A.15-203 as analysis cases S1 through S6. The effect of the concrete cracking on the FWSC site-specific structural load demand is evaluated by comparing the enveloping seismic load demand obtained from the analysis of the UC_{SSE} models with those obtained from the analysis of the CR_{SSE} models. The effect of concrete cracking on the FWSC site-specific ISRS is evaluated by comparing the 5 percent damped broadened and valley filled ISRS results obtained from the SSI analysis of the UC_{OBE} models with those obtained from the analysis of the CR_{SSE} models.

The analyses of CR_{SSE} models were performed for BE, LB, and UB soil profiles for both the surface control motion applied at the FWSC basemat and the deep control motion applied at the bottom of the concrete fill. The applicant has used the guidance in ASCE 43-05 to establish the stiffness reduction factors for cracked concrete members, which is in accordance with the SRP Section 3.7.2 guidance.

The staff reviewed the modeling approach for the cracked and uncracked cases and the models used by the applicant in the sensitivity analyses for the stiffness variations and found them acceptable because: (a) the method is consistent with the approach used for the standard design, (b) the method is consistent with the guidance in SRP 3.7.2, (c) the sensitivity analyses accounted for concrete cracking with the combined effects of the potential variation of the subsurface soil profiles along with the two input control motions, and (d) the use of SSE damping for the cracked models is consistent with the high stress conditions that the FWSC structure would be subjected to during a fully cracked concrete condition.

According to the DCD, SDOF oscillators connected to the stick models are used to represent the out-of-plane seismic response of flexible slabs and walls in the buildings. Therefore, the use of SDOF oscillators in the UC_{OBE} and UC_{SSE} models are acceptable to capture the out-of-plane vibration mode up to 50 Hz for models with uncracked concrete. The staff reviewed the issue of SDOF oscillators for cracked-concrete models for the FWSC and confirmed that, as in the case of RB/FB and CB, the applicant decreased the stiffness properties of existing oscillator and added additional oscillators to the CR_{SSE} model to capture the modes of out-of-plane vibration of the cracked slabs up to a frequency of 50 Hz. FSAR Figure 3A.16.2-203 shows the configuration of the CR_{SSE} stick models for the FWSC with the additional SDOF slab oscillators shown in red. The development of these additional SDOF oscillators under fully cracked conditions is described in the GEH Report SER-DMN-014, Rev. 1, "Additional Oscillators for Fully Cracked Model for RAI 3.7.2-14(f)." No SDOF oscillators are added to the CR_{SSE} models to represent the out-of-plane vibrations of cracked wall because the fully cracked wall frequencies are above the 50 Hz range.

The staff reviewed the information provided in the FSAR Section 3A.17.9 and the GEH Report SER-DMN-014 and found the site-specific representation of the out-of-plane flexibilities of the slabs under a cracked condition for the FWSC acceptable because: (a) the applicant added additional oscillators to represent all modes of slab vibration up to 50 Hz under fully cracked condition, and (b) the additional SDOF oscillators were developed using the same method and eigenvalue analysis that were used for the standard design.

The NRC staff reviewed the results of the North Anna 3 site-specific evaluation presented in the response to RAI 03.07.02-14 and the supporting documents during North Anna 3 Audit 1 to verify that North Anna 3 site-specific demand with upper bound stiffness and OBE/SSE damping values provide site-specific seismic demands on the FWSC that envelop the effect of structural stiffness variations. FSAR Sections 3A.18.1.3 and 3A.18.2 respectively present the approach used for enhancing the site-specific base case seismic load demand and the ISRS to account for the effect of SSSI, concrete cracking, and soil separation. Specifically, the staff verified during North Anna 3 Audit 2 that the applicant used the enhanced site-specific seismic demand in evaluating the ESBWR standard plant FWSC structures for acceptability at the North Anna 3 site. Staff's evaluation of the ESBWR standard plant FSWC structures for the site-specific demand is described in this SER in Section 3.8.4.

SSSI Analysis

To ensure that the site-specific seismic design basis envelopes the site specific effects of SSSI, the staff requested in RAI 03.07.02-16 that the applicant provide in the FSAR an evaluation of the site-specific effect of SSSI on the North Anna 3 site-specific seismic demand. In the response to RAI 03.07.02-16 (ADAMS Accession No. ML15222A240) the applicant performed SSSI sensitivity analyses as described in the FSAR Section 3A.17.11. Evaluations are performed using the combined models of: (a) CB-RB/FB for evaluations of SSSI effects of the heavy RB/FB on the response of CB, (b) CB-FWSC for evaluations of SSSI effects of FWSC on the response of CB, and (c) FWSC-CB for evaluations of SSSI effects of CB on the response of FWSC. FSAR Table 3A.15-204 lists the cases used in the analyses for the SSSI effect of the RB/FB on the CB. FSAR Table 3A.15-205 and Table 3A.15-206 list the cases used in analyses for the SSSI effects of the FWSC on the CB and CB on the FWSC, respectively. These analyses cases and the results are documented in detail in the GEH Reports WG3-U73-ERD-S-0005, Rev. 3, “Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A271) and WG3-U73-ERD-S-0002, Rev. 6, “Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A270).

The staff notes that the RB/FB is considerably more massive than the CB, so the potential SSSI effect of the RB/FB on the CB is more significant than the effect of the CB on the RB/FB. On this basis, the applicant did not evaluate the SSSI effect of the CB on the RB/FB. The staff reviewed the ESBWR DCD and determined that the basis provided by the applicant for neglecting the SSSI effect of the CB on the RB/FB is consistent with the seismic analysis methodology described in the ESBWR DCD, Tier 2, Section 3A.8.11 and is therefore acceptable.

SSSI Combined Models of the CB and RB/FB

The applicant performed the SSSI analyses of the combined model designated as “CB-RB/FB” to evaluate the interaction effect of RB/FB on CB as described in the FSAR Section 3A.17.11. The combined model is shown in the FSAR Figure 3A.17.11-201. The combined model provides an explicit representation of the North Anna 3 site conditions between the two buildings and includes the effects of dynamic interaction between the RB/FB and CB. The details of the analyses and the results for the CB-RB/FB are documented in the GEH Report, WG3-U73-ERD-S-0005, Rev. 3, “Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A271). The SSSI analyses used the SASSI 2010 program with the MSM where only selected nodes of the excavated volume elements are specified as interaction nodes. GEH Report SER-DMN-011, Rev. 1 (ADAMS Accession No. ML15222A283) provides the benchmarking evaluation of the accuracy of the MSM solutions for the North Anna 3 site specific application. Staff’s evaluation of benchmarking of the MSM of the SASSI 2010 computer program is provided earlier in this Section Under the heading “*SSI Analysis Method*.”

The combined models consist of the lumped mass beam models of the CB and RB/FB described in the ESBWR DCD Section 3A.5.1 coupled with the finite element soil model of the subgrade with the site-specific strain compatible dynamic properties. The combined model also includes the Access Tunnel that is isolated from the RB/FB and CB and the near-field solid elements representing the structural and concrete fill materials placed below the Access Tunnel and surrounding the CB. The Access Tunnel is modelled using the shell elements. For comparison purposes, the subgrade dynamic properties and input motions used for the CB-RB/FB SSSI analysis are identical to those used for the SSI analysis of the CB standalone model. The passing frequencies used for the CB-RB/FB combined models shown in the FSAR Tables 3A.15-204 meet the 50 Hz criteria specified in DC/COL-ISG-1 guidance.

Based on staff’s review of the information provided in the FSAR, the technical reports, and the supporting calculations during North Anna 3 Audit 1, the staff finds the SSSI model representation of the CB and the RB/FB acceptable because: (a) the SSSI models explicitly capture the effects of dynamic coupling between the RB/FB and CB at the Unit 3 site, (b) the SSSI models use the same lumped mass beam models as the ones used in the EBSWR DCD, (c) the site specific subgrade properties and the input motions used in the SSSI CB-RB/FB models are identical to the corresponding subgrade properties and input motion used for the stand alone SSI model of the CB, which the staff reviewed and accepted as discussed earlier in this SER, (d) the selection of interaction nodes for the MSM is based on the conclusions of the North Anna 3 benchmarking report SER-DMN-011, Rev. 1, and (e) the maximum aspect ratio of the finite elements was within the aspect ratio limit of the SASSI2010 computer program which the staff found acceptable as discussed later in this SER.

SSSI Effect of RB/FB on CB (CB-RB/FB):

As discussed in the FSAR Section 3A.17.11, analyses of the CB-RB/FB SSSI models were performed for the UB and LB partial columns, and UB full column subgrade profiles representing strain-compatible dynamic soil/rock properties at the CB location, and corresponding in-layer input motions applied at the bottom of the CB foundation.

The site specific SSSI effects of the RB/FB on the CB site specific design basis were evaluated by comparing the results of site specific analysis of CB-RB/FB SSSI model cases listed in the FSAR Table 3A.15-204 with the corresponding CB site specific seismic design basis structural loads and ISRS that were developed as envelope of the results of design basis SSI analysis of the CB standalone models. Comparisons are also made with the corresponding design basis loads used for the standard design. These comparisons are shown in GEH Report, WG3-U73-ERD-S-0005, Rev 3, "Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report," (ADAMS Accession No. ML16076A271).

The staff reviewed the structural responses computed from the site-specific SSSI analyses in terms of the maximum forces and moments, lateral soil pressure on the below grade exterior walls, and the 5-percent damped ISRS at the key locations in the CB identified in ESBWR DCD, Tier 2, Appendix 3A. These results are documented in the GEH Report, WG3-U73-ERD-S-0005, Rev.3. Based on staff's review of the GEH Report and audit of the supporting calculations during North Anna 3 Audit 1, the staff noted that the site-specific seismic structural load demand for the CB does not always envelope the SSSI effects of the RB/FB on the CB. However, the applicant in the FSAR Section 3A.17.11 stated and the staff verified that the site specific SSSI induced shear demand (including the shear induced by torsion) is enveloped by the site-specific enveloping design basis loads specified in FSAR section 3A.17.13.2. The staff also concluded that the exceedance of the lateral pressure on the CB west wall facing the RB/FB has no effect on the CB below-grade wall design based on the supporting configuration of the CB west wall and the location of the lateral pressure exceedance as discussed in the FSAR Section 3A.17.11. With regard to any exceedance in the ISRS, the applicant stated in FSAR Section 3A.17.11 that any exceedance in the ISRS up to 50 Hz due to SSSI effect will be incorporated in the site specific design ISRS envelope. Since the CB site-specific ISRS are enhanced as described in FSAR Section 3A.18.2 for any exceedance due to SSSI effect, the staff found the applicant's approach acceptable.

SSSI Combined Models of the FWSC and CB:

The applicant performed the SSSI analyses of the combined model designated as "CB-FWSC" to evaluate the interaction effect of FWSC on CB and the combined model designated as

“FWSC-CB” to evaluate the interaction effect of CB on the FWSC as described in the FSAR Section 3A.17.11. The combined models are shown in the FSAR Figures 3A.17.11-202 and 3A.17.11-203. The details of the analysis and the results are documented in the GEH Report WG3-U73-ERD-S-0002, Rev 6, “Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report,” (ADAMS Accession No. ML16076A270).

The SSSI analyses used the SASSI 2010 program with the MSM where only selected nodes of the excavated volume elements are specified as interaction nodes. GEH Report SER-DMN-011, Rev. 1 “Benchmarking of SASSI 2010 MSM Results from North Anna 3 Site-Specific SSI Analysis,” provides the benchmarking evaluation of the accuracy of the MSM solutions for the North Anna 3 site specific application. The staff’s evaluation of benchmarking of the MSM of the SASSI2010 computer program is provided below under the heading *“Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM”* in this SER.

The combined models consist of the lumped mass beam models of the CB and FWSC described in the ESBWR DCD Section 3A.5.1 coupled with the finite element soil model of the subgrade with the site-specific strain compatible dynamic properties. The combined model includes the structural and concrete fill materials placed around the CB exterior walls and concrete fill placed below the CB and FWSC basemat. Structural and concrete fill materials surrounding the exterior of the CB and between the two structures are represented in the combined model as the near-field solid elements. For comparison purposes, the subgrade dynamic properties and input motions used for the CB-FWSC SSSI analysis are identical to those used for the SSI analysis of the CB standalone model. Similarly, the subgrade dynamic properties and input motions used for the FWSC-CB SSSI analysis are identical to those used for the SSI analysis of the FWSC standalone model. The passing frequencies used for the CB-FWSC and FWSC-CB combined models are shown in FSAR Tables 3A.15-205 and 3A.15-206.

Based on staff’s review of the information provided in the FSAR and the technical reports and supporting calculations during North Anna 3 Audit 1, the staff finds the SSSI model representation of the CB and the FWSC acceptable because: (a) the SSSI models use the same lumped mass beam models as the one used in the EBSWR DCD, (b) the site specific subgrade properties and the input motions used in the two SSSI models (CB-FWSC and FWSC-CB) are identical to the corresponding subgrade properties and input motion used for the stand alone SSI model of the CB and FWSC, which the staff reviewed and accepted as discussed earlier in this SER, (c) the selection of interaction nodes for the MSM is based on the conclusions of the North Anna 3 GEH Report SER-DMN-011, Rev. 1, and (d) the maximum aspect ratio of the finite elements was within the aspect ratio limit of the SASSI2010 computer program which the staff found acceptable as discussed below under the heading *“Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM”* in this SER.

SSSI Effect of FWSC on CB (CB-FWSC):

As discussed in the FSAR Section 3A.17.11, analysis of the CB-FWSC SSSI model was performed for the UB and LB full column profiles and corresponding in-layer input motions applied at the bottom of the CB foundation. The site specific SSSI effects of the FWSC on the CB site specific design basis were evaluated by comparing the results of site specific analysis of CB-FWSC SSSI model cases listed in the FSAR Table 3A.15-205 with the corresponding CB site specific seismic design basis structural loads and ISRS that were developed as envelope of the results of design basis SSI analysis of the CB standalone models. Comparisons are also made with the corresponding design basis loads used for the standard design.

The staff reviewed the structural responses computed from the site-specific SSSI analyses in terms of the maximum forces and moments and the 5-percent damped ISRS at the key locations in the CB identified in ESBWR DCD, Tier 2, Appendix 3A. These results are documented in the GEH Report WG3-U73-ERD-S-0002, REV. 6 (ADAMS Accession No. ML16076A270). Based on review of this report, the staff concluded that the site-specific North Anna 3 design basis seismic structural load demand for the CB envelope the SSSI effects of the FWSC on the CB response with the exception of the torsional demands on the CB. To address this exceedance the applicant performed calculations to demonstrate that the additional torsion-induced shear in the CB walls are enveloped by the enveloping shear load demands obtained from the site-specific design basis SSI analysis of the CB standalone model. During North Anna 3 Audit 1, the staff reviewed the supporting information and confirmed that the additional torsion-induced shear in the CB walls are enveloped by the enveloping shear load demands obtained from the site-specific SSI analysis of the CB standalone model.

GEH Report WG3-U73-ERD-S-0002, REV. 6 indicates that North Anna 3 site-specific design ISRS based on stand-alone SSI analyses in general envelope the results of the site-specific SSSI analyses of the CB-FWSC combined model. The staff noted that there was one exceedance in the ISRS at the top of the CB basemat in vertical direction near 50 Hz. The applicant in response revised FSAR Section 3A.17.11 to indicate that the CB site-specific ISRS are enhanced as described in FSAR Section 3A.18.2, if any of the sensitivity SSSI analyses of the CB-RB/FB and the CB-FWSC combined models yield 5 percent damped ISRS that exceed the corresponding CB site-specific design ISRS based on stand-alone SSI analyses up to 50 Hz. Since the CB site-specific ISRS are enhanced as described in FSAR Section 3A.18.2 for any exceedance due to SSSI effect, the staff found the applicant’s approach to include the effect of SSSI in the site-specific design envelop acceptable.

SSSI Effect of CB on FWSC (FWSC-CB):

FSAR Section 3A.17.11 and the GEH Report WG3-U73-ERD-S-0002, REV. 6 describe the site-specific evaluation of the SSSI effects of the CB on the FWSC seismic response. The evaluation is based on the comparison of the results of site-specific analysis of the FWSC-CB SSSI model cases (analysis cases FC1 through FC9) listed in the FSAR Table 3A.15-206 with the corresponding FWSC site specific seismic design basis structural loads and ISRS that were developed as an envelope of the results of SSI analysis of the FWSC standalone model for all profiles. The SSSI effects of the CB on the FWSC site-specific design basis loads (structural load demand) are evaluated by comparing the results of the site-specific analysis of FWSC-CB SSSI model with uncracked concrete and SSE damping values (cases FC7 through FC9) with the corresponding seismic demand obtained from the results of the standalone FWSC SSI analyses with the control motion applied at Elevation 220 ft. The effects of SSSI on the site-specific design ISRS (obtained from the standalone SSI analysis of the FWSC) are evaluated based on the ISRS results obtained from the SSSI analysis of the FWSC-CB model with uncracked concrete and OBE damping values (cases FC1 through FC6) with the control motion applied both at Elevation 282 ft. and 220 ft.

The staff reviewed the comparisons provided in the GE-Hitachi Report WG3-U73-ERD-S-0002, REV. 6 of SSSI envelopes (cases FC7 through FC9) with the site-specific SSI enveloping maximum horizontal and vertical load demands obtained from the FWSC standalone site-specific SSI analyses with uncracked properties and SSE damping values with deep input motion at EL 220 ft. Also presented in the report are comparisons of the site-specific seismic demand with those used in the standard design. These comparisons show that the SSSI effect of the CB amplifies some of the site-specific FWSC seismic demands obtained from the standalone SSI analysis and in some instances resulted in exceedance of the loads used in the standard design. The structural design evaluation of the FWSC under site-specific seismic loads exceeding those of the standard design is discussed in SER Section 3.8.4.

The staff reviewed FSAR Figures 3A.17.11-207 through 3A.17.11-209 which provide a comparison of the 5 percent damped ISRS obtained from the site-specific SSSI analysis of the FWSC-CB combined model with the corresponding 5 percent damped North Anna 3 site-specific SSI enveloping ISRS and the standard design ISRS. These Figures show that the SSSI effects of the CB result in significant exceedances in some of the North Anna 3 FWSC site-specific SSI enveloping ISRS.

Based on the above review of the site-specific SSSI effects of the CB on the FWSC response, the staff concluded that the seismic responses obtained from the standalone site-specific design basis SSI analysis of the FWSC do not envelope potential SSSI-induced amplification of the FWSC responses. The applicant in the FSAR Section 3A.17.11 indicated that the results obtained from the analysis of FWSC-CB SSSI model will be used to develop the FWSC site-specific design basis that will envelop the amplifications of the FWSC response due to the SSSI effect of the CB on FWSC. Since the applicant incorporated the results from the FWSC-CB SSSI analysis into the seismic design basis, the staff found this approach acceptable.

Soil Separation Analysis

Soil Separation Consideration for RB/FB and CB

In the FSAR Section 3A.12.2, the applicant stated that consideration of the partial and full embedment configuration in the RB/FB and CB SSI analyses bounds the effects of subgrade stiffness variation related to any potential soil separation. The staff concludes that the SSI analysis with a partial embedment configuration for the RB/FB and the CB bounds the effect of any soil separation because the partial embedment configuration (without the backfill) essentially represents a condition with complete soil separation.

Soil Separation Consideration for FWSC

To evaluate the effect of soil separation between concrete fill below the FWSC foundation and the surrounding soil, the applicant has performed additional evaluation and SSI/SSSI analyses for the FWSC. These analyses are described in Section 3A.17.14.5 of the FSAR and in the

GEH report WG3-U63-ERD-S-0001, Rev 4. The applicant estimated the separation depth from the results of SSI/SSSI analyses of FWSC and FWSC-CB models using the deep input motion at Elevation 220 ft that provides bounding seismic load demands on the FWSC structures. The resultant separation depths vary from case to case in a range of 3.90 m to 8.83 m. The applicant then performed sensitivity analyses to consider the effect of soil separation using the uncracked full column FWSC SSI model (see Table 3A.15-203) and the uncracked FWSC-CB SSSI model. These analyses considered the LB, BE, and UB soil profiles and were performed with concrete fill nodes disconnected from surrounding soils at elevations above the estimated soil separation depths. The applicant used the seismic demand obtained from the soil separation sensitivity analyses to evaluate the acceptability of the site-specific seismic demand established without the consideration of soil separation.

The staff reviewed and confirmed the analytical assumptions and the results obtained from the soil separation sensitivity analyses during North Anna 3 Audit 1 and North Anna 3 Audit 2. The staff found the estimated soil separation depths acceptable because the results generally agree with the ASCE 4-98 provision for soil separation, which is 6 m. The soil separation analyses showed that the maximum increase in structural demands was about 7 percent and the maximum increase in ISRS was about 30 percent, as indicated in FSAR Section 3A.17.14.5.

The applicant also evaluated the sliding stability of the FWSC foundation using the results of the sensitivity analyses of the FWSC standalone and FWSC-CB models, representing fully separated soil conditions and FSAR Table 3A.17.14.5-202 presents a summary of the stability analyses of the FWSC foundation against sliding at the basemat-concrete fill interface. Table 3A.17.14.5-202 also compares the results for lateral load demands on the FWSC shear keys obtained from the calculations accounting for the effect of soil separation with the results obtained from the design basis analyses of the fully bonded models (without soil separation). The comparison shows that the separation between the concrete fill and surrounding soil can amplify the lateral load demand on the FWSC shear keys up to 47 percent. The staff evaluation of the design of the FWSC shear keys against site-specific load demand is presented in SER Section 3.8.5.4.A.3.

These exceedances were not initially considered for the site-specific seismic demand established for the FWSC. The applicant subsequently revised FSAR Section 3A.17.14.5 to indicate that the site-specific evaluations of FWSC structures, basemat, and shear keys use the input seismic loads presented in FSAR Section 3A.18.1.3 which incorporate enhancements to bound all exceedances due to potential separation between the concrete fill and surrounding soil. For ISRS, the FWSC site-specific design ISRS are enhanced if any of the sensitivity analysis cases for soil separation yield 5 percent damped ARS that exceed the corresponding broadened ISRS by more than 10 percent at frequencies up to 50 Hz. The FSAR states that the use of the 10 percent criterion is reasonable considering the conservatism introduced by assuming fully separated condition on all four sides of the concrete fill at all times, which is unlikely during an actual SSE. The staff finds this basis to be acceptable because of the conservatism in the analyses.

The staff's evaluation of the capacity of the concrete fill below the FWSC is discussed in Section 2.5.4 of this SER.

Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM

In response to RAI 03.07.02-10 and RAI 03.07.02-13, (ADAMS Accession No. ML15222A240) the applicant indicated that the V&V of SASSI2010 program modules used in the North Anna 3 SSI analysis are performed in accordance with the Shimizu Quality Assurance Program. FSAR Section 3C.7.4 describes SASSI2010 and its V&V. In addition, the applicant also submitted to the staff the Shimizu Engineering Report SER-DMN-011, Rev. 0, "Benchmarking of SASSI 2010 MSM Results from North Anna 3 Site-Specific SSI Analysis" (designed herein as the North Anna 3 MSM Benchmark Report). The applicant has used the MSM of the SASSI programs because of the computational limitations with the size of the computer models using direct method (DM) for the North Anna 3 SSI and SSSI analyses of models embedded in softer in-situ soil.

The staff reviewed the North Anna 3 V&V and the MSM Benchmark reports. The North Anna 3 V&V Report includes 14 test problems; all were solved using the direct method of SASSI. The North Anna 3 MSM Benchmark report indicated that MSM is used for the North Anna 3 SSI and SSSI analyses of fully embedded models. The staff review focused on problems that are applicable to the North Anna 3 site-specific SSI analyses.

In summary, three main issues were identified with regard to SASSI2010 V&V: (1) models are not fine enough to validate the SASSI 2010 solutions up to 50 Hz and the report did not include a test problem to validate the SASSI kinematic SSI solutions for frequencies up to 50 Hz on a layered soil profile such as North Anna 3 site, (2) the results using the models with symmetry/anti-symmetry conditions are different from the full model, and (3) the validation of element aspect ratio is insufficient.

With regard to MSM Benchmarking, the staff identified one issue. To demonstrate the adequacy of MSM for the North Anna 3 application, the FWSC model was analyzed with FE and the UB soil profile only. Since the LB and BE soil profiles lead to lower fundamental frequencies for the excavated soil volume than the UB soil profile with the same interaction nodes, they represent a higher potential that MSM could produce spurious results at lower frequencies. Therefore, the staff requested that the applicant justify why the MSM provides adequate solutions compared with DM for the LB soil profile.

Therefore in a follow-up RAI 3.7.2-26 (ADAMS Accession No. ML15222A240), the staff requested additional information to address the above issues for the SASSI2010 V&V and MSM Benchmark. In response to this RAI, the applicant provided as reference a non-proprietary report to support the ESBWR DCD, Shimizu Engineering Report, SER-DMN-020, Rev. 1, "*Validation Summary Report for SASSI 2010 and Appendix with Validation Problems for RAI 03.07.02-10 / RAI 03.07.02-26 Response.*" (ADAMS Accession No. ML15222A280). The staff reviewed this summary report prior to the North Anna 3 Audit 1. The staff also reviewed and confirmed the evaluation in the detailed proprietary V&V report, S/VTR-SAS, Revision 1, "Validation Test Report for SASSI 2010 Version 1" during the North Anna 3 Audit 1.

The North Anna 3 V&V test problems were revised to use a refined model and a higher shear wave velocity to be consistent with the North Anna 3 site condition, resulting in a passing frequency up to 70 Hz. FSAR Section 3C.7.4.2 was revised to indicate the passing frequency of the validation report to be 70 Hz. Additional soil layers are added to reach a depth of 325 ft in order to achieve a better comparison with "Day's solution."[3] The response also indicates that

[3] *Day, S. M. 1977, "Finite Element Analysis of Seismic Scattering Problem," Doctoral dissertation, University of California, San Diego.*

both translational and rocking responses are in good agreement with "Day's solution." Since the model passing frequency is higher than 50 Hz, the staff concludes that this RAI is closed and the issue is resolved.

To justify the applicability of SASSI2010 for the SSI analyses to the North Anna 3 layered profiles, the North Anna 3 RAI response references the DTE Energy Company Fermi 3 Reference RCOL in its response to RAI 03.07.02-11, dated July 9, 2013, (ADAMS Accession No. ML13192A302) which also utilizes SASSI2010. Because both sites are similarly layered sites and the contrast in stiffness between the soft soil and the underlying rock is more pronounced at the Fermi 3 site than at the North Anna 3 site, the staff found the response acceptable.

For the issue of correct application of symmetry/anti-symmetry conditions, the RAI response indicates that the observed differences in the responses of the full model and the half model were due to the different coordinate system: the full model using the orthogonal coordinate system and the half model using a cylindrical coordinate system. The revised results using a consistent coordinate system show the difference is negligible. As such, the staff found the response acceptable.

For the issue of validation of the maximum element aspect ratio, the North Anna 3 V&V report is revised to include comparison of maximum absolute acceleration and 5 percent damped ARS for additional locations pertaining to the 3D solid brick elements and thin shell elements that have the largest aspect ratios, in addition to the locations at the top of the CB lumped mass stick model and on the top of the CB basemat. The RAI response indicates that the difference of the maximum acceleration is less than 2 percent and the 5 percent-damped ARS shows good agreement at all nodal locations. The staff concludes that this issue is resolved.

The RAI response indicates that the MSM benchmark study of the FWSC model has been expanded to include an additional case for the LB soil profile besides the original UB soil profile. Section 4 of the MSM benchmark report summarizes the results of the SASSI2010 benchmarking analysis of the FWSC model with the revised 2013 GMPE-based subgrade properties. The benchmark analysis of the FWSC model was performed up to a passing frequency of 36 Hz, while the case of UB soil profile was analyzed up to 70 Hz. The passing frequency of 36 Hz, although lower than 50 Hz, is consistent with the cases of the North Anna 3 FWSC LB soil profile, which do not dominate the enveloping response beyond 25 Hz. The comparison of DM and MSM indicates that the differences in the transfer functions, ISRS, and other seismic responses are very small, indicating that MSM is accurate as compared to DM to the FWSC model. As such, the staff finds the use of SASSI2010 MSM acceptable.

ACS SASSI was used to perform sensitivity analyses for Unit 3 site-specific SSI analysis for Seismic Category I structures. Both the SASSI2010 and ACS SASSI use the same frequency-domain complex-response methodology. FSAR Section 3C.7.6 describes ACS SASSI and its V&V. The V&V of ACS SASSI is also documented in Appendix I to WG3-U71-ERD-S-0001, Rev. 4, "Reactor/Fuel Building Complex Seismic Analysis Report" (ADAMS Accession No. ML16097A203, ML16097A204). During the North Anna 3 Audit 1, Dominion discussed ACS SASSI Product Acceptance Test and other relevant documentation. The verification was performed utilizing the RB/FB model with upper bound structural stiffness properties and OBE damping values for the UB full column profile. Comparisons of transfer functions, ISRS, and other seismic responses with SASSI 2010 indicate that the differences are generally small. The

ACS SASSI MOTION module algorithm produces slightly higher ISRS results at higher frequencies than the SASSI2010. Overall, the level of differences do not affect the conclusions made from the structural stiffness variation study. The applicant documented the comparison of SASSI2010 and ACS SASSI results in FSAR Section 3A.10.1. Based on the above evaluation, the staff concludes that the use of ACS SASSI for North Anna 3 stiffness variation sensitivity analyses is acceptable.

FWSC SSI Confirmatory Analysis

The staff performed a confirmatory SSI analysis of the FWSC using the model provided by the applicant. The purpose of the staff's confirmatory analysis was to assess some of the calculations reported by the applicant. The confirmatory analysis consisted of a base case and a case for soil separation between the concrete fill and surrounding soils. The base-case represents the uncracked concrete properties, OBE damping, the UB soil profile, and full embedment. The in-column control motion at the bottom of the concrete fill (at Elevation 220 ft) was used as the input ground motion. The analysis was performed separately for each of the three directional components of the input ground motion and the results were combined in a manner consistent with what was used by the applicant for comparison purposes. The staff used ACS SASSI (V. 3.0.0) whereas the applicant used SASSI 2010. Both programs were verified and validated by the applicant for use in North Anna 3 SSI analysis as discussed under the heading *"Verification and Validation of SASSI 2010 and ACS SASSI and Benchmarking of the MSM"* above. The staff compared the results of the staff's base-case analysis with the corresponding results reported by the applicant in the FWSC SSI analysis report (GEH Report WG3-U63-ERD-S-0001, Rev. 4; (ADAMS Accession No. ML16148A131) and found the results were in good agreement.

In order to assess the impact of soil separation on the seismic responses of the FWSC superstructure and concrete fill, the staff performed an analysis of a case that considers soil separation by removing from the base-case model the spring elements connecting the concrete fill elements and the excavated soil volume elements for an assumed separation depth. In the staff's confirmatory analysis, the soil separation depth was assumed to be 6 m below grade on all four sidewalls of the concrete fill based on the ASCE 4-98 guideline, which is different from the values used by the applicant and serves for the purpose of confirmatory analysis using reasonably simplified assumptions. The applicant used varying depths of separation based on soil pressure estimates (8.83 m for the NS walls and 3.90 m for the EW walls for the UB subgrade profile). Also, the model provided to the staff was based on the OBE damping values whereas the model actually used by the applicant in soil separation analysis was based on the SSE damping values. Considering these modeling differences, the staff found there was an acceptable agreement between the analyses of the soil-separation case by the applicant and the staff.

Supplemental Information / Departure

- NAPS SUP 3.7-5 — Interaction of Non-Category I Structures with seismic Category I Structures
- NAPS SUP 3.7-8 — Interaction of Non-Category I Structures with seismic Category I Structures – RWB Wall Capacity Pressure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

Interaction of Non-Seismic Category I Structures with Seismic Category I Structures

NRC staff reviewed NAPS SUP 3.7-5 and NAPS DEP 3.7-1 as they relate to North Anna 3 COL FSAR Section 3.7.2.8 on seismic interactions of non-seismic Category I structures with seismic Category I structures as follows:

As supplemental information to ESBWR DCD 3.7.2.8, the applicant refers to the FSAR Figure 2.1-201 and ESBWR DCD Figure 1.1-1 for the locations of site structures. FSAR Section 3.7.2.8 indicates that site-specific non-seismic Category I structures (outside the scope of the ESBWR DCD) are separated from seismic Category I structures by at least a distance equal to their height above grade. Therefore, the collapse of any site-specific non-seismic Category I structure will not cause the non-seismic Category I structure to strike a seismic Category I structure. The locations of structures are depicted in FSAR Figure 2.1-201. The staff concludes that this is consistent with SRP Acceptance Criterion 3.7.2.II.8.A and is therefore acceptable.

FSAR Section 3.7.2.8 states that two sets of site-specific seismic response analyses are performed using the North Anna 3 site-specific design ground motion and subgrade dynamic properties to demonstrate the adequacy of the ESBWR standard plant:

- Site-specific SSI analyses of the standalone TB, RW, SB, and Ancillary Diesel Building (ADB) structures following methodology consistent with the site-specific seismic SSI analyses of the Seismic Category I structures presented in the FSAR Section 3.7.2.4.

- Site-specific seismic structure-soil-structure interaction (SSSI) analyses to evaluate any adverse effects of seismic interaction between the TB, RW, SB, and ADB structures and adjacent Seismic Category I structures.

Results of these site-specific seismic SSI and seismic SSSI analyses will be discussed as part of the ITAAC completion package for the TB, RW, SB, and ADB structures to demonstrate that acceptance criteria in FSAR Tier 1 ITAAC Tables 2.4.15-1, 2.4.16-1, 2.4.17-1, and 2.4.18-1, respectively, are met.

The design and analysis of the non-Seismic Category I structures (TB; SB; and ADB) and the RW-IIa identified in ESBWR DCD, Tier 2, Section 3.7.2.8 will be completed as part of the detailed design phase for the ESBWR standard plant design, per DCD Tier 2, Section 3.7.2.8.1 for the TB, Section 3.7.2.8.2 for the RWB, Section 3.7.2.8.3 for the SB, and Section 3.7.2.8.4 for the ADB; and DCD Tier 1, ITAAC Tables 2.16.8-1 for the TB, 2.16.9-1 for the RW, 2.16.10-1 for the SB, and 2.16.11-1 for the ADB.

The staff found the applicant's approach to address the site-specific effects on the seismic analysis and design of non-Seismic Category I buildings acceptable because: (a) the site-specific SSI analysis and seismic evaluation of these structures are performed following the same method as the one used for the Seismic Category I buildings described in the FSAR Section 3.7.2.4 which the staff found acceptable and (b) the site-specific effects of SSSI with adjacent Seismic Category I structures are evaluated following an approach consistent with the approach used for the Seismic Category I structures which the staff found acceptable.

<u>Interaction of Non-Seismic Category I Structures with Seismic Category I Structures – RWB Wall Capacity Pressure</u>

The NRC staff reviewed NAPS SUP 3.7-8 related to the dynamic pressure capacity of the RWB exterior walls in meeting the requirements of safe separation distance from the liquid hydrogen storage tanks as follows:

In FSAR Section 2.2.3.1.3, the applicant provided the licensing basis to ensure that the nearest key structures meet the safe separation distance to the liquid hydrogen tank. To meet the requirement for safe separation distance, the nearest key structures should have a static wall pressure capacity of 3 psi. In order to assess that the static wall pressure capacity for the applicable structures are met, the staff in RAI 02.02.03-10 requested the applicant to provide in the FSAR an analysis demonstrating that the ESBWR standard plant static wall pressure capacity is at least 3.0 psi for the applicable structures.

In response to RAI 02.02.03-10 (ADAMS Accession No. ML15051A288), the applicant stated that the key structures nearest to the liquid hydrogen tank are the FB (Seismic Category I) and the RWB. The applicant performed calculation for the FB based on the design input (e.g. wall size, span, etc.) determined from the ESBWR DCD Figure 3G.3-5 to demonstrate that the static wall pressure capacity is at least 3 psi. The staff reviewed the calculation included in the response to the RAI and agreed with the applicant's determination that the static wall pressure capacity for the FB is at least 3.0 psi. The staff also confirmed that the design input (e.g., area of tension reinforcement, dimensions of the wall, span, specified yield strength of reinforcement and concrete, etc.) used for establishing the wall pressure capacity for the FB is consistent with the design information provided in the ESBWR DCD.

For the RW, the applicant stated that the detailed design of the RWB has not been finalized. The applicant stated that the final design of the RWB will be verified through ITAAC. In the FSAR 3.7.2.8.2, the applicant stated that the RWB exterior walls will have a static wall pressure capacity of at least 3 psi. ACI 349 will be used in the final design. The staff reviewed the pertinent portion of the FSAR and the proposed site-specific ITAAC (FSAR Tier 1 ITAAC Tables 2.4.16-1) for the RWB. The staff confirmed that the applicant has added under the design commitment a specific requirement that the RW will have an exterior wall static pressure capacity of at least 3.0 psi. On the above basis the staff found the resolution of this issue acceptable.

3.7.2.5 Post Combined License Activities

Site-specific ITAAC and corresponding acceptance criteria for non-seismic Category I structures within the scope of the ESBWR DCD are described in the COLA Part 10 Tables 2.4.2-1, 2.4.15-1, 2.4.16-1, 2.4.17-1, and 2.4.18-1. The review of these site-specific ITAAC is in Section 3.7.2.4 of this SER.

3.7.2.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC 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 North Anna 3 FSAR related to this section. All nuclear safety issues relating to the seismic system analysis that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.2 of NUREG–0800, other NRC RGs, and the Interim Staff Guidance. The staff finds that the applicant has addressed the seismic system analysis in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.7.2.3 of this SER.

3.7.3 Seismic Subsystem Analysis

3.7.3.1 Introduction

This North Anna 3 FSAR section addresses the seismic analysis methods and acceptance criteria used for the ESBWR seismic Category I and non-seismic Category I subsystems (equipment and piping) that are qualified to satisfy the performance requirements according to their seismic Category I or seismic Category II designations. Input motions in the form of ISRS and displacements for the analysis and qualification are usually obtained from the primary system dynamic analysis described in the FSAR Section 3.7.2. Non-seismic Category I systems are designed or physically arranged (or both) to prevent the SSE from causing unacceptable structural interactions with or the failure of seismic Category I systems. The ESBWR method for a standard plant seismic analysis of the seismic Category I and non-seismic Category I subsystems is in Section 3.7.2 of ESBWR DCD, Tier 2, Revision 10.

3.7.3.2 Summary of Application

Section 3.7.3 of the North Anna 3 COL FSAR, Revision 9, incorporates by reference Section 3.7.3 of ESBWR DCD, Revision 10. In addition, in FSAR Section 3.7.3.13, Revision 9, the applicant provides the following:

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

This departure is described in North Anna 3 COL FSAR Part 7, Departures Report. The site-specific horizontal and vertical seismic response spectra as shown in North Anna 3 COL FSAR Figures 2.0-201 through 2.0-204 exhibit exceedances at certain frequencies, when compared to the ESBWR CSDRS. Therefore, the applicant In FSAR Section 3.7.3.13 indicated that the seismic input for the analysis of the seismic Category I buried piping and tunnels will consist of both the single envelope design response spectra defined in DCD Table 3.7-2, using applicable scale factors, as well as the site-specific FIRS.

3.7.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic subsystem analysis, and the associated acceptance criteria, are in Section 3.7.3 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the seismic design basis to reflect appropriate consideration of the most severe earthquakes historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated. In addition, SSCs important to safety should be designed to withstand the effects of earthquakes without losing the capability to perform their intended safety functions.

- 10 CFR Part 50, Appendix S, as it relates to the horizontal component of the SSE ground motion in the free-field at the foundation level of the structures to be an appropriate response spectrum with a peak ground acceleration of at least 0.1g; and if the OBE is chosen to be less than or equal to one-third of the SSE ground motion, it is not necessary to conduct explicit response or design analyses in accordance with Section IV.(2)(i)(A) of 10 CFR Part 50, Appendix S, and the requirement of taking into account SSI effects.

In addition to the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.3 the basis includes the following:

- SRP Section 3.7.1, 3.7.2, and 3.7.3 guidance as applied to seismic Category I subsystems and components for site-specific seismic analysis.

- DC/COL-ISG-1, "Interim Staff Guidance on Seismic Issues of High Frequency Ground Motion," and DC/COL-ISG-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses" in reviewing the seismic input and the SSI dynamic model acceptability for the North Anna 3 site.

- RG 1.61 to determine the acceptability of the damping values used in the structural model.

3.7.3.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.7.3 of the ESBWR DCD. The staff reviewed Section 3.7.3 of the North Anna 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this section. The staff reviewed the information in the NA3 FSAR as follows:

Departure

- NAPS DEP 3.7-1 Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

Seismic Category I Buried Piping, Conduits and Tunnel

FSAR Section 3.7.3.13 describes analysis procedure for Seismic Category I buried piping, conduits, and tunnels, as well as buried Safety Class RW-IIa radwaste piping installed in trenches or tunnels. This FSAR section indicates that "Seismic input motions for the portions located below ground are based on the single envelope design response spectra as defined in DCD Table 3.7-2, using applicable scale factors, and site-specific SSE FIRS." Since site-specific seismic input were not established in the FSAR Section 3.7.1, Revision 6 for the buried SSCs, the applicant was requested in RAI 03.07.03-1 to describe in the FSAR how the seismic input motions for the applicable buried structures would be developed. The applicant was also requested to provide site-specific ITAAC to address the verification of implementation of the commitment that a site-specific analysis following the method as specified in the FSAR for seismic Category I structures has been conducted demonstrating that the as-built Seismic Category I buried piping, conduits, and tunnels conform to their design.

In response to RAI 03.07.03-1 (ADAMS Accession No. ML14204A459), the applicant revised the FSAR Section 3.7.3.13 to describe the development of the seismic input motions for the applicable buried structures. FSAR Section 3.7.3.13, Revision 9 states that the site specific FIRS will be used to define the design input ground motion at the bottom elevations of Seismic Category I buried piping, conduits, and tunnels following the same methodology as used for the development of full column FIRS for the design of Seismic Category I buildings as described in FSAR Sections 2.5.2 and 3.7.1. These FIRS will consider, as applicable, the variations of subgrade conditions and the strain-compatible dynamic properties of in-situ subgrade or backfill materials under and above these structures and components. The FIRS will be amplified as necessary to include the effects of the adjacent heavy foundations on the free field motion and to address the effects of structure-soil-structure interaction on the seismic response of these buried piping, conduits, and tunnels. The applicant also added site-specific ITAAC in FSAR Tier I Sections 2.4.20 through 2.4.22 to verify that site-specific analyses, following the method as specified in the FSAR for seismic Category I structures, have been conducted and to demonstrate that the as-built applicable buried structures conform to their design. The staff found the applicant's approach to develop the site-specific input used for analysis and design of seismic Category I and safety class RW-IIa buried piping conduits, and tunnels acceptable because: (a) the site-specific seismic input is developed following the same method as the one used for the Seismic Category I structures, (b) the site-specific SSE FIRS are amplified to address the effect of adjacent heavy foundations on the seismic input to the buried piping, conduits, and tunnels, (c) the input for the seismic analysis of the buried piping and tunnels consist of both the single envelope design response spectra defined in DCD Table 3.7-2, using applicable scale factors, as well as the site-specific FIRS, and (d) FSAR Tier 1 ITTAC Tables 2.4.20-1, 2.4.21-1, and 2.4.22-1 have been added to verify that a site-specific analyses, following the method as specified in FSAR Section 3.7.1 have been conducted for these as-built buried structures.

3.7.3.5 Post Combined License Activities

The applicant identifies the following site-specific ITAAC for as-built verification of Category I buried structures:

- FSAR Part 10 Table 2.4.20-1, "ITAAC for Seismic Category I Buried Piping, Conduits and Tunnels."

- FSAR Part 10 Table 2.4.21-1, "ITAAC for Access Tunnel"

- FSAR Part 10 Table 2.4.22-1, "ITAAC for Radwaste Tunnel"

3.7.3.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC 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 North Anna 3 FSAR related to this section. All nuclear safety issues relating to the seismic subsystem analysis that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.3 of NUREG–0800, other NRC RGs, and the Interim Staff Guidance. The staff finds that the applicant has addressed seismic subsystem analysis in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.7.3.3 of this SER.

3.7.4 <u>Seismic Instrumentation</u>

3.7.4.1 Introduction

The seismic instrumentation program provides time history data on the seismic response of the free-field containment structure and other seismic Category I structures. The seismic instrumentation program is annunciated in the control room when triggered by a seismic event. Installation of instrumentation that is capable of adequately measuring the effects of an earthquake at the plant site is also addressed. The criteria for the seismic instrumentation include the following:

- Comparison with RG 1.12

- Location and description of the instrumentation

- Control room operator notification

- Comparison of measured and predicted responses

- Tests and inspections

3.7.4.2 Summary of Application

Section 3.7.4 of the NAPS 3 COL FSAR, Revision 9, incorporates by reference Section 3.7.4 of the ESBWR DCD, Revision 10. In addition, in Section 3.7.4, the applicant provided the following:

Supplemental Information

- NAPS DEP 3.7-1

NAPS DEP 3.7-1 describes the SSE ground motion for both the ESBWR Standard Plant and the site-specific SSE representative of the site-specific seismological and geological conditions.

- NAPS SUP 3.7-6

In NAPS SUP 3.7-6, the applicant committed to implementing the seismic monitoring program prior to receiving fuel on site. In addition, the applicant provided details about how the location of the free-field seismic sensor will be selected, and appropriate transfer functions will be determined, to ensure that ground motions recorded at the sensor location are consistent with the geologic conditions under the facility.

Overall Summary

The applicant specified that the SSE for the proposed facility is defined by two separate spectra: the CSDRS for ESBWR SSCs and the site-specific FIRS representative of the site-specific geologic and seismological conditions. Based on the development of two SSE spectra, the applicant used two spectra to define the plant shutdown OBE. For the purposes of exceedance checks used to determine if plant shutdown is required, the applicant defined the OBE as (1) one-third of the CSDRS that define the free-field ground motion at the bottom of the RB/FB and CB foundations and (2) one-third of the site-specific SSE at-grade as described in FSAR Section 3.7.1.1.6. The applicant specified that recorded ground motions must exceed both OBE spectra for the plant to shut down.

As described in Section 2.5.4 of the FSAR, the site subsurface is characterized by significant topographic relief in weathering and subsurface geology. Therefore, the applicant provided a description of how it will select the location of the free-field seismic instrument at the site. In addition, the applicant stated that it applied the appropriate spectral ratios to recorded ground motions to account for potential differences between subsurface geologic conditions at the location of the free-field instrument and the power block area.

3.7.4.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic instrumentation, and the associated acceptance criteria, are in Section 3.7.4 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix S, requires instrumentation to be provided so that the seismic response of safety-related nuclear plant features can be evaluated promptly after an earthquake.

- 10 CFR Part 50.55a, “Codes and standards.”

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.4 is documented below:

- RG 1.12 Revision 2, “Nuclear Power Plant Instrumentation for Earthquakes”

- EPRI Report NP-6695, “Guidelines for Nuclear Plant Response to an Earthquake”

- EPRI Report NP-5930, “A Criterion for Determining Exceedance of the Operating Basis Earthquake”

- EPRI Technical Report TR-100082, “Standardization of the Cumulative Absolute Velocity,” as permitted by RG 1.166

- RG 1.166, “Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions”

- RG 1.167, “Restart of a Nuclear Power Plant Shut Down by a Seismic Event”

3.7.4.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.7.4 of the ESBWR DCD, Revision 10. The staff reviewed Section 3.7.4 of the NAPS 3 COL FSAR, Revision 9 and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff’s review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

The staff reviewed the following supplemental information in the COL FSAR:

Supplemental Information

- NAPS DEP 3.7-1

The site-dependent SSE at grade is defined by enveloping the following two spectra:

1. Performance Based Surface Response Spectra PBSRS calculated at grade (Elevation 290 ft) from full soil column analyses for RB/FB and CB and,

2. The minimum required response spectra defined as the RG 1.60 broadband horizontal and vertical response spectra at 5 percent damping anchored to 0.1g at PGA to satisfy the requirements of SRP 3.7.1.

The applicant defined the site-dependent OBE at grade as one-third of the site-dependent SSE at grade. The site-dependent OBE response spectra at grade are one reference against which the applicant will perform OBE exceedance checks for the purpose of plant shutdown, as described in Section 3.7.1 of the FSAR. FSAR Section 3.7.4.4 includes the criteria used to determine whether a plant shutdown is required following a seismic event.

FSAR Section 2.5.2.6 presents the horizontal and vertical PBSRS at grade. The horizontal and vertical 5 percent damped site-dependent SSE spectra at grade are presented in FSAR Figures 3.7.1-265 and 3.7.1-266, respectively.

The applicant calculated the horizontal and vertical free-field site-dependent OBE at grade as one-third of the site-dependent SSE at grade and presented in FSAR Figure 3.7.1-267.

The 5 percent damped pseudo velocity response spectra for site-dependent OBE at grade is determined by dividing the acceleration response spectra values at each frequency point (*f*) by $2\pi f$. The digital values for the site-dependent SSE and OBE at grade are presented in FSAR Tables 3.7.1-216 and 3.7.1-217, respectively.

The plant is shut down if the walkdown inspections discover damage to equipment that would affect the safe operation of the plant, or the recorded motion in the free-field in any of the three directions (two horizontal and one vertical) exceeds both the certified design and site-specific response spectrum limits and the cumulative absolute velocity limit as follows:

- Certified design response spectrum limit is exceeded if:
- at frequencies between 2 and 10 Hz, the recorded response spectral accelerations of 5 percent damping exceed one-third of the corresponding CSDRS values or 0.2g, whichever is greater; or
- at frequencies between 1 and 2 Hz, the recorded response spectral velocities of 5 percent damping exceed one-third of the corresponding CSDRS values or 6 in/sec (152.4 mm/sec), whichever is greater.

Site-specific response spectrum limit is exceeded if:

- at frequencies between 2 and 10 Hz, the recorded response spectral accelerations of 5 percent damping exceed the corresponding site dependent OBE at grade presented in FSAR Table 3.7.1-216 or 0.2g, whichever is greater; or
- at frequencies between 1 and 2 Hz, the recorded response spectral velocities of 5 percent damping exceed the corresponding OBE values presented in FSAR Table 3.7.1-217 or 6 in./sec (152.4 mm/sec), whichever is greater
- Cumulative absolute velocity limit is exceeded if the cumulative absolute velocity value calculated according to the procedures in EPRI TR-100082 (“Standardization of the Cumulative Absolute Velocity”, EPRI, Palo Alto, CA, December 1991) is greater than 0.16g/sec.

In RAI 3.7.4-2, the staff noted that the applicant considers two different spectra, the site specific SSE and the CSDRS, when determining if a recorded ground motion exceeds the OBE ground motion. The staff requested that the applicant specify how this definition of OBE exceedance meets the requirements of Appendix S to Part 50, and is consistent with the guidance in ISG-01.

In its response, the applicant stated that all safety related SSCs are designed, analyzed, and qualified to meet both the ESBWR CSDRS and the site-specific FIRS (Figure 3.7.4-1). The applicant also clarified that an OBE exceedance is declared when a recorded ground motion exceeds both the (a) CSDRS-derived and (b) site-specific OBE, but that these exceedances need not occur at the same frequency (i.e. envelope of (a) and (b) are not considered). For example, an earthquake response spectrum that falls below the envelope of (a) and (b), but exceeds (b) at low frequency and (a) at high frequency, would be considered an OBE exceedance, requiring plant shutdown if other criteria, as discussed in FSAR Section 3.7.4.4, are also met. Finally, the applicant stated that the consideration of (a) for determining the OBE at grade is conservative, because this selection neglects the effects of ground motion amplification or site response between the elevation of the RB/FB and CB foundations and plant grade.

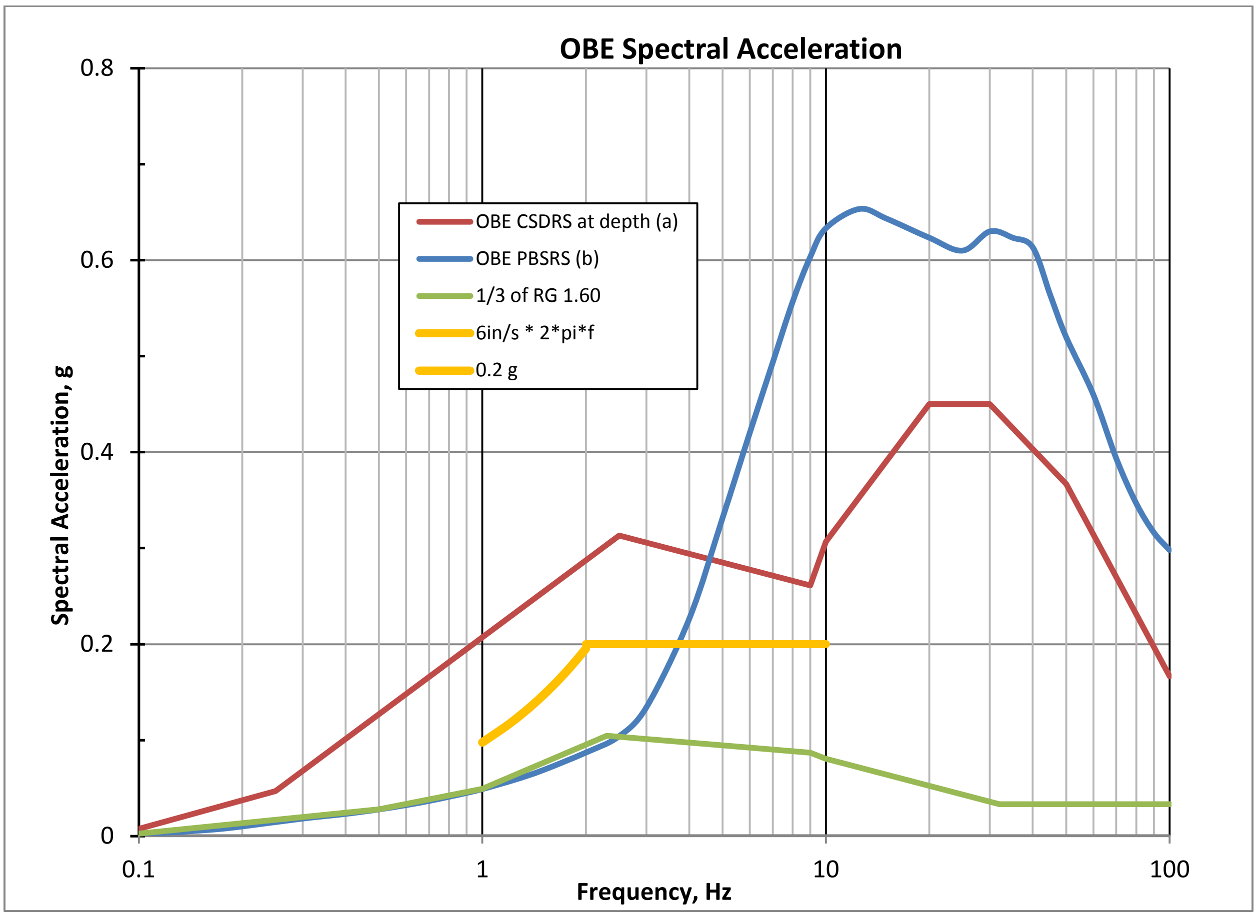

Figure 3.7.4-1. Plot comparing the CSDRS derived OBE (a) and the site-specific OBE (b) with the other requirements used to determine an OBE exceedance.

In Section 3.7.1 of Revision 9 the applicant stated that the response spectra of the 2011 **M** 5.8 Mineral, Virginia earthquake recorded at the Unit 1 containment mat, are closely representative of the Unit 3 site-specific partial column outcrop FIRS. The applicant provided comparisons confirming that the Unit 3 CSDRS envelopes the earthquake recorded motions in East-West, North-South, and vertical directions. Since the horizontal and vertical CSDRS are included in the Unit 3 SSE as the licensing basis for all Seismic Category I SSCs, the August 23, 2011, **M** 5.8, Mineral, Virginia earthquake Unit 1 containment mat recordings are considered within the OBE criteria defined above for the Unit 3 SSCs.

The staff reviewed the applicant's RAI response and FSAR modifications. The applicant's response and proposed modifications adequately explain that the OBE for the site is not defined by the envelope of spectra (a) and (b), but by the individual exceedance of both. In addition, the applicant's response and proposed modifications clarify that all safety related SSCs are designed to both spectra. Therefore, the staff agrees that the proposed OBE criteria for the North Anna site meet the criteria in Appendix S of 10 CFR Part 50 and the guidance in ISG-01 and considers RAI 3.7.4-2 resolved.

- NAPS SUP 3.7-6 Seismic Instrumentation

The seismic sensor located in the free field near the power block structures is used to determine OBE exceedance. Because of the complex subsurface stratigraphy of the site, the staff requested, in RAI 3.7.4-3, that the applicant describe how it would select a site such that recorded ground motions in the free field adequately characterize ground motions experienced by the power block structures.

In its response to RAI 3.7.4-3, the applicant stated that the subsurface geologic structure of the site is considered in determination of the location of the free-field seismic instrument at the site, and the appropriate spectral ratios will be applied to the acceleration response spectra and velocity response spectra of the recorded motion to account for potential differences between the subsurface geologic conditions at the location of the free-field instrument and the power block area.

The staff reviewed the applicants RAI response and proposed FSAR changes. Based on the fact that the free-field data will be scaled using the spectral transfer function to the appropriate level at the power block area, the staff finds the response acceptable. Therefore, the staff considers RAI 3.7.4-3, resolved and closed.

The staff reviewed NAPS SUP 3.7-6 related to the seismic instrumentation included under Section 3.7.4 of the North Anna 3 COL FSAR. The staff concluded that because the seismic instrumentation and monitoring program will be installed and operational before receiving fuel at the NAPS site, and the subsurface geologic structure of the site is considered in determination of the location of the free-field seismic instrument at the site, NAPS SUP 3.7-6 is acceptable.

3.7.4.5 Post Combined License Activities

There are no post COL activities related to this section.

3.7.4.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to seismic instrumentation, and no outstanding information is expected to be addressed in the COL FSAR related to this section. There are no unresolved nuclear safety issues relating to the seismic instrumentation that were incorporated by reference.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.4 of NUREG–0800, and other NRC regulatory guides. The staff finds that the applicant addressed seismic instrumentation in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant satisfied the relevant requirements of the regulations described in Section 3.7.4.3 of this SER. In addition, the staff concludes that the relevant information presented in the COL FSAR is acceptable, because the installation and operability of the seismic monitoring program will be demonstrated before receiving fuel at the North Anna 3 site.

3.7.5 Site-Specific Information

3.7.5.1 Introduction

Section 3.7.5 of the ESBWR DCD references FSAR Chapter 2 Table 2.0-1 which defines the envelope of site-related parameters that the ESBWR Standard Plant is designed to accommodate. These parameters envelope most potential sites in the United States.

The ESBWR DCD Table 2.0-2 references the guidance in NUREG-0800 Standard Review Plan (SRP) and defines the limits imposed on the acceptance criteria in Section II of the various SRPs by (1) the envelope of site-related parameters that the ESBWR plant is designed to accommodate, and (2) the assumptions, both implicit and explicit, related to site parameters that were employed in the evaluation of the ESBWR design.

3.7.5.2 Summary of Application

In the North Anna 3 COL FSAR Section 3.7.5, Revision 9, the applicant incorporated by reference Section 3.7.5 of ESBWR DCD, Revision 10.

In addition, in FSAR Section 3.7.5, the applicant provides the following:

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

3.7.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG-1966, the FSER for the ESBWR DCD.

In addition, the relevant requirements of the Commission regulations and the associated acceptance criteria are given in the NRC SRP.

3.7.5.4 Technical Evaluation

As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.7.5 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.7.5 of the North Anna 3 COL FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD represents the complete scope of information relating to this review topic.[1]

The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to this site specific information.

In addition the staff reviewed the information in the COL FSAR as follows:

Supplemental Information

- NAPS DEP 3.7-1

The NAPS DEP 3.7.1 is a result of the North Anna site-specific FIRS exceeding the CSDRS at certain frequencies. Therefore, the applicant revised the definition for the SSE to include the site-specific FIRS for each seismically qualified structure. These changes are identified in FSAR Sections 1.3, 1.11, 2.0, 3.7, 3.8, 4.2, 9.1, 19.1, 19.2, and 19.5, and FSAR Appendices 3A, 3C, 3G, and 19A. This departure also involves redefinition of the OBE. The changes to the OBE definition are identified in FSAR Section 3.7.1.

In North Anna 3 FSAR Section 3.7.5 the applicant replaced the Tier 2* information in the standard Table 2.0-1 that reflects the Envelope of ESBWR standard plant site parameters including seismic parameters, with the North Anna 3 site specific seismology requirements and site specific SSI analyses for the seismic category I structures to reflect the North Anna 3 site specific SSE definition that is applied to the seismic analysis for North Anna 3 as described in FSAR Section 3.7, Section 3.8 and 2.5.4.

The staff evaluated the NAPS DEP 3.7-1 for each applicable Section of the North Anna 3 FSAR in this staff SER under the applicable SER Chapters. Each FSAR Section that required this NAPS DEP 3.7-1 due to the change in the North Anna 3 site specific SSE definition was evaluated to ensure these proposed departures from the DCD met the commissions' regulations as discussed under their respective SER Sections.

3.7.5.5 Post Combined License Activities

There are no post COL activities related to this section.

3.7.5.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to seismology and SSI analyses for seismic category 1 structures as addressed in primarily in this SER in Sections 3.7 and 3.8, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in the SRP. The staff completed evaluations on NAPS DEP 3.7-1 as applicable in this SER in accordance with the commission regulations, guidance in accordance with the SRP and applicable regulatory guides and industry standards. On this basis, the staff concludes that the applicant satisfied the relevant requirements of the regulations and find that the change to tier 2* information from the ESBWR DCD in Section 3.7.5 of the North Anna 3 FSAR is acceptable.

3.8 Seismic Category I Structures

Seismic Category I structures included in the North Anna 3 design consist of the reactor building/fuel building (RB/FB) complex, control building (CB), and firewater service complex (FWSC). In FSAR Revision 9, Section 3.8 and Appendix 3G, the applicant described the structural analysis and design evaluations of these seismic Category I structures for the North Anna 3 site-specific loads. This FSAR Section incorporates by reference Section 3.8 of the DCD with the departure given below.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the CSDRS as described in the DCD. For this reason, the applicant performed new seismic soil-structure interaction (SSI) and structure-soil-structure interaction (SSSI) analyses with the site-specific ground response spectra and the site-specific subgrade properties. In some cases, the seismic structural loads were found to be higher than those used for in the standard design, and thus, a structural evaluation of the ESBWR standard plant structures for acceptability at the North Anna 3 site was performed. In a few instances where necessary, the standard design was modified to ensure seismic adequacy as described in the FSAR. The structural evaluations of the seismic Category I structures are described in DCD Appendix 3G Sections 3G.1 through 3G.6 for the evaluations using the CSDRS seismic demands, and in North Anna 3 FSAR Chapter 3 Appendix 3G Section 3G.7 through 3G.10 for the evaluations using the site-specific seismic demands.

3.8.1 Concrete Containment

3.8.1.1 Introduction

Section 3.8.1 and Appendix 3G Section 3G.7 of the North Anna 3 FSAR, Revision 9, describe the structural analysis and design of the reinforced concrete containment vessel (RCCV), which is integrally connected to the RB/FB complex. The RCCV includes the reinforced concrete structure and the containment liner. Other metal components of the containment that are not backed by concrete are addressed under FSAR Section 3.8.2.

The RCCV is designed to house and support the nuclear reactor system and other internal systems and components. It is also designed to act as an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment. The RCCV is designed to withstand various operating loads; environmental loads such as wind, seismic, and tornado; and abnormal loads such as the loss of coolant accident (LOCA). The ESBWR design approach for the standard plant design of RCCV is provided in Section 3.8.1 and Appendix 3G Section 3G.1 of ESBWR DCD, Tier 2, Revision 10.

3.8.1.2 Summary of Application

Section 3.8.1 and Appendix 3G of the North Anna 3 FSAR, Revision 9, incorporate by reference Section 3.8.1 and Appendix 3G of the ESBWR DCD, with the departure and supplement given below.

Supplemental Information

- NAPS SUP 3.8-1 — ASTM Standards C1260 and C1293 are used in testing aggregates for potential alkali-silica reactivity (ASR).

This supplement in the FSAR Section 3.8.1.6.1 relates to the potential degradation effects associated with alkali-silica reaction in reinforced concrete structures.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the DCD CSDRS. As a result, the applicant performed new site-specific seismic SSI and SSSI analyses with the site-specific ground response spectra and the site-specific subgrade properties. In some cases, the site-specific seismic structural loads were found to be higher than those used for the standard design, and thus, a structural assessment of the ESBWR standard plant structures for acceptability at the North Anna 3 site was performed. In a few instances as required for site-specific conditions, the standard design is modified to ensure seismic adequacy.

In FSAR Appendix 3G, Section 3G.7, the applicant described the site-specific structural evaluation of the RB/FB complex. Since the RCCV is integral with the RB and both the RB and FB are supported by a common basemat, the analysis of the RCCV is coupled with the RB and FB. The analytical models used for the RB/FB are described in FSAR Section 3G.7.4. In Section 3G.7.5, the applicant described the structural analysis and design. This includes the site design parameters used in the structural evaluation, design loads, load combinations, and material properties. FSAR Section 3G.7.5.4 describes the structural design evaluation which includes the RCCV wall, RCCV top slab and suppression pool slab, and RCCV foundation mat. The foundation stability evaluation is described in FSAR Section 3G.7.5.5, which includes the evaluation for seismic sliding and overturning, and soil bearing pressure.

The results in terms of RCCV member forces, from the evaluations performed for the site-specific seismic loads, are presented in FSAR Tables 3G.7-202 through 3G.7-204. The combined member forces and moments for selected load combinations that include seismic loads are presented in FSAR Tables 3G.7-205a through 3G.7-205e. The calculated stresses of the concrete and steel reinforcement and their comparison to code limits are presented in FSAR Tables 3G.7-206a through 3G.7-206e. The calculated transverse shear and tangential shear, and their comparison to code limits are presented in FSAR Tables 3G.7-207 and 3G.7-208, respectively. The calculated RCCV liner strains and its comparison to code limits are presented in FSAR Table 3G.7-210.

For stability evaluation, the factors of safety for the RB/FB foundation stability for overturning and sliding are presented in FSAR Table 3G.7-225. The maximum calculated soil dynamic bearing pressure demand for the RB/FB is presented in FSAR Table 3G.7-231.

The results of the evaluation for the site-specific seismic loads show that, although some of the forces on the RCCV are higher than those from the DCD design, the stresses and strains of the RCCV meet the code limits. For foundation stability a factor of safety of 1.1 for sliding and overturning is met in accordance with SRP 3.8.5. The soil dynamic bearing pressures are determined to be less than the allowable dynamic bearing pressures provided in FSAR Table 2.5.4-211.

3.8.1.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). In addition, the relevant requirements of the Commission regulations for the concrete containment, and the associated acceptance criteria, are in Section 3.8.1 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, as they relate to concrete containment being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design of the concrete containment being able to withstand the most severe natural phenomena such as winds, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.

- 10 CFR Part 50, Appendix A, GDC 4 as it relates to the concrete containment being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

- 10 CFR Part 50, Appendix A, GDC 16 as it relates to the capability of the concrete containment to act as a leak-tight membrane to prevent the uncontrolled release of radioactive effluents to the environment.

- 10 CFR Part 50, Appendix A, GDC 50 as it relates to the concrete containment being designed with sufficient margin of safety to accommodate appropriate design loads.

- 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 50.44, as it relates to demonstrating the structural integrity of BWRs with Mark III type containments, all PWRs with ice condenser containments, and all containments used in future water-cooled reactors for loads associated with combustible gas generation.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

In addition, the acceptance criteria, regulatory guidance, and industry codes/standards associated with the review of FSAR Section 3.8.1 include the following:

- SRP Section 3.8.1 guidance to review the design, construction, and testing of the concrete containment to ensure that the containment maintains its structural integrity and can perform its intended safety function during all loading conditions.

- RG 1.7, “Control of Combustible Gas Concentrations in Containment”

- RG 1.91, “Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants”

- RG 1.136, “Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments”

- RG 1.216, “Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure”

- RG 1.61 to determine the acceptability of the damping values used in the structural model.

- RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants”

- 2004 ASME Boiler and Pressure Vessel Code, Section III, Division 2, Subsection CC, “Code for Concrete Reactor Vessels and Containments”

3.8.1.4 Technical Evaluation

As documented in NUREG–1966 (ADAMS Accession No. ML14100A304), NRC staff reviewed and approved Section 3.8.1 and Appendix 3G of the ESBWR DCD. The staff reviewed Section 3.8.1 and Appendix 3G of the North Anna 3 FSAR Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic[1]. The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this Section. The staff reviewed the information in the North Anna 3 FSAR as discussed below.

In addition, the staff conducted an audit (ADAMS Accession No. ML16193A047) (hereinafter referred to as North Anna 3 Audit 2) during the week of March 21, 2016 at the Wilmington, North Carolina offices of the applicant's contractor GEH. The purpose of this audit was to (1) review detailed analysis reports and design calculations performed by the applicant that support the information in the FSAR, (2) confirm the basis supporting the applicants' RAI responses, and (3) review the draft FSAR revisions from RAI responses to ensure consistency with the applicant's design basis information. The staff held almost weekly public meetings with the applicant and GEH starting from the public meeting held on April 15, 2015 up through Audit 2 and some weeks after where the applicant's technical reports, draft FSAR responses and RAI responses were discussed to ensure resolution of all staff issues. An issue resolution table was developed and discussed during these numerous public meeting interactions with the applicant.

The results of the staff's technical review of the North Anna 3 FSAR is given below.

Supplement Information

- NAPS SUP 3.8-1 — ASTM Standards C1260 and C1293 are used in testing aggregates for potential alkali-silica reactivity (ASR).

NRC staff reviewed NAPS SUP 3.8-1 related to the addition of ASTM Standards C1260 and C1293 for testing aggregates for potential alkali-silica reactivity (ASR). The use of these ASTM standards is intended to prevent the degradation of reinforced concrete due to ASR. The potential degradation from ASR and the use of these ASTM standards to prevent ASR are described in NRC Information Notice 2011-20 (ADAMS Accession No. ML112241029). The staff finds the addition of these ASTM standards to be acceptable because they are intended to prevent potential ASR in the reinforced concrete containment.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to the applicant's structural evaluation of the RCCV for the site-specific seismic loads applied to the RCCV. These evaluations are described in FSAR Section 3G.7. The staff's technical evaluation of the RCCV design considering these site-specific loads is given below. As described earlier in this report, the model and analyses of the RCCV are included in the RB/FB evaluation because the RCCV is integrally connected to the RB and these structures are on a common basemat. Therefore, the RB/FB evaluation includes the RB, FB, RCCV, and containment internal structures (CIS).

As indicated in FSAR Appendix 3G Section 3G.7.1, DCD Appendix 3G Section 3G.1 remains applicable for the analysis and design of the RB, RCCV, and CIS with the seismic loads based on the CSDRS. The evaluation of the RCCV for the site-specific seismic loads is provided in

FSAR Section 3G.7 in order to address the exceedances from the standard design seismic loads.

<u>*Analytical Models*</u>

FSAR Section 3G.7.4.1 states that the North Anna 3 site-specific structural models are based on the standard design structural models described in DCD Sections 3G.1.4.1 for the RB and 3G.3.4 for the FB. FSAR Section 3G.7.4.2 indicates that the North Anna 3 site-specific foundation models are based on the standard design foundation models described in DCD Section 3G.1.4.2. Since the RCCV, CIS, RB, and FB are on a common basemat and the RCCV and RB are integrally connected, the structural models for these structures, including their foundations, are combined into a single integrated RB/FB global model. Therefore, the staff evaluations of the analytical models of the RCCV, CIS, RB, and FB are discussed in this SER in Section 3.8.1.4 under the heading of "*Analytical Models*," rather than evaluating the models of the CIS, RB, and FB separately in SER Sections 3.8.3.4 and 3.8.4.4.

FSAR Section 3G.7.5.2 indicates that the standard design model with the updates to address updated LOCA thermal loads also included standard design changes in the pool gate and upper pools. This updated DCD global finite element model (FEM) is used for the North Anna 3 structural evaluations that include dead load, pressure loads, temperature loads in the RB upper pools, and North Anna 3 seismic loads. FSAR Section 3G.7.5.2 also indicates that other North Anna 3 load cases are used with the original global FEM, because these cases are not affected by design changes in the pools and are the same as those considered in the standard design, DCD Section 3G.1.5.2.1.6.

In addition to the information provided in FSAR Section 3G.7, the staff reviewed the following GEH reports with regard to the analytical models used for the North Anna 3 structural evaluations for the combined RB/FB, RCCV, and CIS:

1. WG3-U71-ERD-S-0004, Rev. 2, "Reactor Building Structural Design Report," (ADAMS Accession No. ML16148A081, ML16148A146 Non-public)

2. WG3-T12-ERD-S-0001, Rev. 0, "Structural Design Report for Containment Internal Structures," (ADAMS Accession No. ML15342A146)

3. WG3-U97-ERD-S-0001, Rev. 2, "Fuel Building Structural Design Report," (ADAMS Accession No. ML16148A128, ML16148A169 Non-public)

4. WG3-T11-DRD-S-0001, Rev. 2, "RCCV Structural Design Report," (ADAMS Accession No. ML16148A049, ML16148A169 Non-public)

5. WG3-T11-DRD-S-0002, Rev. 0, "Structural Design Report for Containment Liner Plate," (ADAMS Accession No. ML15357A308)

6. DE-ES-0096, Rev. 0, "Liner Anchorage Evaluation," (ADAMS Accession No. ML16167A447)

The staff reviewed GEH report WG3-U71-ERD-S-0004, Rev. 2 regarding the modeling of the RB/FB global finite element model. The RB/FB complex, including the fully enclosed RCCV and

CIS, consists of mostly reinforced concrete slabs/walls and some steel members such as roof trusses and liners. The major structural components include the basemat, RCCV, floor slabs, external walls, shear walls, frame members, and major containment internal structures such as the vent wall, the diaphragm floor slab, the GDCS pool, the reactor shield wall, and the RPV support brackets. The part of the FB located above EL 22.5 m is not included in the model, because that part is seismic Category II; however, the weights of this part of the FB are applied to the nodes at the positions of columns supporting the roof slab. This is consistent with the approach used in the standard design. Major penetrations in the RCCV are included in the model in order to consider local reduction of the wall stiffness.

The RB/FB complex is modeled and is analyzed using the NASTRAN computer code. Thick shell elements are used to model the RCCV, basemat, pools, walls, and slabs, which consider the membrane force, in-plane and transverse shear forces, and bending moment. Membrane elements are used to model liners that consider the membrane force and in-plane shear. Bar elements (i.e. beam elements) are used to model columns, girders, and roof trusses, which consider the axial force, bending moment, and transverse shear force. Rigid bar elements are used to connect the basemat and the bottom of the shear walls, as well as the shear walls and the liners. Rod elements (i.e., truss elements) are used to model penetration sleeves, which consider only the axial force.

In the North Anna 3 and standard design evaluations, the ground is modeled with spring elements. Three independent spring elements, one vertical and two horizontal, are attached to each of the basemat nodal points. The spring constants are calculated based on the generic soft site condition considered for the ESBWR standard design. The ground is assumed to be elastic and the basemat uplift is not considered in the model. The validities of using generic soft site condition for the North Anna 3 rock site and of neglecting the basemat uplift are evaluated in this SER Section under the "*Structural Analysis*" heading.

Based on the review of the information provided in FSAR Section 3.8 and Appendix 3G, the GEH reports identified above, and NRC North Anna 3 Audit 2 (ADAMS Accession No. ML16193A047), the staff concluded that the analytical models used for the North Anna 3 structural evaluation of the RB/FB complex are based on the DCD analytical global FEMs. Therefore, the use of these analytical models for the site-specific structural evaluations is considered to be acceptable.

Site Design Loads, Load Combinations, and Material Properties

The description of the site design loads, load combinations, and material properties for the RCCV is provided in FSAR Appendix 3G Section 3G.7.5.2. The FSAR indicates that with the exception of seismic loads, the site-specific structural evaluations utilize the loads, load combinations, and acceptance criteria that were used in the standard design. The FSAR lists the various loads and the corresponding sections in the ESBWR DCD where these are described. In addition, the staff did not identify any changes or deviations from the material properties identified in the standard design.

FSAR Appendix 3G Section 3G.7.5.2 also indicates that North Anna 3 seismic loads are developed from the site-specific SSI analyses results described in FSAR Appendix 3A Section 3A.18.1.1. These seismic loads consider the effects of structural stiffness variations described in

FSAR Appendix 3A Section 3A.17.9.1. The effects of SSSI and structure soil separation on the overall RB/FB complex are discussed in SER Section 3.8.4 below.

Based on the review of the information provided in FSAR Section 3.8 and Appendix 3G, the GEH reports identified above, and the North Anna 3 Audit 2, the staff concluded that for the non-seismic loads, the North Anna 3 structural evaluation utilized the same non-seismic loadings, the same load combinations, and the same material properties as the standard design. For the seismic loads, the staff reviewed and confirmed that the site-specific seismic bounding load results presented in FSAR Appendix 3A Section 3A.18.1.1 for the RCCV were used for the RCCV structural evaluation. Therefore, the North Anna 3 site design loads, load combinations, and material properties are considered to be acceptable.

Structural Analysis

During its review of Revision 8 of FSAR Section 3.7.2.4.1.6.1, the staff noted that the North Anna 3 site-specific enveloping seismic loads computed from the site-specific SSI analyses of the RB/FB, CB, and FWSC exceed the corresponding standard design loads at a number of locations in the RB/FB and CB. FSAR (Revision 8) Section 3.7.2.4.1.6.1 also describes a design evaluation method that utilizes the “stress ratios” (i.e., the standard design stress demand over capacity) and “scale factors” (i.e., maximum ratios of site-specific enveloping seismic loads over standard design enveloping seismic loads). Following this method, if the products of the stress ratios and the scale factors are less than 1.0 for a given location in the structure and for the governing load combination, that location in the structure would be identified as passing the design evaluation.

The staff’s review found that the applicant’s simplified approach proposed in FSAR Revision 8, may not be appropriate because its required linear dependence of the seismic stress ratios with respect to all seismic load components may not be valid for some design situations and load combinations. Since adequate calculation of the member forces with proper consideration of the individual member force components is essential in design to ensure the structural integrity, the staff requested, in RAI 03.07.02-17, that the applicant provide the results of detailed stress checks for the seismic Category I structures without using the stress factors and scale factors, where the site-specific seismic loads exceed the corresponding ESBWR standard design.

In the response to this RAI question (ADAMS Accession No. ML16146A789), and as described in the applicant’s Seismic Closure Plan (SCP), submitted to the NRC by letter dated October 22, 2014 (ADAMS Accession Number ML14297A199), the applicant indicated that design margins will be explicitly calculated based on the site-specific seismic stress demands obtained from finite element analyses using the same methodology as used for the standard design. FSAR Revision 9 Sections 3.7, 3.8, Appendix 3A, and Appendix 3G present the updated North Anna 3 site-specific structural evaluations of the seismic Category I structures of the ESBWR standard design at the North Anna 3 site. Staff’s assessment of this evaluation is presented later in this SER Section.

The applicant in Revision 8 of the FSAR also did not consider the structural fill above the top of the Zone III rock in the SSI analysis of the RB/FB and CB models. Therefore, as part of the RAI 03.08.04-37, the staff requested the applicant to provide a justification on the adequacy of their design evaluation of the walls below grade to resist lateral soil pressure. In response to this RAI question (ADAMS Accession No. ML15364A384), the applicant performed additional SSI analysis with full embedment considering the structural fill and in-situ Saprolite soil and revised appropriate sections of the FSAR to document the results. Staff's evaluation of the SSI analysis of the fully embedded models is presented in SER Sections 3.7.2.4. FSAR, Revision 9, Appendix 3A Section 3A.18 presents the bounding seismic loads used in the North Anna 3 site-specific design evaluation that envelops the partial and full embedment cases. Bounding dynamic lateral soil pressures are described in FSAR Revision 9 Appendix 3G. Staff's evaluation of the use of the bounding seismic loads in evaluating the adequacy of ESBWR standard plant structures is described later in this SER Section.

As discussed in FSAR Revision 9, Appendix 3G Sections 3G.7.4, 3G.7.5, and 3G.9.4, the structural models for the RCCV, CIS, RB, and FB are integrated into a single RB/FB global model. Therefore, the staff evaluation of the structural analysis of the RCCV, CIS, RB, and FB is presented in this SER under the "Structural Analysis" heading.

The description of the structural analysis for the design evaluation of the RB/FB complex is provided in FSAR Revision 9, Sections 3.8.1, Appendix 3G Sections 3G.7, and 3G.9, and GEH reports listed in Section 3.8.1.4 under the heading "Analytical Models," of this SER. The FSAR indicates that the North Anna 3 site-specific design evaluation uses the same standard design methodologies, standard design load combinations and selected elements, and the standard design loads, except that the standard design seismic loads are replaced with the North Anna 3 site-specific seismic loads. The standard design structural evaluations continue to apply and remain valid for the CSDRS seismic response. FSAR Appendix 3G also indicates that the site-specific structural evaluations supplement the standard design evaluations to address site-specific conditions including the site-specific seismic input motion exceeding the CSDRS in some frequency ranges and that the standard design of the seismic Category I structures is maintained, except where the standard design is modified by providing additional reinforcement to ensure seismic adequacy.

The staff reviewed the information provided in FSAR Appendix 3G Sections 3G.7.5 and 3G.9.5, and GEH reports as described in SER Section 3.8.1.4B.1 above with regard to the structural analysis used for the site-specific structural evaluations of the RB/FB global model. Based on this review, the staff confirmed that the North Anna 3 site-specific structural analysis of the RB/FB global model was performed consistently with the procedure used for the standard design and utilized the NASTRAN finite element computer code, which is the same computer code used for the standard design as described in DCD Section 3.8.1.4.1.1. The global stress analysis model of the RB/FB complex is the same as the updated DCD model used for the standard design, and the site-specific seismic loads applied to the RB/FB global model for the site-specific stress analyses are determined from the design site-specific seismic loads as described in FSAR Appendix 3A Section 3A.18. As described in FSAR Appendix 3G Section 3G.7.5.2, the seismic loads applied to the model include all bounding seismic response loads (two horizontal, one vertical, one torsional, and two overturning moments applied at each floor elevation).

Based on staff's review above and as confirmed during the North Anna 3 Audit 2, the staff found the North Anna 3 site-specific NASTRAN analysis of the updated RB/FB model acceptable because the applicant (a) performed an explicit site-specific FEM analysis to calculate the site-specific stress demand using an approach consistent with the DCD approach, and (b) applied the site-specific bounding seismic load obtained from the site-specific seismic analysis to the NASTRAN model following the same method as used for the standard design.

The staff further evaluated the following site-specific issues in more detail related to the structural analysis of the RB/FB model: (1) the use of DCD soft-soil subgrade properties, (2) the application of bounding seismic loads to the NASTRAN design model, and (3) application of RCCV thermal loads.

Use of DCD soft-soil subgrade properties for North Anna 3 NASTRAN analysis

FSAR Appendix 3G Sections 3G.7.5.1 and 3G.9.5.1 indicate that the North Anna 3 structural evaluation utilizes the key site design parameters identified in DCD Appendix 3G Section 3G.1.5.1, based on soft site subgrade stiffness conditions, which are considered conservative for the Unit 3 hard rock site.

DCD Section 3.8.5.4 indicates that the worst case scenario for foundation basemat design is the soft soil because it results in the largest mat deformation. In order to confirm the appropriateness of this condition, this DCD Section provided a comparison of the basemat deformation and sectional moment between the soft soil case [Vs = 300 m/sec (984 ft/sec)] and the hard rock case [Vs = 1700 m/sec (5577 ft/sec)]. Basemat deformation for the soft soil condition was found to be much larger than that of the hard rock condition. Bending moments for the soft soil were found to be larger than the moments for the hard rock condition with few exceptions. The DCD concluded that the higher bending moments at some locations for the hard rock site have no effect on the design because they are much less than the maximum moments of the soft soil site on which rebar sizing is based.

Although North Anna 3 site-specific structural evaluations use the same generic “soft-soil” subgrade stiffness properties as those used in the standard design and the generic soft soil was justified for the standard design, the staff requested the applicant to provide a justification for using DCD generic soft-soil subgrade stiffness in evaluating the ESBWR seismic Category I structures for the North Anna 3 rock site. The rationale for this staff request is to consider the few exceptions for the hard rock conditions that are observed above in the DCD evaluation and the fact that the North Anna 3 seismic loads exceed the standard design seismic loads in some instances.

In response to this request, the applicant in FSAR Appendix 3G explains that the site-specific evaluations are based on the results of static analyses performed on NASTRAN finite element models that are identical to those used for the standard design described in DCD Appendix 3G Section 3G.1.4, including the use of the same linear elastic spring elements and subgrade stiffness properties. Dominion also explained during the North Anna 3 Audit 2 that the design of the basemat for the soft-soil conditions is conservative because the reinforcement in a given region of the basemat is based on the maximum moments calculated in that region rather than specifying different reinforcement to closely match the moment diagram across the basemat. The design evaluation using the generic soft-soil subgrade stiffness provides design demands that envelop the effects of the stiffer site-specific rock subgrade and foundation uplift with a few exceptions that nevertheless do not affect the conclusions of the site-specific structural evaluations. For these exceptions, FSAR Appendix 3G also indicates that the results of sensitivity evaluations show that amplifications at some locations due to the higher site-specific subgrade stiffness and foundation uplift are small and that the basemat design has sufficient margin to envelop the effects of the small amplifications due to the higher site-specific subgrade stiffness or foundation uplift.

The staff reviewed the information in FSAR Appendix 3G, and confirmed this information during North Anna 3 Audit 2. The staff review concludes that the applicant's use of the generic soft soil for North Anna 3 design evaluations is acceptable because the resultant basemat design has higher capacities than the seismic demands due to the North Anna 3 site-specific seismic input motions, North Anna 3 rock site conditions and effect of uplift.

Application of Bounding Seismic Loads to NASTRAN Design Model

In order to review how the site-specific seismic demands described in FSAR Section 3.7 and FSAR Appendix 3A Section 3A.18 are translated into input loads for the detailed NASTRAN finite element models used in the structural design evaluation described in FSAR Section 3.8, the staff requested the applicant provide relevant information and explanation of the process involved. In response, the applicant made a presentation during a public meeting dated March 3, 2016 (ADAMS Accession No. ML16204A243), on how the site-specific bounding seismic demands obtained from seismic analyses using the lumped mass stick models (LMSMs) are applied to the NASTRAN finite element models for static stress analyses. The applicant explained that the methodology used to convert North Anna 3 site-specific seismic loads from LMSMs to NASTRAN FEMs is identical to the methodology used in the standard design. The applicant also explained that the loads applied to the NASTRAN models represent the same distribution of the seismic load demands as those presented in the bounding reports which were reviewed during the North Anna 3 Audit 2 and are described in the staff's Audit Summary Report (ADAMS Accession No. ML16193A047). Section 6.2.3.9.1 of the RB structural design report (WG3-U71-ERD-S-0004, Rev. 2) describes how seismic loads are developed from RB/FB LMSMs and applied to RB/FB finite element models. The same methodology is used for the CB and FWSC. The global seismic loads from LMSMs are applied to the NASTRAN finite element models at floor elevations that correspond to the LMSM nodal elevations. Dynamic soil pressure loads are applied on external below-grade walls and hydrodynamic loads are applied on walls and slabs of pools at their corresponding elevations. The applicant showed comparisons between the demands calculated from LMSM seismic analyses and the loads actually applied to the NASTRAN finite element models, which provides a check that the LMSM to NASTRAN FEM load translations are acceptable.

Based on staff's review above and as discussed during a public meeting dated March 3, 2016, and as confirmed during North Anna 3 Audit 2, the staff found the application of bounding seismic loads to the NASTRAN design model acceptable because (a) the approach of applying the bounding seismic loads is the same as the DCD approach, and (b) the applicant confirmed that the applied site-specific seismic loads to the NASTRAN model are consistent with the bounding seismic loads calculated from the LMSM seismic analyses.

Application of RCCV Thermal Loads

FSAR Sections 3.8.1 and FSAR Appendix 3G Section 3G.7.5.2 describe that for the RCCV thermal loads, the method using 3D nonlinear analyses that was utilized in the standard design, is not used for the site-specific structural evaluation. These FSAR Sections indicate that the effects of concrete cracking due to the thermal load are considered by reducing the thermal stress using the SSDP-2D computer code described in DCD Appendix 3G Section 3G.1.5.4. The use of SSDP-2D in the site-specific structural evaluations was possible because the design changes for the RB upper pools, described in DCD Appendix 3G Section 3G.5.3, provided increased strength in the structures so that the thermal forces did not need to be redistributed through the 3D nonlinear program. The FSAR concludes that since the method using SSDP-2D is more conservative than the 3D nonlinear method, and because the SSDP-2D method is used for normal operating loads, it is acceptable to use the SSDP-2D method for the reduction of thermal stresses in the RCCV structural evaluation.

The staff noted that the 3D nonlinear analysis approach was utilized in the standard design in order to reduce the effects of thermal loading beyond what the SSDP computer code would provide. This occurs because the 3D nonlinear analysis method is able to redistribute member forces when cracking occurs, whereas the SSDP code does not do that. Therefore, the staff agreed that the use of the SSDP method rather than the 3D nonlinear method is conservative, and thus, acceptable for the North Anna 3 design assessment.

In summary, based on the review of the structural analysis approach used for the RCCV, CIS, RB and FB described in FSAR Section 3.8 and Appendix 3G, the GEH reports identified above, and as confirmed in the North Anna 3 Audit 2, the staff concludes that the North Anna 3 structural analysis approach is essentially the same method as in the standard design and in the instances where they differed, as discussed above, the North Anna 3 structural analysis approach was determined to be conservative and thus, acceptable.

Structural Design

Reinforced Concrete Sections

The description of the structural design evaluation for the RCCV is provided in FSAR Appendix 3G Section 3G.7.5.4 and GEH report WG3-T11-DRD-S-0001, Rev. 2. FSAR Appendix 3G Section 3G.7.5.4 indicates that site-specific evaluations use the standard design models, analysis methods, loads (as described in FSAR Appendix 3G Section 3G.7.5.2), load combinations, and acceptance criteria. However, the standard design seismic loads are replaced with the seismic loads determined from the site-specific seismic analyses described in FSAR Appendix 3A Sections 3A.10 through 3A.19.

As described in FSAR Appendix 3G Section 3G.7.5.4.1, the site-specific evaluations show that the RCCV standard design is adequate to resist the North Anna 3 site-specific seismic loads in combination with non-seismic standard design loads. Furthermore, the FSAR indicates that the results of the site-specific stress checks demonstrate that the stresses of the concrete and rebar are less than the allowable stresses specified in the code and the cross sectional areas of the primary and shear reinforcement, which have been provided, meet the required values.

The staff reviewed the information in FSAR Appendix 3G Section 3G.7.5.4 and GEH report WG3-T11-DRD-S-0001, Rev. 2. The staff found that the industry codes and standards, structural materials and their properties, loads and load combinations used in the design evaluations, and the method for checking the design of the RCCV were consistent with those used in the standard design. The staff also reviewed the results of the design evaluation for seventeen representative locations of the RCCV and found that the calculated stresses of the concrete and steel reinforcement were below allowable values. In addition, the provided reinforcement is shown to be greater than the required reinforcement for the primary and shear reinforcement. Therefore, the staff concluded that the site-specific structural design evaluation for the reinforced concrete portion of the RCCV is acceptable.

Containment Liner and Liner Anchorage

The staff reviewed FSAR Appendix 3G Section 3G.7.5.4.1 and GEH reports WG3-T11-DRD-S0002, Rev. 0 and DE-ES-0096, Rev. 0, regarding the site-specific evaluation of the containment liner plate and liner anchorage. These documents indicate that an evaluation of the structural integrity of the liner plate utilized the same methodology and acceptance criteria as that used for the standard design. The strain of the liner plate was obtained using the NASTRAN model analysis for the site-specific seismic loads combined with the non-seismic standard design loads. The results of this evaluation, which are presented in FSAR Appendix 3G Table 3G.7-210, demonstrate that the maximum strains of the containment liner plate are less than the allowable limits. The staff concluded that the structural design evaluation is acceptable on the basis that it utilized the same methodology and acceptance criteria that were used in the standard design and because it demonstrated that the calculated strains are less than the code limits.

In the case of the liner anchorage, GEH report DE-ES-0096, Rev. 0, describes the evaluation of the containment liner anchorage for the North Anna 3 site-specific loadings. The evaluation approach was based on the Bechtel Topical Report BC-TOP-1, Containment Building Liner Plate Design Report, and ACI 349-01. The effect of the fabrication/erection tolerances on the liner anchor displacement was also evaluated. Since the liner plate anchorage system was shown to satisfy the force and displacement allowable values in the ASME code Section III, Division 2, Subsection CC, the staff concluded that the evaluation of the containment liner and liner anchorage for the North Anna 3 site-specific loadings is acceptable.

3.8.1.5 Post Combined License Activities

There are no post COL activities related to this Section. ITAAC in DCD Tier 1, Revision 10, with the modification of the SSE definition will address the as-built verification of the concrete containment for the North Anna 3 seismic demand.

3.8.1.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). The staff reviewed the North Anna 3 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 North Anna 3 FSAR related to this Section. All nuclear safety issues relating to the concrete containment that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.1 of NUREG–0800, and other NRC RGs. The staff finds that the applicant has addressed the areas related to concrete containment in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.8.1.3 of this SER.

3.8.2 Steel Components of the Reinforced Concrete Containment

3.8.2.1 Introduction

Section 3.8.2 and Appendix 3G Section 3G.7 of the North Anna 3 FSAR, Revision 9, describe the structural analysis and design of the steel components of the RCCV that are not backed by concrete. These components include the drywell head, penetrations, personnel air locks, equipment hatches, and passive containment cooling system (PCCS) condenser. The ESBWR design approach for the standard plant design of steel components of the RCCV is provided in Section 3.8.2 and Appendix 3G Section 3G.1 of ESBWR DCD, Tier 2, Revision 10.

3.8.2.2 Summary of Application

Section 3.8.2 and Appendix 3G of the North Anna 3 FSAR, Revision 9, incorporate by reference Section 3.8.2 and Appendix 3G of the ESBWR DCD, with the departure given below.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the DCD CSDRS. As a result, the applicant performed new site-specific seismic SSI and SSSI analyses with the site-specific ground response spectra. In some cases, the seismic structural loads were found to be higher than those obtained in the standard design, and thus, a structural evaluation of the ESBWR standard plant structures for acceptability at the North Anna 3 site was performed. In a few instances as required for site-specific conditions, the standard design is modified to ensure seismic adequacy. Including as discussed in FSAR Appendix 3G Section 3.G.7.5.4.1 the PCCS Condenser support saddle bolts and their embedment are designed to withstand the site-specific seismic loads.

In FSAR Appendix 3G Section 3G.7, the applicant described the site-specific structural evaluation of the RB/FB complex including the evaluation of the steel components of the RCCV. The loads, load combinations, and material properties are provided in FSAR Appendix 3G Section 3G.7.5.2, and the analysis and design evaluation are provided in FSAR Appendix 3G Section 3G.7.5.4.1. The analysis approach and the results of the drywell head evaluation are described in FSAR Appendix 3G Section 3G.7.5.4.1.4. The analysis approach and the results of the PCCS condenser evaluation are described in FSAR Appendix 3G Section 3G.7.5.4.1.5

The results of the evaluation for the drywell head show that the calculated stresses meet ASME Code limits using the standard design process. The results of the evaluation for the PCCS condenser show that although certain loads are higher than the standard design loads, the PCCS stresses remain below the allowable stress limits. The evaluation also indicated that the PCCS condenser saddle support bolt tension load due to the North Anna 3 seismic demand has increased. These bolts and their embedment will be designed to withstand the increased tension load during the final embedment design.

3.8.2.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the steel portions of the containment, and the associated acceptance criteria, are in Section 3.8.2 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, GDC 1, as they relate to designing, fabricating, erecting, testing, and inspecting steel containments to quality standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to designing steel containments to be capable of withstanding the most severe natural phenomena such as winds, tornados, floods, and earthquakes and the appropriate combination of all loads.

- 10 CFR Part 50, Appendix A, GDC 4, as it relates to the capability of steel containments to withstand the dynamic effects of equipment failures, including missiles, pipe whipping, and blowdown loads associated with LOCAs.

- 10 CFR Part 50, Appendix A, GDC 16, as it relates to the capability of the steel containment to act as a leak-tight membrane to prevent the uncontrolled release of radioactive effluents to the environment.

- 10 CFR Part 50, Appendix A, GDC 50, as it relates to designing steel containments with sufficient margin of safety to accommodate appropriate design loads.

- 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 50.44, as it relates to the capability of the steel containment of existing plants and new plants to resist those loads associated with combustible gas generation from a metal-water reaction of the fuel cladding.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

In addition, the acceptance criteria, regulatory guidance, and industry codes/standards associated with the review of FSAR Section 3.8.2 include the following:

- SRP Section 3.8.2 guidance to review the design, construction, and testing of the steel components of the containment to ensure that the containment maintains its structural integrity and can perform its intended safety function during all loading conditions.

- RG 1.7, “Control of Combustible Gas Concentrations in Containment”
- RG 1.57, “Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components”
- RG 1.216, “Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure”
- 2004 ASME Code, Section III, Division 1, “Nuclear Power Plant Components,” Subsection NE, Class MC

3.8.2.4 Technical Evaluation

As documented in NUREG–1966 (ADAMS Accession No. ML14100A304), NRC staff reviewed and approved Section 3.8.2 and Appendix 3G of the ESBWR DCD. The staff reviewed Section 3.8.2 and Appendix 3G of the North Anna 3 FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this Section. The staff reviewed the information in the North Anna 3 FSAR as given below.

In addition, the staff conducted a structural audit (North Anna 3 Audit 2) during the week of March 21, 2016 at the applicant's contractor GEH office in Wilmington, North Carolina. The purpose of this audit was to (1) review detailed analysis reports and design calculations performed by the applicant that support the information in the FSAR, (2) confirm the basis supporting the applicants' RAI responses, and (3) review the draft FSAR revisions from RAI responses to ensure consistency with the applicant's design basis information.

Departure

- NAPS DEP 3.7-1 Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to the applicant's structural evaluation of the steel components of the RCCV for the site-specific seismic loads applied to the RCCV. These evaluations are described in FSAR Appendix 3G Section 3G.7. The staff's technical evaluation of the steel components of the RCCV design considering these site-specific loads is given below.

As indicated in FSAR Appendix 3G Section 3G.7.1, DCD Appendix 3G Section 3G.1 remains applicable for the analysis and design of the RB, RCCV, and CIS with the seismic loads based on the DCD CSDRS. The evaluation of the RCCV for the site-specific seismic loads is provided in FSAR Appendix 3G Section 3G.7 in order to address the exceedances from the standard design seismic loads.

Analytical Models

The steel components of the RCCV consisting of the drywell head, penetrations, personnel air locks, equipment hatches, and PCCS condenser were not discretely modeled in the global FEM. Each of the steel component was evaluated separately. Therefore, the specific analytical models used for each of the steel components of the RCCV are addressed below under the heading, "*Structural Design*," of this SER.

Site Design Loads, Load Combinations, and Material Properties

The description of the site design loads, load combinations, and material properties is provided in FSAR Appendix 3G Section 3G.7.5.2. The FSAR indicates that with the exception of seismic loads, the site-specific structural evaluations utilize the loads, load combinations, and acceptance criteria that were used in the standard design. The FSAR lists the various loads and the corresponding sections in the ESBWR DCD where these are described. In addition, the staff did not identify any changes or deviations from the material properties used in the standard design.

FSAR Appendix 3G Section 3G.7.5.2 also indicates that North Anna 3 seismic loads are developed from the site-specific SSI analyses described in FSAR Appendix 3A Section 3A.18.1.1. These seismic loads consider the effects of structural stiffness variations described in FSAR Appendix 3A Section 3A.17.9.1. The effects of seismic SSSI and structure soil separation on the overall RB/FB complex are discussed in SER Section 3.8.4 below.

In addition to the information provided in FSAR Appendix 3G Section 3G.7.5.2, the staff reviewed the GEH reports listed below related to steel components of the RCCV that are not backed by concrete.

1. WG3-T11-DRD-S-0003, Rev. 0, "Structural Design Report for Containment Metal Components," (ADAMS Accession No. ML15362A008, ML15362A013 Non-public)

2. DE-ES-0089, Rev. 0, "Stress Analysis Report for Drywell Head," (ADAMS Accession No. ML15362A012)

3. 002N8530, Rev. 4, "North Anna 3 PCCS Condenser Seismic Analysis" (ADAMS Accession No. ML16125A366)

The information provided in FSAR Appendix 3G Section 3G.7.5.2, regarding loads, load combinations, and material properties is acceptable because, with the exception of the seismic loads, the standard design loads, load combinations, and material properties were used. The staff also reviewed the GEH reports and found that for these components, the non-seismic loads, load combinations, and material properties are the same as those in the standard design. The site-specific seismic loads were found to be acceptable because they correspond to the seismic loads described in FSAR Appendix 3A Section 3A.18.

Structural Analysis

Since the steel components of the RCCV were not discretely modeled in the RB/FB global FEM, the steel components were evaluated separately. Therefore, the site-specific structural analysis used for the steel components of the RCCV is addressed below under the heading of "Structural Design," below.

Structural Design

In FSAR Section 3.8.2, the applicant only made one change which is to replace the last paragraph in DCD Section 3.8.2.4.1.5 regarding the PCCS. The change made to this paragraph was to indicate that the details of the site-specific analysis of the PCCS condenser, which uses the same approach as the DCD but with North Anna 3 seismic loads, can be found in GEH report 002N8530, Revision 4.

The staff notes that other changes to the DCD regarding the steel components of the RCCV are described in FSAR Appendix 3G Section 3G.7, and these are also discussed below for each of the RCCV steel components.

PCCS

In response to RAI 03.07.02-21 (North Anna 3-15-037, ML15364A384), the applicant described the site-specific seismic evaluation of the PCCS condenser in FSAR Appendix 3G Sections 3G.7, 3G.7.5.4.1, and 3G.7.5.4.1.5. The staff reviewed these sections regarding the evaluation of the PCCS. These sections indicate that a site-specific structural evaluation was performed for the PCCS condenser and its support, using the standard design models and methods, and the North Anna 3 site-specific seismic in-structure response spectra (ISRS) as input. Results of the site-specific analyses indicated that some of the site-specific loads were higher than the standard design loads. However, the PCCS condenser stresses were bounded by the standard design stresses or were shown to be below allowable stresses. For the North Anna 3 PCCS condenser support, an increase in the tension load was calculated in the support saddle bolts and this increased load will be used in the design of the bolts and the embedment.

The staff further reviewed the information in FSAR Sections 3.8.2 and FSAR Appendix 3G Section 3G.7, GEH report 002N8530, Rev. 4, and other supporting documents during North Anna 3 Audit 2. The staff found that the analysis approach, industry codes and standards, structural materials and their properties, loads and load combinations, and the method for checking the design of the steel components were consistent with those used in the standard design. The staff verified that the response spectra used for the analysis are the North Anna 3 bounding design ISRS obtained from the site-specific bounding SSI analysis described in FSAR Appendix 3A Section 3A.18.2. The staff also reviewed the results of the design evaluation for the steel components and the anchor bolt loads. The staff noted that with the exception of the tension load on the support saddle bolts, the calculated stresses and loads were below allowable values. Since the PCCS anchor bolts are designed during the detailed design phase, the applicant indicated that the support saddle bolts will be designed for the increased tension load due to the increased North Anna 3 seismic demand. In addition, the applicant stated that further assurance of the as-built PCCS condenser and its support to withstand the site-specific seismic load is provided through performance of ITAAC 5 of DCD Tier 1, Table 2.15.4-2.

The staff found the site-specific evaluation of the PCCS condenser and its anchorage due to increase in the North Anna 3 site-specific seismic demand acceptable because: (a) the site-specific evaluation is based on the same methodology as the standard design, but with the North Anna 3 seismic demand, (b) the PCCS saddle bolts will be designed for the increased tension load due to the North Anna 3 seismic demand, (c) the as-built PCCS condenser and its support to withstand the seismic load will be verified through ITAAC 5 of DCD Tier 1, Table 2.15.4-2, and (d) the definition of SSE for the performance of the ITAAC is changed in COLA Part 10 to include both the CSDRS and the North Anna 3 response spectra to ensure ITAAC verification for DCD CSDRS and the North Anna 3 seismic load.

RCCV Drywell Head

The staff reviewed FSAR Appendix 3G Sections 3G.7.5.4.1 and 3G.7.5.4.1.4 regarding the evaluation of the RCCV drywell head. These sections describe the analysis and design of the drywell head using the NASTRAN finite element computer code. These sections also indicate that the stresses developed from the combination of applicable loads and the North Anna 3 site-specific seismic load were shown to be below allowable stresses except for one case under ASME Service Levels A and B, as in the standard design. In this case, it was shown to be acceptable based on the simplified elastic-plastic analysis approach in NE-3228.3 of the ASME BPVC, Section III, using the same process as in the standard design.

The staff reviewed FSAR Appendix 3G Table 3G.7-211 which contains the summary of the drywell head stresses and confirmed that the calculated stresses were less than the allowable stresses, and in the one exception, the simplified elastic-plastic approach in NE-3228 was utilized.

The staff also reviewed the information in two GEH reports related to the drywell head. GEH report WG3-T11-DRD-S-0003, Rev. 0 provides the site-specific evaluation for the overall drywell head. GEH report DE-ES-0089, Rev. 0 provides the site-specific evaluation of subcomponents of the drywell head consisting of the drywell head flange and flange plates, gusset plates of the flange plates, and concrete portion at the flange plates. The staff found that the structural model; loads, load combinations, and material properties; acceptance criteria; and design approach for the drywell head were consistent with those used in the standard design.

Since the North Anna 3 evaluation for the site-specific seismic loads used the same methodology as the standard design and it was demonstrated that the code limits were satisfied, the design of the drywell head is considered acceptable.

Air Lock, Hatches and Penetrations

The description, typical details, loads and load combinations, design and analysis procedures, and acceptance criteria for the air lock, hatches, and penetrations are provided in DCD Sections 3.8.2 and DCD Appendix 3G Section 3G.1. While procedures are provided for the analysis and design of the air lock, hatches, and penetrations, the design results for these components were not provided because the DCD only provided the analysis and design results for representative/critical structural sections/components. The remaining structural sections/components would be performed as part of the detailed design stage. In the case of components such as penetrations, the loading from connecting piping were not known at the time. Similarly, in the North Anna 3 FSAR, the analysis and design results were provided for the same critical sections/components that were considered in the standard design, which did not include the air lock, hatches, and penetrations. To address the analysis and design results of these components, as well as the remaining structural members and components, the staff relies on the ITAAC for containment which are given in Table 2.15.1-2 of DCD Tier 1, Revision

10. In the case of North Anna 3, an evaluation will need to be performed considering the North Anna 3 site-specific seismic demand and this will be ensured by the ITAAC on containment which requires an ASME Code Design Report to ensure the design is acceptable.

3.8.2.5 Post Combined License Activities

There are no post COL activities related to this Section. ITAAC in DCD Tier 1, Revision 10, with the modification of the SSE definition will address the as-built verification of the steel components of the RCCV for the North Anna 3 seismic demand.

3.8.2.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). NRC staff reviewed the North Anna 3 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 North Anna 3 FSAR related to this Section. All nuclear safety issues relating to the steel components of the concrete containment that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.2 of NUREG–0800, and other NRC RGs. The staff finds that the applicant has addressed the areas related to steel components of the concrete containment in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.8.2.3 of this SER.

3.8.3 Concrete and Steel Internal Structures of the Concrete Containment

3.8.3.1 Introduction

Section 3.8.3 and Appendix 3G of the North Anna 3 FSAR, Revision 9, describe the structural analysis and design evaluation of the concrete and steel internal structures of the RCCV. These components include the diaphragm floor, vent wall, gravity-driven cooling system (GDCS) pool walls, reactor shield wall (RSW), RPV support brackets, and miscellaneous platforms. The ESBWR design approach for the standard plant design of the Containment Internal Structures (CIS) is provided in Section 3.8.3 and Appendix 3G of ESBWR DCD, Tier 2, Revision 10.

3.8.3.2 Summary of Application

Section 3.8.3 and Appendix 3G of the North Anna 3 FSAR, Revision 9, incorporate by reference Section 3.8.3 and Appendix 3G of the ESBWR DCD, with the departure given below.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the DCD CSDRS. As a result, the applicant performed new site-specific seismic SSI and SSSI analyses with the site-specific ground response spectra and the site-specific subgrade properties. In some cases, the site-specific seismic structural loads were found to be higher than those used for the standard design, and thus, a structural evaluation of the ESBWR standard plant structures for acceptability at the North Anna 3 site was performed. In a few instances as required for site-specific conditions, the standard design is modified to ensure seismic adequacy.

In FSAR Appendix 3G Section 3G.7, the applicant described the site-specific structural evaluation of the RB/FB complex including the evaluation of the CIS. The loads, load combinations, and material properties for the CIS are provided in FSAR Appendix 3G Section 3G.7.5.2, and the structural analysis and design evaluation of the CIS are provided in FSAR Appendix 3G Section 3G.7.5.4.2.

FSAR Appendix 3G Section 3G.7.5.4.2 indicates that the site-specific evaluations of the CIS are performed using the same methodology as the standard design. No design changes from the standard design were needed. Also, the CIS are within the acceptance criteria of the standard design with the exception of the diaphragm floor. However, as discussed in FSAR Appendix 3G Section 3G.7.5.4.2.1 and FSAR Appendix 3G Table 3G.7-212, the standard design of the diaphragm floor is acceptable. Thus, no design change is required.

3.8.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). In addition, the relevant requirements of the Commission regulations for the CIS and the associated acceptance criteria are in Section 3.8.3 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, GDC 1, as they relate to the design, fabrication, erection, and testing of containment internal structures in accordance with quality standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the ability of the containment internal structures without loss of capability to perform their safety function, to withstand the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and the appropriate combination of all loads..

- 10 CFR Part 50, Appendix A, GDC 4, as it relates to the protection of containment internal structures against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit..

- 10 CFR Part 50, Appendix A, GDC 5, as it relates to safety-related structures not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.

- 10 CFR Part 50, Appendix A, GDC 50, as it relates to the design of containment internal structures with sufficient margin of safety to accommodate appropriate design loads.

- 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

In addition, the acceptance criteria, regulatory guidance, and industry codes/standards associated with the review of FSAR Section 3.8.3 include the following:

- SRP Section 3.8.3 guidance to review the design, construction, and testing of the CIS to ensure that the CIS maintain their structural integrity and can perform their intended safety function during all loading conditions.

- RG 1.69, "Concrete Radiation Shields for Nuclear Power Plants"

- RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)"

- RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"

- RG 1.199, "Anchoring Components and Structural Supports in Concrete"

- ANSI/AISC N690-1994 and Supplement 2, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities and Supplement 2"

3.8.3.4 Technical Evaluation

As documented in NUREG–1966 (ADAMS Accession No. ML14100A304), NRC staff reviewed and approved Section 3.8.3 and Appendix 3G of the ESBWR DCD. The staff reviewed Section 3.8.3 and Appendix 3G of the North Anna 3 FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this Section. The staff reviewed the information in the North Anna 3 FSAR as given below.

In addition, the staff conducted a structural audit (North Anna 3 Audit 2) during the week of March 21, 2016 at the applicant's office in Wilmington, North Carolina. The purpose of this audit was to (1) review detailed analysis reports and design calculations performed by the applicant that support the information in the FSAR, (2) confirm the basis supporting the applicants' RAI responses, and (3) review the draft FSAR revisions from RAI responses to ensure consistency with the applicant's design basis information.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to the applicant's structural evaluation of the CIS for the site-specific seismic loads applied to seismic Category I structures. These evaluations are described in FSAR Appendix 3G Section 3G.7.5.4.2. The staff's technical evaluation of the design of CIS considering the site-specific seismic loads is given below.

As indicated in FSAR Appendix 3G Section 3G.7.1, DCD Appendix 3G Section 3G.1 remains applicable for the analysis and design of the RB, RCCV, and CIS with the seismic loads based on the DCD CSDRS. The evaluation of the CIS for the site-specific seismic loads is provided in FSAR Appendix 3G Section 3G.7 in order to address the exceedances from the standard design seismic loads.

Analytical Models

FSAR Appendix 3G Section 3G.7.4.1 indicates that the North Anna 3 site-specific structural models are based on the standard design structural models described in DCD Appendix 3G Sections 3G.1.4.1 for the RB and DCD Appendix 3G Section 3G.3.4 for the FB. Since the RCCV, CIS, RB, and FB are on a common basemat and the RCCV and RB are integrally connected, the structural models for these structures are combined into a single integrated RB/FB global model.

In addition to the information provided in FSAR Appendix 3G Section 3G.7, the staff reviewed the following GEH reports with regard to the analytical models used for the North Anna 3 structural evaluations for the CIS:

1. WG3-T12-ERD-S-0001, Rev. 0, "Structural Design Report for Containment Internal Structures," (ADAMS Accession No. ML15342A146)

2. DE-ES-0090, Rev. 0, "Local Analysis Model for GDCS Pool," (ADAMS Accession No. ML16022A115)

The RB/FB global model, which includes the CIS, is analyzed as one integrated structure utilizing the finite element computer code NASTRAN. The description and staff's technical evaluation of the RB/FB global finite element model is provided in this SER Section 3.8.1.4 under the heading "*Analytical Models*."

In the case of the GDCS pools, separate local models are utilized to perform a detailed stress analysis. Both the large and small pools are analyzed using the same analysis methodology as the standard design. The staff reviewed GEH report DE-ES-0090, Rev. 0, and confirmed that the finite element models of the GDCS pools are the same as those used in the standard design. On this basis, the staff finds the analytical models to be acceptable.

Site Design Loads, Load Combinations, and Material Properties

The description of the site design loads, load combinations, and material properties for the CIS is provided in FSAR Appendix 3G Sections 3G.7.5.2 and 3G.7.5.4.2. The FSAR indicates that with the exception of seismic loads, the site-specific structural evaluations utilize the same loads, load combinations, and acceptance criteria as those used in the standard design. The FSAR lists the various loads and the corresponding sections in the ESBWR DCD where these are described. In addition, the staff did not identify any changes or deviations from the material properties used in the standard design.

The site-specific seismic loads for the CIS are presented in FSAR Appendix 3A Section 3A.18.1.1. FSAR Appendix 3G Section 3G.7.5.2 also indicates that North Anna 3 site-specific seismic loads are developed from the site-specific SSI analyses based on the site-specific ground motion response spectra and the RB/FB FIRS. The site-specific seismic structural load demand in some cases exceeds the corresponding load demand of the standard design. These site-specific seismic loads consider the effects of structural stiffness variations described in FSAR Appendix 3A Section 3A.17.9.1. The effects of seismic SSSI and structure soil separation on the overall RB/FB complex are discussed in SER Section 3.8.4 below.

The staff reviewed FSAR Appendix 3G Sections 3G.7.5.2 and 3G.7.5.4.2, GEH report WG3-T12-ERD-S-0001, Rev. 0, and the other supporting information during North Anna 3 Audit 2. Based on this review, the staff concluded that the information provided in FSAR Appendix 3G Sections 3G.7.5.2 and 3G.7.5.4.2, regarding loads, load combinations, and material properties is acceptable because the standard design non-seismic loads, load combinations, and material properties, along with the North Anna 3 site-specific seismic loads were used.

Structural Analysis

Since the CIS are included and analyzed as part of the RB/FB global model, the description and staff technical evaluation of the CIS structural analysis is provided under the "*Structural Analysis*" heading of this SER.

In the case of the three GDCS pools, separate local models are utilized to perform a detailed structural analysis. These pools are analyzed using the same analysis methodology as the standard design. On this basis, the staff concluded that the structural analysis approach for the GDCS pools is acceptable.

Structural Design

The description of the structural design evaluation for the CIS is provided in FSAR Appendix 3G Section 3G.7.5.4.2 and GEH report WG3-T12-ERD-S-0001, Rev. 0. FSAR Appendix 3G Section 3G.7.5.4.2 indicates that site-specific evaluations of the CIS are performed using the same methodology used in the standard design. FSAR Appendix 3G Section 3G.7.5.4 indicates that the standard design seismic loads are replaced with the seismic loads determined from the site-specific seismic analyses described in FSAR Appendix 3A Sections 3A.10 through 3A.19.

The site-specific seismic loads for the CIS are presented in FSAR Appendix 3A Section 3A.18.1.1. As described in FSAR Appendix 3G Section 3G.7.5.4.2, the site-specific evaluations show that, with the exception of some diaphragm floor steel members, the CIS are within the acceptance criteria of the standard design. The applicant stated that the standard design of the diaphragm floor is still acceptable based on a refined calculation for the diaphragm floor. The refined calculation uses equivalent average acceleration for the diaphragm floor instead of the maximum acceleration load applied on the total weight of the diaphragm floor slab. The method used for calculating the site-specific equivalent average acceleration for the diaphragm floor in the refined calculation is consistent with the DCD method used for the development of out-of-plane loads for other flexible slabs. Application of maximum acceleration to the total weight of the diaphragm floor slab, as was done for the DCD evaluation, results in overly conservative load demand. The refined calculation using the average acceleration yields a significantly lower demand on the slab and reduces the stress demands below the code allowable values.

The staff reviewed FSAR Appendix 3G Section 3G.7.5.4.2, FSAR Appendix 3A Table 3A.18.1.1-203 and other supporting documents during North Anna 3 Audit 2, and concluded that no design change for the diaphragm floor is necessary at North Anna 3 based on the following: (1) the refined method used by the applicant to calculate the equivalent average acceleration for the diaphragm floor is acceptable because the maximum acceleration level is not uniform throughout the slab and is consistent with the DCD methodology used for other flexible slabs, (2) the use of maximum acceleration applied on the total weight of the diaphragm floor slab in the DCD evaluation is overly conservative because the slab does not experience the maximum acceleration at every location, and (3) the refined calculation using the average acceleration yields a significantly lower demand on the slab and reduces the stress demands below the code allowable values.

The staff also reviewed GEH reports WG3-T12-ERD-S-0001, Rev. 0, and DE-ES-0090, Rev. 0, and other supporting information confirmed by the staff during North Anna 3 Audit 2 regarding the structural evaluation of the CIS and the GDCS pools, respectively. Based on this review, the staff confirmed that the structural design evaluation for the CIS is consistent with the approach used for the standard design. For the other structural members comprising the CIS (vent wall, GDCS pool walls, RSW, and RPV support brackets), the staff also reviewed GEH report WG3-T12-ERD-S-0001, Rev. 0, and confirmed that the calculated stresses are below the allowable values, deformation limits were satisfied, and calculated anchorage loads are less than allowable values. Therefore, the site-specific structural design evaluation for the CIS is acceptable.

3.8.3.5 Post Combined License Activities

There are no post COL activities related to this Section. ITAAC in DCD Tier 1, Revision 10, with the modification of the SSE definition will address the as-built verification of the CIS for the North Anna 3 seismic demand.

3.8.3.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). NRC staff reviewed the North Anna 3 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 North Anna 3 FSAR related to this Section. All nuclear safety issues relating to the CIS that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.3 of NUREG–0800, and other NRC RGs. The staff finds that the applicant has addressed the areas related to CIS in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.8.3.3 of this SER.

3.8.4 Other Seismic Category I Structures

3.8.4.1 Introduction

Section 3.8.4 and Appendix 3G of the North Anna 3 FSAR, Revision 9, describe the structural analysis and design of other seismic Category I structures. These include the RB, FB, CB, and FWSC. The ESBWR design approach for the standard plant design of these structures is provided in Section 3.8.4 and Appendix 3G of ESBWR DCD, Tier 2, Revision 10.

3.8.4.2 Summary of Application

Section 3.8.4 and Appendix 3G of the North Anna 3 FSAR, Revision 9, incorporate by reference Section 3.8.4 and Appendix 3G of the ESBWR DCD, with the departure given below.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the DCD CSDRS. As a result, the applicant performed new site-specific seismic SSI and SSSI analyses with the site-specific ground response spectra and the site-specific subgrade properties. In some cases, the seismic structural loads were found to be higher than those used for the standard design, and thus, a structural evaluation of the ESBWR standard plant structures for acceptability at the North Anna 3 site was performed. In a few instances as required for site-specific conditions, the standard design is modified to ensure seismic adequacy.

Summary of RB and FB

In FSAR Appendix 3G Sections 3G.7 and 3G.9, the applicant describes the site-specific structural evaluation of the RB/FB complex. Since the RB and FB are supported by a common basemat with the RCCV and CIS, and are integrated at higher elevations with each other and with the RCCV, a global integral model was analyzed for the RCCV, CIS, RB, and FB. The analytical models used for the RB and FB are described in FSAR Appendix 3G Sections 3G.7.4 and 3G.9.4, respectively. In FSAR Appendix 3G Sections 3G.7.5 and 3G.9.5, the applicant describes the structural analysis and design. The description includes the site design parameters used in the structural evaluation, design loads, load combinations, and material properties. FSAR Appendix 3G Sections 3G.7.5.4 and 3G.9.5.4 describes the structural design evaluations of RB and FB including the basemat, respectively. The foundation stability evaluation is described in FSAR Appendix 3G Sections 3G.7.5.5 and 3G.9.5.5. These FSAR Sections include the evaluation for seismic sliding and overturning, and soil bearing pressure.

The results in terms of member forces for the RB, from the evaluations performed for the site-specific seismic loads, are presented in FSAR Appendix 3G Tables 3G.7-202 through 3G.7-204. The combined member forces and moments for selected load combinations that include seismic loads are presented in FSAR Appendix 3G Table 3G.7-220. FSAR Appendix 3G Table 3G.7-221 shows the sectional thicknesses and rebar ratios used in the evaluation of the RB. The calculated stresses of the concrete and steel reinforcement and comparison to code limits are presented in FSAR Appendix 3G Table 3G.7-222. The calculated transverse shear and comparison to code limits are presented in FSAR Appendix 3G Table 3G.7-223.

For the FB, the results in terms of member forces, from the evaluations performed for the site-specific seismic loads, are presented in FSAR Appendix 3G Table 3G.9-201. The combined member forces and moments for a selected load combination that includes seismic loads are presented in FSAR Appendix 3G Table 3G.9-202. FSAR Appendix 3G Table 3G.9-203 shows the sectional thicknesses and rebar ratios used in the evaluation of the FB. The calculated stresses of the concrete and steel reinforcement and comparison to code limits are presented in FSAR Appendix 3G Table 3G.9-204. The calculated transverse shear and comparison to code limits are presented in FSAR Appendix 3G Table 3G.9-205. FSAR Appendix 3G Table 3G.9-206 shows the maximum stress ratios for flexure and membrane forces and identifies the element with an overstress condition that requires the application of an alternative approach to meet the ASME Code requirement.

For stability evaluation, the factors of safety for the RB/FB foundation stability for overturning and sliding are presented in FSAR Appendix 3G Table 3G.7-225. The maximum calculated soil dynamic bearing pressure demand for the RB/FB is presented in FSAR Appendix 3G Table 3G.7-231.

FSAR Appendix 3G Table 3G.7-232 shows the dynamic lateral pressure loads on the RB/FB below-grade walls that were considered in the seismic structural analysis of the RB/FB global model.

<u>Summary of CB</u>

In FSAR Appendix 3G Section 3G.8, the applicant described the site-specific structural evaluation of the CB. The analytical models used for the CB are described in FSAR Appendix 3G Section 3G.8.4. In FSAR Appendix 3G Section 3G.8.5, the applicant described the structural analysis and design of the CB. This Section includes the site design parameters used in the structural evaluation, design loads, load combinations, and material properties. FSAR Appendix 3G Section 3G.8.5.4 describes the structural design evaluation of the CB including the basemat. The foundation stability evaluation is described in FSAR Appendix 3G Section 3G.8.5.5. This Section includes the evaluation for seismic sliding and overturning as well as soil bearing pressure.

The NASTRAN analysis results in terms of CB member forces, from evaluations performed for the site-specific seismic loads, are presented in FSAR Appendix 3G Tables 3G.8-202 through 3G.8-204. The combined member forces and moments for a selected load combination that includes seismic loads are presented in FSAR Appendix 3G Table 3G.8-205. The calculated stresses of the concrete and steel reinforcement and comparison to code limits are presented in FSAR Appendix 3G Tables 3G.8-206a and 3G.8-206b. The calculated transverse shear and comparison to code limits are presented in FSAR Appendix 3G Table 3G.8-207.

For stability evaluation, the factors of safety for the CB foundation stability for overturning and sliding are presented in FSAR Appendix 3G Tables 3G.8-208, 3G.8-209a and 3G.8-209b. The stresses and calculated transverse shear of CB external wall against wall capacity passive pressure for a selected load combination and the comparison to code limits are presented in FSAR Appendix 3G Tables 3G.8-210a and 3G.8-210b.

The maximum calculated soil dynamic bearing pressure demand for the CB is presented in FSAR Appendix 3G Tables 3G.8-211a and 3G.8-211b. The dynamic lateral pressure loads on CB below-grade walls are presented in FSAR Appendix 3G Table 3G.8-212.

Summary of FWSC

In FSAR Appendix 3G Section 3G.10, the applicant described the site-specific structural evaluation of the FWSC. The analytical models used for the FWSC are described in FSAR Appendix 3G Section 3G.10.4. In FSAR Appendix 3G Section 3G.10.5, the applicant described the structural analysis and design. This includes the site design parameters used in the structural evaluation, design loads, load combinations, and material properties. FSAR Appendix 3G Section 3G.10.5.4 describes the structural design evaluation of the FWSC including the basemat. The foundation stability evaluation is described in FSAR Appendix 3G Section 3G.10.5.5, which includes the evaluation for seismic sliding and overturning as well as soil bearing pressure.

The NASTRAN analysis results in terms of FWSC member forces, from evaluations performed for the site-specific seismic loads, are presented in FSAR Appendix 3G Table 3G.10-202. The combined member forces and moments for a selected load combination that includes seismic loads are presented in FSAR Appendix 3G Table 3G.10-203. FSAR Appendix 3G Table 3G.10-204 shows the sectional thicknesses and rebar ratios of the FWSC used in the evaluation. The calculated stresses of the concrete and steel reinforcement and comparison to code limits are presented in FSAR Appendix 3G Table 3G.10-205. The calculated transverse shear and comparison to code limits are presented in FSAR Appendix 3G Table 3G.10-206. For stability evaluation, the factors of safety for the FWSC foundation stability for overturning and sliding are presented in FSAR Appendix 3G Table 3G.10-214. The maximum calculated soil dynamic bearing pressure demand for the FWSC is presented in FSAR Appendix 3G Table 3G.10-215.

3.8.4.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for other seismic Category I structures, and the associated acceptance criteria, are in Section 3.8.4 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, as they relate to SSCs being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design of the safety-related structures being able to withstand the most severe natural phenomena such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.

- 10 CFR Part 50, Appendix A, GDC 4, as it relates to safety-related structures being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

- 10 CFR Part 50, Appendix A, GDC 5, as it relates to safety-related structures not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.

- 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

In addition, the acceptance criteria, regulatory guidance, and industry codes/standards associated with the review of FSAR Section 3.8.4 include the following:

- SRP Section 3.8.4 guidance to review the design, construction, and testing of other seismic Category I structures to ensure that these structures maintain their structural integrity and can perform its intended safety function during all loading conditions.

- RG 1.69, “Concrete Radiation Shields for Nuclear Power Plants”

- RG 1.91, “Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants”

- RG 1.115, “Protection Against Low-Trajectory Turbine Missiles”

- RG 1.136, “Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments”

- RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)”

- RG 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants”

- RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"
- RG 1.199, "Anchoring Components and Structural Supports in Concrete"
- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants"
- 2004 ASME Boiler and Pressure Vessel Code, Section III, Division 2, Subsection CC, "Code for Concrete Reactor Vessels and Containments"
- ACI 349-01, "Code Requirement for Nuclear Safety Related Concrete Structures"
- ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety-related Structures for Nuclear Facilities," and Supplement No. 2.

3.8.4.4 Technical Evaluation

As documented in NUREG–1966 (ADAMS Accession No. ML14100A304), NRC staff reviewed and approved Section 3.8.4 and Appendix 3G of the ESBWR DCD. The staff reviewed Section 3.8.4 and Appendix 3G of the North Anna 3 FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this Section. The staff reviewed the information in the North Anna 3 FSAR as given below.

In addition, the staff conducted a structural audit (North Anna 3 Audit 2) during the week of March 21, 2016 at the applicant's contractors GEH office in Wilmington, North Carolina. The purpose of this audit was to (1) review detailed analysis reports and design calculations performed by the applicant that support the information in the FSAR, (2) confirm the basis supporting the applicants' RAI responses, and (3) review the draft FSAR revisions from RAI responses to ensure consistency with the applicant's design basis information.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to the applicant's structural evaluation of other seismic Category I structures for the site-specific seismic loads. These evaluations are described in FSAR Appendix 3G Sections 3G.7 through 3G.10 for the RB, CB, FB, and FWSC, respectively. The staff's technical evaluation of the design of other seismic Category I structures considering these revised loads is given below.

Evaluation of RB and FB

The staff reviewed FSAR Sections 3.8.4, FSAR Appendix 3A Section 3A.18, FSAR Appendix 3G Section 3G.7, and 3G.9, as well as the following GEH reports with regard to the North Anna 3 structural evaluations for the RB and FB:

1. WG3-U71-ERD-S-0004, Rev. 2, “Reactor Building Structural Design Report,” (ADAMS Accession No. ML16148A081, ML16148A146 Non-public)

2. WG3-U97-ERD-S-0001, Rev. 2, “Fuel Building Structural Design Report,” (ADAMS Accession No. ML16148A128, ML16148A169 Non-public)

Analytical Models (RB and FB)

The RB/FB global model, which includes the RCCV and CIS, is analyzed as one integrated structure utilizing the finite element computer code NASTRAN. Therefore, the description and staff’s technical evaluation of the RB/FB global finite element model is provided in this SER Section 3.8.1.4 under the heading “*Analytical Models.”*

Site Design Loads, Load Combinations, and Material Properties

The description of the site design loads, load combinations, and material properties for the RB/FB is provided in FSAR Appendix 3G Sections 3G.7.5.2 and 3G.9.5.2, and GEH reports WG3-U71-ERD-S-0004, Rev. 2 and WG3-U97-ERD-S-0001, Rev. 2, respectively for the RB and FB. The FSAR Appendix 3G Sections 3G.7.5.2 and 3G.9.5.2 indicate that with the exception of seismic loads, the site-specific structural evaluations utilized the same loads and load combinations as those used in the standard design. The seismic loads in the standard design was replaced with the North Anna 3 site-specific seismic loads. The same acceptance criteria used in the ESBWR standard design were also used for the North Anna 3 site-specific design evaluation, with a few elements that required a refined evaluation following an alternative approach that is also allowed by the ASME code. This alternative approach is evaluated in more detail later under the heading, “*Evaluation of the Alternative Approach for Concrete Element Overstress*,” in this SER below. The FSAR Appendix 3G Sections 3G.7.5.2 and 3G.9.5.2 list the various loads and the corresponding sections in the ESBWR DCD where these loads are described.

FSAR Appendix 3G Sections 3G.7.5.2 and 3G.9.5.2 also indicate that North Anna 3 site-specific seismic loads described in FSAR Section 3A.18.1.1 are developed from the site-specific SSI analyses results. The bounding seismic loads for the design evaluation of the RB/FB complex are provided in FSAR Appendix 3A Section 3A.18 and FSAR Appendix 3G Section 3G.7.5.6, the latter of which describes the site-specific dynamic lateral soil pressures imposed on the RB/FB exterior below grade walls. The site-specific bounding seismic loads are used as input in the structural evaluation of the RCCV, CIS, and RB/FB. The bounding structural responses include: bounding maximum forces and moments, maximum accelerations, maximum accelerations at slabs and roofs, and maximum dynamic lateral pressures. The supporting information for the development of bounding seismic loads was reviewed and confirmed by the staff during North Anna 3 Audit 2.

FSAR Appendix 3G Section 3G.7.5.2 indicates that the site-specific evaluations of the RB/FB global model utilized the bounding dynamic soil pressure loads (shown in FSAR Appendix 3G Table 3G.7-232) obtained from the SSI analyses described in FSAR Appendix 3A Section 3A.17.12 and the lateral at-rest soil pressures that are the same as those used for the standard design shown in DCD Appendix 3G Figure 3G.1-19. The site-specific evaluations also considered the lateral passive resistance pressures (shown in FSAR Appendix 3G Figure 3G.7-207) obtained from the results of the sliding stability analyses in FSAR Appendix 3G Section

3G.7.5.5. The applicant found that lateral passive resistance pressures on RB/FB walls are enveloped by the corresponding standard design loads.

The staff reviewed the information provided in FSAR Section 3.8 and Appendix 3G, the GEH reports identified above, and the North Anna 3 Audit 2. The staff's review confirmed that the bounding seismic loads envelop the effects of structural stiffness variations, structure-soil separation, and variations in the subgrade material properties. The bounding seismic design loads for the RB/FB complex in some instances exceed the seismic design loads of the standard design. These seismic loads consider the effects of structural stiffness variations (cracked vs uncracked concrete) as described in FSAR Appendix 3A Section 3A.17.9.1. The effects of seismic SSSI of the CB on RB/FB are expected to be minimal as the RB/FB is larger and heavier than the CB. This is consistent with the ESBWR standard design which does not consider the SSSI effect of CB on the RB/FB. In addition, the interaction of RB/FB with the nearby non-seismic Category I structures, namely the Turbine Building, Radwaste Building, Service Building, and Ancillary Diesel Building, will be addressed through the ITAAC completion package as described in FSAR Section 3.7.2.8. The SSI analysis of RB/FB includes cases of full embedment and partial embedment (by removing the Saprolite soil layer to 5.2 m below the ground surface), the latter of which represents the maximum structure soil separation on the overall RB/FB complex. Variations in subgrade material properties and structural fill and concrete fill are also considered explicitly by using three deterministic soil profiles (LB, BE, and UB). The detailed staff evaluation of seismic analysis cases to consider various loading environments is presented in SER Section 3.7.2.

In particular, in the SSI analyses of the uncracked model, OBE damping instead of SSE damping was conservatively used for developing structural responses in addition to the in-structure response spectra (ISRS). This conservatism can contribute to the few overstress conditions for RB and FB that are identified in the FSAR. However, the applicant's reconciliation of these overstress conditions does not rely entirely on this conservatism. The overstress conditions are evaluated using an alternative approach that is also allowed by the ASME Code to meet the code limits. The evaluation of this alternative approach is described under "*Structural Design (RB and FB),*" below in this SER.

In summary, the staff review confirmed that except for the seismic loads, the North Anna 3 site-specific structural evaluation utilized the same non-seismic loadings, the same load combinations, and the same material properties as those used in the standard design. In the case of the site-specific seismic loads, the staff reviewed and confirmed during North Anna 3 Audit 2 that the site-specific seismic bounding load results presented in FSAR Appendix 3A Section 3A.18 and FSAR Appendix 3G Section 3G.7.5.6 were used for the RB/FB structural evaluation. The staff review concluded that the applicant's development of seismic loads for the design evaluation of the RB/FB complex considered applicable loading/site condition variations and conservatively used the OBE damping in the uncracked model for structural response calculation. In addition, the staff did not identify any changes or deviations from the material properties used in the standard design for concrete, reinforcing steel, and structural steel. Therefore, the staff concluded that the North Anna 3 site design loads, load combinations, and material properties are acceptable.

Structural Analysis (RB and FB)

Since the RB/FB global model includes the RB, FB, RCCV, and CIS and is analyzed as an integral finite element model using the NASTRAN code, the description and staff technical evaluation of the RB/FB structural analysis is provided in this SER under the "*Structural Analysis*" heading.

Structural Design (RB and FB)

The applicant's structural design evaluation of the RB/FB complex utilized an alternative approach to evaluate the overstress conditions at a few locations, and included more locations in the structures than the DCD locations where the North Anna 3 site-specific structural responses are expected to be higher based on the characteristics of the North Anna 3 input motion. These aspects are evaluated below under the heading," *Evaluation of the Alternative Approach for Concrete Element Overstress"* and "*Evaluation of the Sensitivity Study of NA3 Selected Elements,"* as generic procedures for structural design evaluation. Some of the following staff evaluation is also applicable to the CB.

Staff evaluation of the applicant's structural design evaluations of the RB and FB is provided in this SER under the headings, "*Design of the RB"* and "*Design of the FB,"* respectively.

Evaluation of the Alternative Approach for Concrete Element Overstress

FSAR Sections 3.8.4.5, FSAR Appendix 3G Sections 3G.7.5.4, and 3G.9.5.4 indicate that the structural acceptance criteria for the site-specific structural evaluations of the RB and FB are the same as the acceptance criteria for the standard design, with an exception that the site-specific structural evaluations may use a refined evaluation (hereinafter referred to as an *alternative approach*). Most of the design evaluation was performed using the SSDP-2D computer program for the RB/FB to satisfy both ASME Boiler and Pressure Vessel Code (BPVC) Section III 2004 and ACI 349-01, which are consistent with the DCD design criteria. The FSAR also indicates that for cases where an element exceeds the ASME acceptance criteria using the SSDP-2D analysis, additional reinforcing steel is added or the element is evaluated using axial load-moment interaction curves which satisfy both ACI 349-01 and the alternative ASME acceptance criteria. The alternative approach allowed by the ASME code involves the parabolic concrete stress-strain relationship and applicable ASME allowable stresses for a cross section subjected to membrane loads and moments due to factored loads. As compared to this alternative approach, the SSDP-2D analysis is considered more conservative because it utilizes an approach for meeting ASME Code requirements for factored loads based on the linear concrete stress-strain relationship and the concrete principal stress for comparison with the code allowable stress.

Most of the DCD selected elements and the North Anna 3 additional selected elements satisfy both ACI 349-01 and the ASME standard through the application of the SSDP-2D computer program. However, a few elements were found to exceed the ASME allowable stress in the design evaluation using the SSDP-2D program. Therefore, the approach used to design non-containment reinforced concrete members was reviewed by the applicant regarding the modification of the structural acceptance criteria identified in North Anna 3 FSAR Section 3.8.4. More specifically, the need to revise the criteria arose because the site-specific structural evaluations indicate that one segment of the FB external wall experiences compression stress demand under combined flexure and membrane forces that exceeds the acceptance criteria of the ASME BPVC for allowable compressive stress based on the linear concrete stress-strain relationship. Similarly, among the North Anna 3 selected elements in the sensitivity study (evaluated under the heading in this SER, "*Evaluation of the Sensitivity Study of North Anna 3 Selected Elements",* below), there are three elements in the RB external wall that also exceed the ASME allowable compressive stress in concrete and allowable tensile stress for rebar. These exceedances occurred as a result of using the SSDP-2D computer program, which was used in the standard design. As indicated by the applicant, the SSDP-2D computer program is more conservative than the parabolic or nonlinear stress distribution that is also accepted by ASME BPVC, Section III, Division 2, Subsection CC.

More details on the alternate approach are discussed in the applicant's response to RAI 7536 Question 03.07.02-17 (ADAMS Accession No. ML16146A789). The staff reviewed the related information and GEH reports that support the applicant's RAI response during North Anna 3 Audit 2.The alternative approach, also allowed by the ASME Code, ensures that the more limiting acceptance criteria of the ASME Code and the ACI 349-01 Code are met. During the audit, the applicant discussed with the staff in more detail this alternative approach and the conservatism in the SSDP-2D program. Based on this review, the staff found this alternative approach for design evaluation acceptable because it is in accordance with the ASME code and the ACI 349-01 code.

Evaluation of the Sensitivity Study of North Anna 3 Selected Elements

FSAR Appendix 3G indicates that the adequacy of the seismic Category I structures for the North Anna 3 site-specific conditions is demonstrated by comparing the site-specific demands with the structural members section capacities for the same set of selected elements as those considered for the standard design.

In addition to the DCD selected elements, FSAR Section 3G also indicates that the applicant performed a sensitivity study to evaluate additional elements for North Anna 3. During the public meeting on November 20, 2014 on Dominion's Seismic Closure Plan, the staff discussed with Dominion that given the North Anna 3 seismic ground motion exceeds the CSDRS at some frequencies, whether some other locations in addition to the DCD selected elements should be evaluated during the North Anna 3 design evaluation. As discussed in the March 3, 2016 public meeting and documented in FSAR Section 3G, a sensitivity study was performed for the design evaluation of additional elements in RB/FB and CB particularly at locations where North Anna 3 site-specific bounding seismic loads exceed the corresponding DCD seismic loads. There was no need for additional North Anna 3 site-specific elements for RCCV, CIS and FWSC as the DCD elements evaluated for these structures are considered sufficient. Design evaluations were performed for 96 North Anna 3 additional selected elements (62 for RB, 27 for FB, and 7 for CB). The applicant concluded that no changes to the standard design concrete member dimensions are necessary and most of the North Anna 3 selected elements were adequate by simply using the SSDP-2D approach that is also used in the DCD. However, the applicant did find three of the North Anna 3 selected elements in the RB that did not meet the ASME allowable stress using the SSDP-2D approach. The design evaluation of these elements required the use of the alternative approach, i.e., using the parabolic concrete stress-strain relationship that is also allowed by ASME, and the applicable ASME allowable stresses for a cross section subjected to membrane loads and moments due to factored loads. In addition, 12 new rebar schedules have been designed and incorporated into the structural drawings.

More details on this sensitivity study are discussed in the applicant's response to RAI 7536 Question 03.07.02-17 (ADAMS Accession No. ML16146A789). The staff reviewed the related information and GEH report that support the applicant's RAI response during North Anna 3 Audit 2. Based on this review, the staff finds the North Anna 3 sensitivity study acceptable since it evaluates additional locations in the seismic Category I structures where the North Anna 3 site-specific seismic demands are higher than the DCD demands, and provides additional confidence in the ESBWR standard design at the North Anna 3 site. The staff notes that for the design of the remaining structural members, not included in the design of the DCD selected elements and North Anna 3 additional selected elements reviewed by the staff, will be designed during the detailed design stage using the same methodology described in the DCD and FSAR.

Design of the RB

The description of the structural design evaluation for the RB is provided in FSAR Appendix 3G Section 3G.7.5.4.3 and GEH report WG3-U71-ERD-S-0004, Rev. 2. FSAR Appendix 3G Section 3G.7.5.4 indicates that with the exception of seismic loads, site-specific evaluations of the RB use the same standard design models, analysis methods, loads (as described in FSAR Appendix 3G Section 3G.7.5.2), load combinations, and acceptance criteria that were used in the standard design. However, the standard design seismic loads are replaced with the seismic loads determined from the North Anna 3 site-specific seismic analyses described in FSAR Appendix 3A Sections 3A.10 through 3A.19.

As described in FSAR Appendix 3G Section 3G.7.5.4.3, the site-specific evaluations show that the RB standard design is adequate to resist the North Anna 3 site-specific seismic loads in combination with non-seismic standard design loads, with the exception of a change in the arrangement of shear ties for a single wall to withstand the North Anna 3 site-specific seismic loads. The affected wall section is at the exterior wall of the RB, Elevation 22.50 m to Elevation 24.60 m, column line R7/F1. With this change in the arrangement of shear ties, the FSAR indicates that the stresses of the concrete and rebar are less than the allowable stresses specified in the codes and the areas of the primary and shear reinforcement, which have been provided, meet the required values. FSAR Appendix 3G Section 3G.7.5.4.3 also indicates that the stresses of steel members are less than the allowable stresses specified in the code. Furthermore, as an overall conclusion, the FSAR indicates that there is no need for any change to the standard design concrete member properties (e.g., wall and slab thicknesses, beam and column sizes) to meet the standard design structural acceptance criteria.

The staff reviewed the information in FSAR Appendix 3G Section 3G.7.5.4 and GEH report WG3-U71-ERD-S-0004, Rev. 2 regarding the structural design evaluation of the RB. The staff's review found that the analysis model and approach, the industry codes and standards, structural materials and their properties, loads and load combinations used in the design evaluations, and the method for checking the design of the RB were consistent with those used in the standard design. The staff reviewed the results of the design evaluation for 109 representative locations of the RB (including 47 DCD-selected elements and 62 North Anna 3-selected elements), which included shear walls, basemat outside containment, floor slabs, pool girders, main steam tunnel floors and walls, and IC/PCCS pool. The staff also reviewed the change in the arrangement of shear ties for one wall and the applicant's use of the alternative approach (i.e. using the parabolic concrete stress-strain relationship and applicable ASME allowable stresses for a cross section subjected to membrane loads and moments due to factored loads). The staff found that the calculated stresses of the concrete and steel reinforcement were below allowable values, the areas of the provided primary and shear reinforcement meet the required values, and the stresses of steel members are less than the allowable stresses specified in the code. Therefore, the staff concluded the site-specific structural design evaluation for the RB is acceptable.

Design of the FB

The description of the structural design evaluation for the FB is provided in FSAR Appendix 3G Section 3G.9.5.4 and GEH report WG3-U97-ERD-S-0001, Rev. 2. FSAR Appendix 3G Section 3G.9.5.4 indicates that with the exception of seismic loads, site-specific evaluations use the same standard design models, analysis methods, loads (as described in FSAR Appendix 3G Section 3G.9.5.2), load combinations, and acceptance criteria that were used in the standard design. However, the standard design seismic loads are replaced with the seismic loads determined from the site-specific seismic analyses described in FSAR Appendix 3A Sections 3A.10 through 3A.19.

FSAR Appendix 3G Section 3G.9.5.4 describes the site-specific evaluations which show that the FB standard design is adequate to resist the North Anna 3 site-specific seismic loads in combination with non-seismic standard design loads, with the following exceptions:

1. An overstress condition at the exterior wall element (Element 72004 from Elevation 4.65 m to Elevation 6.60 m), which exceeds the allowable SSDP-2D stresses by 3 percent for the axial-flexural behavior and is resolved using the alternative approach that is described in FSAR Section 3.8.4.5. This alternative approach that is also allowed in the ASME Code is evaluated above under the heading, "*Evaluation of the Alternative Approach for Concrete Element Overstress*," of this SER;

2. A change in the arrangements of reinforcements in two FB exterior wall segments (Elements 72001 and 72004, at the exterior wall, between Elevations 4.65 m and 6.60 m between columns FA and FF); and

3. A change in the arrangement of exterior wall shear ties (Element 72004) at exterior FB wall between Elevations 4.65 m and 6.60 m between columns FA and FF).

With these changes in reinforcement and the resolution of the overstress condition, the FSAR indicates that the results of the site-specific stress checks demonstrate that the stresses of the concrete and rebar are less than the allowable stresses specified in the codes and the areas of the primary and shear reinforcement, which have been provided, meet the required values. The FSAR also indicates that the stresses of steel members are less than the allowable stresses specified in the code. Furthermore, as an overall conclusion, the FSAR indicates that there is no need for any change to the standard design concrete member properties (e.g., wall and slab thicknesses, beam and column sizes) to meet the standard design structural acceptance criteria.

The staff reviewed the information in FSAR Appendix 3G Section 3G.9.5.4 and GEH report WG3-U97-ERD-S-0001, Rev. 2. The staff found that the industry codes and standards, structural materials and their properties, loads and load combinations used in the design evaluations, and the method for checking the design of the FB were consistent with those used in the standard design. The staff also reviewed the results of the design evaluation for 53 representative locations of the FB (including 26 DCD-selected elements and 27 North Anna 3-selected elements), which included shear walls and spent fuel pool walls, floor slabs, and basemat. The staff also reviewed the three changes in the arrangement of rebar and shear ties and the applicant's use of the alternative approach (i.e. using the parabolic concrete stress-strain relationship and applicable ASME allowable stresses for a cross section subjected to membrane loads and moments due to factored loads). The staff found that the calculated stresses of the concrete and steel reinforcement were below allowable values and the provided reinforcement was greater than the required reinforcement for the primary and shear reinforcement. Therefore, the staff concluded the site-specific structural design evaluation for the FB is acceptable.

Evaluation of CB

The staff reviewed FSAR Sections 3.8.4, FSAR Appendix 3A Section 3A.18, and FSAR Appendix 3G Section 3G.8, as well as the following GEH report with regard to the North Anna 3 structural evaluations for the CB:

1. WG3-U73-ERD-S-0004, Rev. 3, "Control Building Structural Design Report" (ADAMS Accession No. ML16148A051, ML16148A126 Non-public).

Analytical Model (CB)

The description of the analytical model for the CB is provided in FSAR Appendix 3G Section 3G.8.4. FSAR Appendix 3G Section 3G.8.4.1 indicates that site-specific structural model for the CB is based on the standard design structural model described in DCD Appendix 3G Section 3G.2.4.1. FSAR Appendix 3G Section 3G.8.4.2 also indicates that the site-specific foundation model for the CB is based on the standard design foundation model described in DCD Appendix 3G Section 3G.2.4.2. The staff noted in FSAR Appendix 3G Section 3G.8.5.1 that the site-specific foundation model for the CB uses spring elements based on generic soft soil conditions considered for the ESBWR DCD. GEH report WG3-U73-ERD-S-0004, Rev. 3 provides more details of the analytical model used for the site-specific structural evaluations for the CB.

The staff reviewed FSAR Appendix 3G Sections 3G.8.4 and 3G.8.5.1, DCD Appendix 3G Section 3G.2.4, and GEH report WG3-U73-ERD-S-0004, Rev. 3. The staff also reviewed the supporting information on the site specific GEH analytical model during North Anna 3 Audit 2. Based on this review, the staff confirmed that the site-specific structural model and foundation model for the CB are consistent with the models used for the standard design. The staff's conclusions on the acceptability of using generic soft soil conditions for North Anna 3 site is discussed in SER Section 3.8.1.4 under the heading *"Structural Analysis."* The staff found that the results of the study for site subgrade stiffness conditions performed for RB/FB also apply to the CB because the site subgrade stiffness conditions for both CB and RB/FB are similar. Therefore, the staff concluded that the use of the CB analytical model as described in FSAR Appendix 3G Section 3G.8.4 for the site-specific structural evaluations is acceptable.

Site Design Loads, Load Combinations, and Material Properties (CB)

The description of the site design loads, load combinations, and material properties for the CB is provided in FSAR Appendix 3G Section 3G.8.5.2 and GEH report WG3-U73-ERD-S-0004, Rev. 3. FSAR Appendix 3G Section 3G.8.5.2 indicates that with the exception of seismic loads, the site-specific structural evaluations of the CB utilize the same loads, load combinations, and acceptance criteria that were used in the standard design. The seismic loads in the standard design were replaced with the North Anna 3 site-specific seismic loads. FSAR Appendix 3G Section 3G.8.5.2 lists the various loads and the corresponding sections in the ESBWR DCD where these loads are described. In addition, FSAR Appendix 3G Section 3G.8.5.2 indicates that the site specific structural evaluations for the CB utilize the same material properties of concrete, reinforcing steel, and structural steel as those used in the standard design. The staff did not identify any changes or deviations from the material properties used in the standard design.

The bounding site-specific seismic structural load demand for the CB is provided in FSAR Appendix 3A Section 3A.18.1.2. This Section indicates that site-specific seismic loads for the CB are developed from the site-specific SSI analyses of CB stand-alone model with full stiffness and SSE damping properties. The site-specific seismic structural load demand in some cases exceeds the corresponding load demand of the standard design. These site-specific seismic loads consider the effects of soil separation (partially and fully embedded conditions) described in FSAR Appendix 3A Section 3A.16.3.2 and structural stiffness variations (concrete cracking) described in FSAR Appendix 3A Section 3A.17.9.2. However, the CB bounding site-specific seismic structural load demand does not include SSSI effects of the FWSC and RB/FB on the CB. The site-specific evaluations of effects of seismic SSSI of the FWSC and RB/FB on the seismic response of CB in FSAR Appendix 3A Section 3A.17.11 show a few small exceedances in some of the local load demand, which have a negligible effect on the CB. Therefore, these exceedances are not included in the site-specific evaluation of the CB. In addition, the interaction of CB with the nearby non-seismic Category I structures will be addressed through the ITAAC completion package as described in FSAR Section 3.7.2.8. Variations in subgrade material properties and structural fill and concrete fill are considered explicitly by using three deterministic soil profiles (LB, BE, and UB).

FSAR Appendix 3G Section 3G.8.5.2 indicates that the site-specific structural evaluations of the CB consider: (1) at-rest static soil pressure loads same as the ones used for the standard design shown in DCD Appendix 3G Figure 3G.2-12, (2)site-specific lateral dynamic pressure loads (shown in FSAR Appendix 3G Table 3G.8-212) obtained from the site-specific SSI analyses described in FSAR Appendix 3A Section 3A.17.13.4, and (3) site-specific passive resistance pressures (shown in FSAR Appendix 3G Table 3G.8-213) obtained from the sliding stability calculations in FSAR Appendix 3G Section 3G.8.5.6.

The staff reviewed FSAR Appendix 3G Section 3G.8.5.2, GEH report WG3-U73-ERD-S-0004, Rev. 3, and other supporting information as confirmed during North Anna 3 Audit 2. Based on this review, the staff determined that with the exception of seismic loads, the site-specific structural evaluations of the CB utilize the same loads, load combinations, acceptance criteria, and material properties as those used in the standard design. The staff also confirmed that the bounding site-specific seismic load demand for the CB was used as input to the CB structural evaluations. The staff further confirmed that the bounding structural loads envelop the effects of: (1) soil separation (partially and fully embedded conditions) described in FSAR Appendix 3A Section 3A.16.3.2, and (2) structural stiffness variations (concrete cracking) described in FSAR Appendix 3A Section 3A.17.9.2. In addition, the staff reviewed SSSI effects of the FWSC and RB/FB on the CB, and determined that a few small exceedances in some of the local load demand have no effect on the CB structural evaluation. The staff confirmed that at-rest static soil pressure loads for the CB site-specific structural evaluation were consistent with those at-rest static soil pressure loads used in the standard design. The staff also confirmed that site-specific lateral dynamic pressure loads shown in FSAR Appendix 3G Table 3G.8-212 and site-specific passive resistance pressures shown in FSAR Appendix 3G Table 3G.8-213 along with at-rest static soil pressure loads were used as input to the CB structural evaluations. Therefore, the staff concluded that the North Anna 3 site design loads, load combinations, and material properties used for the CB site-specific structural evaluations are acceptable.

Structural Analysis (CB)

The description of the structural analysis performed for the CB is provided in FSAR Appendix 3G Section 3G.8.5 and GEH report WG3-U73-ERD-S-0004, Rev. 3. The structural analysis of the CB is performed consistently with the procedure used for the standard design, and the CB model is analyzed using the same NASTRAN finite element computer program used for the standard design, as described in DCD Section 3C.2.

Section 6.2.3.6 of the CB structural design report (WG3-U73-ERD-S-0004, Rev. 3) describes how site-specific seismic loads are developed from the CB lumped mass stick model (LMSM) and applied to the CB finite element model. The methodology used to convert North Anna 3 site-specific seismic loads from LMSM to NASTRAN finite element model is identical to the methodology used in the standard design. The staff's acceptability of applying bounding site-specific seismic loads to NASTRAN design model is discussed in this SER Section 3.8.1.4 under the heading "*Structural analysis*." The combined member forces and moments for a selected load combination that include site-specific seismic loads are presented in FSAR Appendix 3G Table 3G.8-205.

The staff reviewed FSAR Appendix 3G Section 3G.8.5, GEH report WG3-U73-ERD-S-0004, Rev. 3 and other supporting information was confirmed by the staff during the North Anna 3 Audit 2. Based on this review, the staff determined that: (1) the NASTRAN finite element model for the CB is the same model as one used for the standard design, (2) with the exception of seismic loads, the site-specific structural evaluations of the CB utilize the same analysis methods, loads, load combinations, and material properties as those used in the standard design, (3) site-specific seismic loads developed from the CB site-specific seismic analyses are used to replace DCD seismic loads, and (4) the site-specific seismic forces applied to the CB model for the structural evaluation are the same as the bounding site-specific seismic load demand discussed in this SER Section 3.8.4.4 under the heading "*Site Design Loads, Load Combinations, and Material Properties (CB)*." Therefore, the staff concluded that the structural analysis performed for the CB is acceptable.

Structural Design (CB)

The description of the structural design evaluation for the CB is provided in FSAR Appendix 3G Section 3G.8.5.4 and GEH report WG3-U73-ERD-S-0004, Rev. 3. FSAR Appendix 3G Section 3G.8.5.4 indicates that the site-specific structural evaluation of the CB utilizes the same models, analysis methods, loads (other than seismic loads), load combinations, and acceptance criteria as those used in standard design. However, the standard design seismic loads are replaced with the seismic loads (as described in FSAR Appendix 3G Section 3G.8.5.2) determined from the site-specific seismic analyses described in FSAR Appendix 3A Sections 3A.10 through 3A.19. The FSAR also indicates that the site-specific structural evaluation of the CB utilizes the same methodology used for the DCD structural evaluation described in DCD Appendix 3G Section 3G.2.5.

The site-specific evaluations in FSAR Appendix 3G Section 3G.8.5.4 show that the standard design CB, with a design change in steel girder SG23 (NASTRAN finite element model CBAR ID 21016, Elevation 4.65m on Column-Row CB), is adequate to resist the site-specific seismic load demands in combination with the non-seismic ESBWR standard plant loads.

The results of site-specific stress check in FSAR Appendix 3G Section 3G.8.5.4 also indicate that: (1) the stresses of the concrete and rebar are less than the allowable stresses specified in the code, and the areas of the primary and shear reinforcement satisfy the required values, and (2) the stresses of steel members are less than the allowable stresses specified in the code with the change in steel girder SG23.

As discussed in this SER Section 3.8.4.4 under the heading "*Evaluation of the Sensitivity Study of NA3 Selected Elements,"* regarding North Anna 3 selected elements, the sensitivity study of the CB identified 7 additional elements for further site-specific structural evaluation in addition to the elements selected in the DCD. The staff reviewed FSAR Appendix 3G and confirmed supporting information during North Anna 3 Audit 2. The staff determined that the additional site-specific structural evaluation results from the sensitivity study do not change the standard design member properties (e.g., wall and slab thickness, beam and column sizes) except for adding localized reinforcement as part of the detailed design.

The staff reviewed FSAR Appendix 3G Section 3G.8, GEH report WG3-U73-ERD-S-0004, Rev. 3, and other supporting information confirmed during North Anna 3 Audit 2. Based on this review, the staff determined that with the exception of seismic loads, the CB analysis model and approach, industry codes and standards, structural materials and their properties, loads and load combinations, acceptance criteria used in the design evaluations, and the method for applying loads were consistent with those used in the standard design. The staff also confirmed that the North Anna 3 structural design evaluation of CB utilizes the same methodology as the DCD and uses the same SSDP-2D computer program, which in addition to ACI 349-01, also follows the 2004 ASME code. According to DCD Table 3.8-15, the acceptance criteria for CB section strength are based on the strength design method per ACI 349-01. The staff found that the CB section design is conservatively taken to be more limiting of ACI 349-01 and 2004 ASME Section III, Division 2, Subsection CC requirements. For the reinforced concrete structures of the CB, the staff reviewed the calculated stresses of the concrete and steel reinforcement and comparison to code limits for a selected load combination shown in FSAR Appendix 3G Tables 3G.8-206a and 3G.8-206b; the staff also reviewed the calculated transverse shear and comparison to code limits shown in FSAR Appendix 3G Table 3G.8-207. Based on this review, the staff confirmed that: (1) the stresses of the concrete and rebar are less than the allowable stresses specified in the code, and (2) the areas of the primary and shear reinforcement satisfy the required values. For the steel structures of the CB, the staff reviewed the selected calculations of steel structures including design change for one structural steel girder SG23 during the North Anna 3 Audit 2. Based on this review, the staff confirmed that the stresses of the steel members are less than the allowable stresses specified in the code, with the change in steel girder SG23.

In conclusion, the staff found that the standard design CB, with the change in the steel girder SG23, is adequate to resist the site-specific seismic load demand at North Anna 3 site.

Evaluation of FWSC

The staff reviewed FSAR Sections 3.8.4, FSAR Appendix 3A Section 3A.18,FSAR Appendix 3G Section 3G.10, as well as the following GEH report with regard to the North Anna 3 structural evaluations for the FWSC:

1. WG3-U63-ERD-S-0003, Rev. 2, "Firewater Service Complex Structural Design Report" (ADAMS Accession No. ML16148A050, ML16148A125 Non-public)

Analytical Model (FWSC)

The description of the analytical model for the FWSC is provided in FSAR Appendix 3G Section 3G.10.4. FSAR Appendix 3G Section 3G.10.4.1 indicates that the North Anna 3 site-specific structural model for the FWSC is based on the standard design structural model described in DCD Appendix 3G Section 3G.4.4.1. FSAR Appendix 3G Section 3G.10.4.2 indicates that the North Anna 3 site-specific foundation model for the FWSC is based on the standard design foundation model described in DCD Appendix 3G Section 3G.4.4.2. The staff noted in FSAR Appendix 3G Section 3G.10.5.1 that the site-specific foundation model for the FWSC is based on the generic soft soil conditions considered for the ESBWR DCD. GEH report WG3-U63-ERD-S-0003, Rev. 2 provides more details of the analytical model used in the site-specific structural evaluations of the FWSC.

The staff reviewed the information in FSAR Appendix 3G Section 3G.10, DCD Appendix 3G Section 3G.4, and GEH report WG3-U63-ERD-S-0003, Rev. 2. The staff also reviewed and confirmed the supporting information on analytical model during North Anna 3 Audit 2. Based on this review, the staff determined that the site-specific structural model and foundation model for the FWSC are consistent with the corresponding models for the standard design. The staff's acceptability of using the generic soft soil conditions for North Anna 3 site is discussed in this SER 3.8.1.4 under the heading, "*Structural Analysis.*" The staff found that the results of the study for site subgrade stiffness conditions performed for RB/FB also apply to the FWSC because the site subgrade stiffness conditions for both FWSC and RB/FB are similar. Therefore, the staff concluded that the use of the FWSC analytical model as described in FSAR Appendix 3G Section 3G.10.4 for the site-specific structural evaluations of the FWSC is acceptable.

Site Design Loads, Load Combinations, and Material Properties (FWSC)

The description of the site design loads, load combinations, and material properties for the FWSC is provided in FSAR Appendix 3G Section 3G.10.5.2 and GEH report WG3-U63-ERD-S-0003, Rev. 2. FSAR Appendix 3G Section 3G.10.5.2 indicates that, with the exception of seismic loads, the site-specific structural evaluations of the FWSC utilize the same loads, load combinations, and acceptance criteria that were used in the standard design. The seismic loads in the standard design were replaced with the North Anna 3 site-specific seismic loads. FSAR Appendix 3G Section 3G.10.5.2 lists the various loads and the corresponding sections of the ESBWR DCD where these loads are described. In addition, FSAR Appendix 3G Section 3G.10.5.2 indicates that the site-specific structural evaluations of the FWSC utilize the same material properties of concrete, reinforcing steel, and structural steel as those used in the standard design. The staff did not identify any changes or deviations from the material properties used in the standard design.

FSAR Appendix 3G Section 3G.10.5.2 also indicates that the seismic loads used for the structural evaluations of the FWSC are based on the site-specific seismic demands presented in FSAR Appendix 3A Section 3A.18.1.3. This section indicates that the site-specific seismic demands bound the effects of structural stiffness variations described in FSAR Appendix 3A Section 3A.17.9.3, SSSI with the CB described in FSAR Appendix 3A Section 3A.17.11, and separation between the concrete fill and surrounding soil described in FSAR Appendix 3A Section 3A.17.14.5. In addition, the interaction of FWSC with the nearby non-seismic Category I structures will be addressed through the ITAAC completion package as described in FSAR Section 3.7.2.8.

The staff reviewed FSAR Appendix 3G Section 3G.10.5.2, WG3-U63-ERD-S-0003, Rev. 2, and confirmed the supporting information during North Anna 3 Audit 2. Based on this review, the staff determined that, with the exception of seismic loads, the site-specific structural evaluations of the FWSC utilized the same loads, load combinations, acceptance criteria, and material properties as those used in the standard design. The staff also confirmed that the bounding site-specific seismic load demands for the FWSC were used in the structural evaluations of the FWSC. The staff further confirmed that the bounding site-specific seismic demands envelop the effects of: (1) the variation of subgrade material conditions, (2) separation between the concrete fill and surrounding soil, (3) structural stiffness variations (concrete cracking), and (4) SSSI with the CB. Therefore, the staff concluded that the North Anna 3 site design loads, load combinations, and material properties used for the FWSC site-specific structural evaluations are acceptable.

Structural Analysis (FWSC)

The description of the structural analysis performed for the FWSC is provided in FSAR Appendix 3G Section 3G.10.5 and GEH report WG3-U63-ERD-S-0003, Rev. 2. The structural analysis of the FWSC is performed consistently with the procedure used for the standard design, and the FWSC model is analyzed using the same NASTRAN finite element computer program used for the standard design, as described in DCD Section 3C.4.

Section 6.2.3.6 of the FWSC structural design report (WG3-U63-ERD-S-0003, Rev. 2) describes how site-specific seismic loads are developed from the FWSC lumped mass stick model (LMSM) and applied to the FWSC finite element model. The methodology used to convert North Anna 3 site-specific seismic loads from LMSM to NASTRAN finite element model is identical to the methodology used in the standard design. The staff's acceptability of applying the bounding site-specific seismic loads to the NASTRAN model is discussed in this SER Section 3.8.1.4 under the heading "*Structural Analysis.*" The combined member forces and moments for a selected load combination that include site-specific seismic loads are presented in FSAR Appendix 3G Table 3G.10-203. Section 5.6 of FWSC structural design report (WG3-U63-ERD-S-0003, Rev. 2) describes that the site-specific hydrodynamic pressures on the FWS walls and floors due to the seismic ground motions are developed following the same methodology as used in the standard design and that the site-specific lateral pressure loads applied along the FWSC shear keys are considered in the site-specific structural evaluations of the FWSC.

The staff reviewed FSAR Appendix 3G Section 3G.10.5, GEH report WG3-U63-ERD-S-0003, Rev. 2, and confirmed the supporting information during the North Anna 3 Audit 2. Based on this review, the staff determined that: (1) the NASTRAN finite element model for the FWSC is the same model as the one used for the standard design, (2) with the exception of seismic loads, the site-specific structural evaluations of the FWSC utilize the same analysis methods, loads, load combinations, and material properties as those used in the standard design, (3) site-specific seismic loads developed from the FWSC site-specific seismic analyses are used to replace the DCD seismic loads, and (4) the site-specific seismic loads applied to the FWSC model for the structural evaluations are consistent with the bounding site-specific seismic load demands discussed in this SER Section 3.8.4.4 under the heading "*Site Design Loads, Load Combinations, and Material Properties (FWSC)*." Therefore, the staff concluded that the structural analysis performed for the FWSC is acceptable.

Structural Design (FWSC)

The description of the structural design evaluation for the FWSC is provided in FSAR Appendix 3G Section 3G.10.5.4 and GEH report WG3-U63-ERD-S-0003, Rev. 2. FSAR Appendix 3G Section 3G.10.5.4 indicates that the site-specific structural evaluation of the FWSC utilizes the same models, analysis methods, loads (other than seismic loads), load combinations, and acceptance criteria as those used in the standard design. However, the standard design seismic loads are replaced with the seismic loads determined from the site-specific seismic analyses as described in FSAR Appendix 3A Sections 3A.10 through 3A.19. The FSAR also indicates that the site-specific structural evaluations of the FWSC utilize the same methodology as used for the DCD structural evaluations of the FWSC described in DCD Appendix 3G Section 3G.4.5.

The site-specific evaluations presented in FSAR Appendix 3G Section 3G.10.5.4 show that the standard design FWSC is adequate to resist the site-specific seismic load demands in combination with the non-seismic ESBWR standard plant loads except for a few instances in which a design change is required. Specifically, the applicant modified the standard design by changing steel reinforcement and shear ties to the following structural elements of the FWSC:

- Basemat (Element 227): primary reinforcement ratio in the E-W direction is increased from 0.604 percent to 0.705 percent.
- Shear Key (Element 72008): primary reinforcement ratio in the E-W direction is increased from 0.377 percent to 0.629 percent; shear tie reinforcement ratio is increased from 0.177 percent to 0.484 percent.
- Shear Key (Element 73017): shear tie reinforcement ratio is increased from 0.177 percent to 0.484 percent.

The staff confirmed that the details of changed reinforcement and shear ties to these elements are provided in FSAR Appendix 3G Table 3G.10-204.

With the change of rebar in the basemat and rebar and shear ties in the shear key as discussed above, site-specific stress check calculations for the FWSC are performed to evaluate the adequacy of the FWSC at the North Anna 3 site. This design check is performed in accordance with SSDP-2D, following the same methodology as that used for the standard design. The site-specific stress checks demonstrated that the FWSC structures are adequate to resist site-specific seismic load demands in combination with non-seismic ESBWR standard plant loads. Specifically, the stresses of the concrete and rebar are less than the allowable stresses specified in the code, and the provided area of primary and shear reinforcement, including the reinforcement changes as described above, satisfy the required values.

The staff reviewed FSAR Appendix 3G Section 3G.10, GEH report WG3-U63-ERD-S-0003, Rev. 2, and confirmed the supporting information during North Anna 3 Audit 2. Based on this review, the staff determined that with the exception of seismic loads, the FWSC analysis model and approach, industry codes and standards, structural materials and their properties, loads and load combinations, acceptance criteria used in the design evaluations, and the method for applying loads are consistent with those used in the standard design. The staff also confirmed that the North Anna 3 structural design evaluations of the FWSC utilize the same methodology as the standard design. For the reinforced concrete structures of the FWSC, the staff reviewed the calculated stresses of the concrete and steel reinforcement and comparison to code limits for a selected load combination shown in FSAR Appendix 3G Table 3G.10-205. The staff also reviewed the calculated transverse shear and comparison to code limits shown in FSAR Appendix 3G Table 3G.10-206. Based on this review, the staff confirmed, with enhanced steel reinforcement and shear ties to the basemat and shear keys as described in FSAR Appendix 3G Table 3G.10-204, that: (1) the stresses of the concrete and rebar are less than the allowable stresses specified in the code, and (2) the areas of the primary and shear reinforcement satisfy the required values.

In conclusion, the staff found that the standard design FWSC, with changes of steel reinforcement and shear ties to the basemat and shear keys, is adequate to resist the site-specific seismic load demand in combination with the non-seismic ESBWR standard plant loads at the North Anna 3 site.

Fuel Rack and Spent Fuel in Spent Fuel Rack

The staff reviewed FSAR Section 9.1, as well as the following GEH reports with regard to the North Anna 3 structural evaluations for the fuel rack and spent fuel in the spent fuel rack:

1. 002N8467, Revision 4, "North Anna 3 Fuel Rack Seismic Analysis" (ADAMS Accession No. ML16125A364)

2. 003N0526, Revision 1, "North Anna 3 Seismic Qualification of Spent Fuel in the Spent Fuel Racks" (ADAMS Accession No. ML16153A388, ML16125A367 Non-public)

As a result of the staff's review of the prior FSAR Revision 8, the staff noted that FSAR Section 9.1 provides the structural assessment of the new and spent fuel storage racks in the buffer pool and spent fuel pool, based on the DCD seismic demands, and not the North Anna 3 site-specific seismic loadings. Therefore, the staff requested, in RAI 03.07.02-20, that the applicant provide a site-specific structural assessment of the acceptability of the new and spent fuel storage racks for the site-specific departure (NAPS DEP 3.7-1), related to any exceedances in the seismic inputs at the North Anna 3 site. In response to this RAI (ADAMS Accession No. ML15364A384), the applicant revised FSAR Sections 9.1.1 and 9.1.2 to describe the site-specific seismic evaluations of the structural design of the new fuel storage racks and the spent fuel storage racks, respectively. The revised FSAR Section 9.1.2.4 also provides evaluations of the adequacy of the spent fuel stored in the spent fuel racks to withstand the site-specific North Anna 3 SSE. Details of the site-specific assessments are described in GEH reports 002N8467, Rev. 4 and 003N0526, Rev. 1.

In FSAR Revision 9, Section 9.1, the applicant stated that the site-specific assessment of the structural design of the spent and new fuel storage racks was performed using the same method as the standard design evaluations, but used the North Anna 3 seismic demand. The applicant used the guidance of Appendix D of SRP Section 3.8.4 in its assessment. Based on its site-specific evaluation for the fuel racks, the applicant concluded that: (1) the standard design of the spent fuel racks in the spent fuel pool is adequate for the site-specific seismic demand, (2) for the spent fuel racks in the buffer pool deep pit, changes in the size of the anchor bolts and the welds from the enveloping plate to the base stiffener plate are necessary to ensure seismic adequacy of these racks for North Anna 3 seismic demand, (3) for the new fuel storage racks located only in the buffer pool, changes in the size of the anchor bolts are necessary to ensure seismic adequacy of these racks for North Anna 3 site-specific seismic demand, and (4) for both the spent fuel racks in the buffer pool deep pit and the new fuel storage racks in the buffer pool, the site-specific embedment design loads for the concrete anchors are higher than the corresponding standard design embedment loads. The applicant also indicated that the increase in North Anna 3 embedment loads due to increase in site-specific seismic demand will be accommodated during the detailed design phase.

In addition to the information provided in FSAR Section 9.1, the staff reviewed the GEH report 002N8467, Rev. 4, to confirm the basis for the FSAR results. In addition the staff reviewed the response to RAI 03.07.02-20 (ADAMS Accession No. ML15364A384) and confirmed the supporting analysis used during the North Anna 3 Audit 2. GEH report 002N8467, Rev. 4 summarizes the analysis of all three fuel rack designs: spent fuel storage racks in the spent fuel pool, spent fuel storage racks in the buffer pool deep pit, and the new fuel storage racks in the buffer pool. The fuel racks were reanalyzed using the North Anna 3 site-specific ISRS. A comparison of the North Anna 3 site-specific ISRS to the standard design input response spectra used previously was presented in the report. There were some increases in the North Anna 3 ISRS at certain frequency ranges, with the more significant increases occurring primarily in the vertical direction.

The staff noted that both the transient analysis approach and the response spectra analysis approach were used for the analysis of the fuel storage racks. The transient analysis approach requires developing synthetic acceleration time histories whose spectra should envelop the input response spectra. The staff reviewed the applicant's approach for developing the synthetic time histories used in the transient analysis of the fuel racks from the site-specific input response spectra. The staff noted that for the spent fuel storage racks in the spent fuel pool and the new fuel storage racks in the buffer pool, the synthetic time histories were developed from the site-specific bounding ISRS at the corresponding locations obtained from the site-specific SSI analyses of the RB/FB. The staff also verified during North Anna 3 Audit 2 that the response spectra generated from these time histories envelop the site-specific ISRS. However, the staff noted that the site-specific buffer pool response spectra, used to develop the synthetic time histories for the evaluation of the spent fuel storage racks in the buffer pool deep pit (at a lower elevation), do not envelop the response spectra at the location of the buffer pool deep pit.

As a result of this issue as well as questions related to the review of earlier revisions of GEH reports 002N8467 and 003N0526, the staff raised several concerns related to the spent fuel racks, new fuel racks, and spent fuel in the spent fuel racks during a public meeting on March 3, 2016 (ADAMS Accession No. ML16204A243). The staff's technical evaluation of these concerns and issues is described below.

Fuel Storage Racks - Synthetic Time Histories

The first question was to demonstrate the adequacy of the synthetic time histories used to perform the nonlinear dynamic analyses of the fuel racks. During the North Anna 3 Audit 2, the applicant provided and the staff reviewed Equipos Nucleares, S.A. (ENSA) Technical Note "ESBWR Fuel Building Pool Bottom Synthesized SSE Accelerations Time Histories," Document 5926ATN02, Revision 3 (as described in the North Anna 3 Audit 2 Summary Report, ML16193A047). For the spent fuel racks in the spent fuel pool, this report showed a spectral comparison between the spectra corresponding to the synthetic time histories and the required North Anna 3 floor response spectra for the spent fuel rack analysis. The staff noted that there were significant margins in the spectra comparison for the X (horizontal) direction for frequencies above the lowest rack frequency. In the Y (other horizontal direction) and Z (vertical) directions there were some small margins. The staff also noted that the stress results for the racks were substantially smaller than the allowable stress limits. Thus, the synthetic time histories were considered to be acceptable for the spent fuel rack time history analyses in terms of spectral matching to the corresponding input response spectra.

For the spent fuel racks in the buffer pool deep pit, the applicant explained that the spent fuel racks are anchored to the pool floor and thus, a response spectrum analysis is performed for evaluation of the racks. The time history analysis is only performed for evaluation of the fuel in the rack and to obtain the horizontal and vertical impact forces onto the rack due to the gaps between the fuel and the rack. For this set of time histories, the staff reviewed Empresarios "Design Report of the Spent Fuel Storage Racks in Reactor Building for North Anna 3," Document 092-175-F-M-00003, Revision 1 (as described in the North Anna 3 Audit 2 Summary Report, ML16193A047). Based on the spectral matching comparisons of the spectra corresponding to the synthetic time histories and the required response spectra, the substantial margin in the rack bottom plate stress, and the margins in the acceleration values for the fuel, the synthetic time histories used as input in the time history analyses were considered to be acceptable in terms of spectral matching to the corresponding input response spectra.

For the new fuel racks in the buffer pool, the fuel racks are also anchored to the pool floor and thus, a response spectrum analysis is performed for evaluation of the racks. The time history analysis is only performed for evaluation of the fuel in the rack and to obtain the horizontal and vertical impact forces onto the rack due to the gaps between the fuel and the rack. For this set of time histories, the staff reviewed Empresarios "Design Report of the New Fuel Storage Racks in the Reactor Building for North Anna 3," Document 092-322-F-M-00002, Revision 2 (as described in the North Anna 3 Audit 2 Summary Report, ML16193A047). Based on the spectral matching comparisons of the spectra corresponding to the synthetic time histories and the required response spectra, the substantial margin in the rack bottom plate calculated stress, and the margins in the acceleration values for the fuel, the synthetic time histories used as input in the time history analyses were considered to be acceptable in terms of spectral matching to the corresponding input response spectra.

Fuel Storage Racks - Correlation Coefficients of Seismic Synthetic Time Histories

For the new fuel racks in the buffer pool, and the spent fuel in the buffer pool deep pit the seismic time history correlation coefficients were determined to be 0.14 which are less than the 0.16 acceptance criterion provided in SRP 3.7.1, Rev. 4, and thus, are considered to be acceptable. However, for the spent fuel racks in the spent fuel pool some of the correlation coefficients are greater than 0.16. During the North Anna 3 Audit 2, the applicant provided additional technical information to address this issue, which was included as an update in GEH report 002N8467 Revision 4. The information provides justification based on very small coupling between horizontal and vertical response, conservative method of utilizing the peak impact dynamic loads obtained from the time history analyses and applying them to the FEM as static forces, and the substantial margins in the calculated stresses. On this basis, the staff concluded that the exceedances in correlation coefficients between pairs of synthetic time histories are acceptable.

Fuel Storage Racks - Use of Buffer Pool Response Spectra for Time History Analysis of Spent Fuel Racks in Buffer Pool Deep Pit

For the seismic time history analysis of the spent fuel racks in the buffer pool deep pit, the synthetic time histories were developed based on the response spectra of the buffer pool (at a higher elevation) rather than the elevation of the buffer pool deep pit, or the envelope of the two elevations of the two buffer pools. The applicant explained that based on the spectra comparison of the two elevations, exceedances in the spectra for the lower elevation occur only in the horizontal direction. Also, the time history analysis is only performed for evaluation of the fuel in the rack and to obtain the horizontal and vertical impact forces from the fuel onto the fuel rack due to the gaps between the fuel and the rack. The horizontal forces at the top of the rack are negligible, and the vertical spectrum used in developing the vertical time history was larger than the spectrum at the deep buffer pool elevation, and thus acceptable. Lastly, the stress analysis of the bottom plate of the rack shows substantial margin, and as discussed below, the fuel assembly qualification shows sufficient margin as well. Therefore, the staff concluded that the use of the buffer pool response spectra for evaluation of the spent fuel racks in the buffer pool deep pit is acceptable.

Spent Fuel Stored in the Spent Fuel Racks

The staff reviewed GEH report 003N0526, Rev. 0, and discussed with the applicant several questions that arose from this review. The seismic qualification methodology for the spent fuel was the same as the approach used in the ESBWR standard plant except that the results were generated using the North Anna 3 site-specific seismic input. The results of this North Anna 3 site-specific analysis provided the maximum horizontal and vertical accelerations of the fuel in the rack and compared these demand accelerations with the acceleration limits previously determined for the fuel. In the horizontal direction, the maximum accelerations in the two perpendicular directions were combined by the SRSS method to obtain the resultant horizontal peak acceleration. To demonstrate adequacy of the fuel in the rack, Table 2 in GEH report 003N0526, Rev. 0 provides comparisons between the fuel accelerations in the spent fuel pool and the buffer pool and the GE14 fuel acceleration acceptance limits. The horizontal and vertical demand acceleration values were less than the corresponding acceleration acceptance limits. However, the potential for interaction of the horizontal and vertical demand acceleration values was not considered; therefore, the staff requested the applicant to consider the interaction effects that would exist for the GE fuel. As a result, the applicant provided a figure showing the interaction curve for the GE fuel acceptance limit. The calculated demand horizontal and vertical acceleration values fell within the interaction acceptance curve demonstrating the fuel is qualified. This information was included in the GEH report 003N0526, Revision 1 which was reviewed and information confirmed during the North Anna 3 Audit 2. Based on the above evaluation, the staff concluded that the spent fuel stored in the spent fuel racks are structurally adequate.

Summary of Staff Evaluation for Fuel Racks and Spent Fuel in Spent Fuel Racks

Based on the staff review of the information provided in the North Anna 3 FSAR, GEH reports, North Anna 3 Audit 2, and the above discussion, the staff found that the analysis approach, industry codes and standards, structural materials and their properties, loads and load combinations, and the method for checking the design of the steel components were consistent with those used in the standard design. The staff verified that the site-specific input response spectra used for the analysis are the North Anna 3 bounding design ISRS obtained from the site-specific bounding SSI analysis described in FSAR Appendix 3A Section 3A.18.2. With the several design changes as described in this SER under the heading "*Fuel Rack and Spent Fuel in Spent Fuel Rack,"* above, which will be addressed in detailed design for North Anna 3 plant, the results of the reanalysis of the fuel racks show that the forces, displacements, component stresses, and maximum reactions on the bearing pads in the pool liner are either bounded by the results presented in NEDO-33373, Rev. 5, Dynamic Load-Drop and Thermal-Hydraulic Analyses for ESBWR Fuel Racks," September 2010 (GEH report for the ESBWR standard design of the racks, ML102990229) or are below their code allowable values. For the spent fuel stored in spent fuel racks, the applicant demonstrated that the calculated North Anna 3 site-specific demand horizontal and vertical acceleration values for the fuel fell within the interaction acceptance limits, demonstrating the fuel integrity.

3.8.4.5 Post Combined License Activities

There are no post COL activities related to this Section. ITAAC in DCD Tier 1, Revision 10, with the modification of the SSE definition will address the as-built verification of the other Seismic Category I structures for the North Anna 3 seismic demand.

3.8.4.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). NRC staff reviewed the North Anna 3 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 North Anna 3 FSAR related to this Section. All nuclear safety issues relating to other seismic Category I structures that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.4 of NUREG–0800, and other NRC RGs. The staff finds that the applicant has addressed the areas related to other seismic Category I structures in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.8.4.3 of this SER.

3.8.5 Foundations

3.8.5.1 Introduction

FSAR Section 3.8.5 and Appendix 3G address the structural analysis and design of foundations for the RB/FB, CB, and FWSC structures. The ESBWR design approach for the standard plant design of these structures is provided in Section 3.8.5 and Appendix 3G of ESBWR DCD, Tier 2, Revision 10.

3.8.5.2 Summary of Application

FSAR Section 3.8.5 and Appendix 3G of the North Anna 3 FSAR, Revision 9, incorporate by reference Section 3.8.5 and Appendix 3G of the ESBWR DCD, with the departure given below.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra.

This departure relates to the North Anna 3 site-specific horizontal and vertical seismic ground response spectra. These spectra result in exceedances at certain frequencies when compared to the DCD CSDRS. As a result, the applicant performed new site-specific seismic SSI and SSSI analyses with the site-specific ground response spectra and the site-specific subgrade properties. In some cases, the seismic structural loads were found to be higher than those used for the standard design, and thus, a structural evaluation of the North Anna 3 structures was performed. As a result of the increased seismic loads, a number of additions and deletions were made to Appendix 3G related to the analysis and design of the foundations.

FSAR Appendix 3G Section 3G.7 provides the site-specific structural evaluation of the RB foundation which is part of the RB/FB complex. FSAR Appendix 3G Section 3G.8 provides the site-specific structural evaluation of the CB foundation. FSAR Appendix 3G Section 3G.9 provides the site-specific structural evaluation of the FB foundation. FSAR Appendix 3G Section 3G.10 provides the site-specific structural evaluation of the FWSC foundation. The loads, load combinations, material properties, analysis and design evaluations are provided within each of these FSAR Sections.

3.8.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). In addition, the relevant requirements of the Commission regulations for the foundations of seismic category I structures, and the associated acceptance criteria, are in Section 3.8.5 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design of the safety-related structures that are capable of withstanding the most severe natural phenomena, such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.

- 10 CFR Part 50, Appendix A, GDC 4, as it relates to appropriately protecting safety-related structures against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

- 10 CFR Part 50, Appendix A, GDC 5, as it relates to not sharing safety-related structures among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions..

- 10 CFR Part 50, Appendix B as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.8.5 include the following:

- SRP Section 3.8.5 guidance to review the design, construction, and testing of foundations to ensure that these structures maintain their structural integrity and can perform their intended safety function during all loading conditions.

- RGs listed in SER Section 3.8.1.3 and Section 3.8.4.3 as applicable.

3.8.5.4 Technical Evaluation

As documented in NUREG–1966 (ADAMS Accession No. ML14100A304), NRC staff reviewed and approved Section 3.8.5 and Appendix 3G of the ESBWR DCD. The staff reviewed Section 3.8.5 and Appendix 3G of the North Anna 3 FSAR, Revision 9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the North Anna 3 FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information relating to this section. The staff reviewed the information in the North Anna 3 FSAR as given below.

In addition, the staff conducted a structural audit (North Anna 3 Audit 2) during the week of March 21, 2016 at the applicant's office in Wilmington, North Carolina. The purpose of this audit was to (1) review detailed analysis reports and design calculations performed by the applicant that support the information in the FSAR, (2) confirm the basis supporting the applicants' RAI responses, and (3) review the draft FSAR revisions from RAI responses to ensure consistency with the applicant's design basis information.

Departure

- NAPS DEP 3.7-1 — Ground Response Spectra for Seismic Structural Loads and Floor Response Spectra

NRC staff reviewed NAPS DEP 3.7-1 related to the applicant's structural evaluation of foundations for the site-specific seismic loads applied to seismic Category I structures. These evaluations are described in FSAR Appendix 3G Sections 3G.7 through 3G.10 for the RB, CB, FB, and FWSC, respectively. The staff's technical evaluation of the design of foundations considering these site-specific loads is given below.

Foundation Evaluation of RB and FB

As described in this SER Section 3.8.1.4 for the RB/FB complex, the foundations of the RB and FB are included in the modeling, analysis, and design of the RB/FB. Therefore, the staff technical evaluation of the analytical model; site design loads, load combinations, and material properties; structural analysis; and structural design of the foundations for the RB/FB is provided in this SER Section 3.8.1.4.

The staff evaluation of other aspects of the site-specific structural evaluations for the RB/FB foundations is described in this SER Section below under the heading, "*Dynamic Bearing Pressures.*" These include site-specific evaluations performed for stability, dynamic bearing pressure beneath the foundations, and lateral subgrade pressures on embedded walls. The site-specific evaluations for these items are described in FSAR Appendix 3G Sections 3G.7.5.5 and 3G.7.5.6 and in the GEH report identified below:

1. WG3-U71-ERD-S-0003, Rev. 1, "Reactor/Fuel Building Complex Stability Analysis Report," (ADAMS Accession No. ML15362A009)

Stability Evaluation

The staff reviewed FSAR Appendix 3G Section 3G.7.5.5 and GEH report WG3-U71-ERD-S-0003, Rev. 1, which contain the site-specific stability evaluation of the RB/FB for overturning and sliding when subjected to the site-specific seismic loading. As stated in FSAR Appendix 3G Section 3G.7.5.5 and this GEH report, for the overturning stability evaluation, the energy approach described in DCD, Tier 2, Section 3.7.2.14 was used. This approach calculated the maximum kinetic energy imparted on the RB/FB from the seismic event and the energy that is needed to overturn the structure. The energy needed to overturn the structure is equivalent to the maximum potential energy of the structure as it rotates about a pivot point before it tips over. The effect of buoyancy due to groundwater is included to reduce the weight of the structure, which reduces the potential energy. The staff also noted that the effects of embedment in providing some resistance to overturning were conservatively neglected in the calculations. The factor of safety was defined as the ratio of the energy needed to overturn the structure to the kinetic energy imparted on the RB/FB.

The calculations for overturning, as well as sliding stability, dynamic bearing pressure, and lateral soil pressures, were performed for the LB, BE, and UB of the partial and full column soil profiles. Each of these calculations considered pairs of NS and vertical and then EW and vertical seismic motions, which result in a total of 12 overturning cases. The results, as presented in FSAR Appendix 3G Table 3G.7-225(a), show that the minimum factor of safety (FOS) for all of these cases was 924 which is substantially larger than the minimum FOS of 1.1 used as the acceptance criterion. The staff noted that the minimum FOS criterion of 1.1 and the load combination used for the overturning stability evaluation are in accordance with SRP Section 3.8.5.

During the public meeting on March 3, 2016 (ADAMS Accession No. ML16204A243) prior to the North Anna 3 Audit 2, the staff questioned the applicant about the use of the North Anna 3 site-specific seismic loading corresponding to the RB/FB upper bound stiffness (uncracked) concrete properties and OBE damping values for the seismic demand in the various stability evaluations. The applicant explained that the analyses of models with the upper bound stiffness properties provide seismic demands that bound the effects of structural stiffness variations on the stability, dynamic bearing pressures beneath the structure foundation, and lateral pressure demands on the embedded walls. In addition, there is no need to check the seismic demand from SSSI analyses because as discussed in this SER Section 3.8.4.4 under the heading "*Site Design Loads, Load Combinations, and Material Properties*," the RB/FB is much more massive than the adjacent CB, and thus the seismic SSSI effects would not significantly affect the seismic SSI loads. Lastly, considering the very large FOS values calculated the use of only the SSI seismic loads are considered to be acceptable.

For sliding stability evaluation, the approach used is consistent with the methodology utilized for the standard design presented in DCD Tier 2, Section 3.8.5.5. The RB/FB sliding stability evaluations consider the critical sliding plane located at the bottom of the RB/FB basemat. The sliding evaluation is performed separately for NS and vertical directions and then EW and vertical directions, using a linear time history analysis approach. At each time step the FOS is calculated, and the minimum value obtained during the duration of the site-specific ground motion is identified as the sliding stability FOS. The sliding stability evaluation considered the frictional resistance at the bottom of the basemat, and if needed, the lateral resistance pressure on the embedded exterior wall and basemat opposite to the direction of the seismic motion. The staff notes that the calculations conservatively neglected the skin friction resistance provided by the (a) vertical surfaces of the basemat side and shear key side parallel to the direction of motion, (b) lateral resistance pressure on the shear key opposite to the direction of motion, and (c) lateral resistance from the structural fill above the Zone III rock (i.e., upper 17 ft).

The coefficient of friction value of 0.6 was used in the sliding evaluation which the staff confirmed is consistent with the value for the foundation to Zone III-IV rock interface presented in FSAR Section 2.5.4. The FOS was calculated as the ratio of the friction resistance force at the bottom of the RB/FB basemat to the time history results of the horizontal seismic driving (demand) force. The friction resistance force considered the seismic gravity load as the sum of the dead load and 25% of live load. In addition, the effect of buoyancy due to the ground water, in reducing the gravity load, was considered. The seismic driving force did consider the effect of the lateral soil force on the RB due to the turbine building surcharge load, which would increase the driving force. Thus the staff concludes that all applicable loads were included in the calculation of the FOS.

At a particular instance of time, if the base friction resistance beneath the basemat alone was not sufficient to develop the minimum FOS of 1.1 against sliding, the additional lateral resistance force acting on the embedded exterior wall and basemat opposite to the direction of motion was calculated. These passive lateral pressure calculations conservatively assume that the lateral resistance against sliding is provided only by the concrete fill and the Zone III rock, and neglects the lateral resistance that could be provided above the upper 17 ft of structural fill and the Zone III rock.

As in the overturning stability evaluations discussed above, the sliding stability evaluations also were performed for the LB, BE, and UB of the partial and full column soil profiles. The results, as presented in FSAR Appendix 3G Table 3G.7-225(b), show that the minimum factor of safety (FOS) of 1.1 is satisfied in some of the 12 cases analyzed when relying only on the friction resistance force beneath the basemat and in the other cases some passive lateral pressure resistance is needed to maintain the FOS of 1.1. As discussed below in this SER Section under the heading of "*Dynamic Bearing Pressures*," these lateral passive pressures are used in the design evaluations of the RB/FB foundation walls which are enveloped by the corresponding standard design loads.

Based on the above discussion, the staff concluded that the seismic overturning and sliding stability evaluations are acceptable.

Dynamic Bearing Pressures

The staff reviewed FSAR Appendix 3G Section 3G.7.5.5 and GEH report WG3-U71-ERD-S-0003, Rev. 1 which contain the site-specific evaluation of the RB/FB for developing the dynamic bearing pressures on the Zone III-IV rock beneath the RB/FB basemat. As stated in the above FSAR section and the GEH report, the maximum dynamic bearing pressure demands from the RB/FB basemat on the supporting Zone III-IV rock at the North Anna 3 site are evaluated using the Energy Balance/Modified Energy Balance (EB/MEB) method consistent with the methodology used in the standard design. The SASSI2010 analysis results for the spring forces at the bottom of the RB/FB basemat from the SSI analyses of RB/FB for the partial and full column LB, BE, and UB subsurface profiles were used to determine the dynamic bearing pressures. The dynamic bearing pressure evaluation considered the seismic weight of the RB/FB that consists of the building dead load and 25% of the design live loads. Since this method of analysis is consistent with the standard design and the criteria in SRP 3.8.5, the staff considers this approach acceptable.

As shown in FSAR Appendix 3G Table 3G.7-231, the calculations of the maximum dynamic bearing pressure demand beneath the RB/FB foundation, results in a maximum toe bearing pressure demand of 1.37 MPa (28.6 ksf) which is lower than the maximum toe bearing pressure demand of 2.7 MPa (56.4 ksf) determined by the standard design (DCD Appendix 3G Table 3G.1-58). In addition, the maximum calculated dynamic bearing pressure demand is also lower than the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock underlying the RB/FB foundation. The staff confirmed that the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock matches the allowable value given in FSAR Table 2.5.4-211. Therefore, the staff concluded that the calculated maximum site-specific dynamic bearing pressure is considered to be acceptable, with a large margin.

Lateral Pressures on Exterior Embedded Walls

The staff reviewed FSAR Appendix 3G Section 3G.7.5.6 and GEH report WG3-U71-ERD-S-0003, Rev. 1 which contains the site-specific evaluation of the RB/FB for developing the lateral pressures acting on below grade exterior walls. The plots of the vertical distribution of lateral pressures acting on the various walls due to the at-rest static pressure, seismic dynamic pressure, sum of the static and dynamic pressure, as well as the passive pressure distributions are shown in FSAR Appendix 3G Figures 3G.7-205 through 3G.7-212. These figures also show the lateral pressure distributions from the standard design to enable comparisons to be made.

The GEH report indicates that the site-specific lateral pressure demands on the embedded exterior walls were developed following the same approach that was used for the standard design. The distribution of the static pressure includes the at-rest static soil pressure and the hydrostatic pressure from the groundwater using the North Anna 3 site-specific values of the at-rest soil coefficients of lateral earth pressure and the groundwater level depth.

The dynamic pressure distributions are developed based on the SSI analysis results for horizontal forces of the contact springs located at the wall-subgrade interfaces. FSAR Appendix 3G Figures 3G.7-205 through 3G.7-212 show the envelope of the lateral pressure results obtained from the SSI analyses of the LB, BE and UB subgrade profiles. The site-specific static and dynamic lateral pressure demands are compared with the corresponding static and dynamic lateral pressure loads used for the standard design of the RB/FB.

In addition, total lateral pressures corresponding to the sum of the site-specific static and dynamic lateral pressures are presented in FSAR Appendix 3G Figures 3G.7-205 through 3G.7-212 and the GEH report. These plots also present the distributions of the maximum site-specific passive lateral pressures that are determined from the results of the sliding stability evaluation discussed above in order to satisfy the sliding FOS of 1.1. These two sets of site-specific lateral pressures are compared with the corresponding total lateral soil pressures calculated in the standard design and the standard design wall capacity passive resistance pressures.

The comparisons of the lateral soil pressure distributions presented in FSAR Appendix 3G Figures 3G.7-205 through 3G.7-212 show that near the floor slab at El. 270.3 ft, the site-specific total lateral pressures exceed the lateral pressures used for the standard design. Therefore, for seismic loads, the North Anna 3 site-specific seismic demand pressures were bounded by the standard design. The lateral passive pressures, needed to maintain sliding stability, were also considered in the structural evaluations. For the static lateral pressures, the higher standard design envelopes the few site-specific exceedances of lateral pressure loads.

Based on the above discussion, the staff considers that the approach to calculate the lateral soil pressures is acceptable, and where the lateral pressures exceed the pressures used in the standard design, these higher demand loads are also acceptable because they are used in the site-specific design evaluations.

Foundation Evaluation of CB

The foundation for the CB is included in the modeling, analysis, and design of the CB structure. Therefore, the staff evaluation of the analytical model; site design loads, load combinations, and material properties; structural analysis; and structural design of the foundation for the CB is provided in SER Section 3.8.4.4.

The staff evaluation of other aspects of the site-specific structural evaluations for the CB foundation is described in this SER Sections that follow below. These include site-specific evaluations performed for stability, dynamic bearing pressure beneath the foundation, and lateral soil pressures on embedded walls. The site-specific evaluations for these items are described in FSAR Appendix 3G Sections 3G.8.5.5 and 3G.8.5.6 and in the GEH report identified below:

1. WG3-U73-ERD-S-0003, Rev. 3, “Control Building Stability Analysis Report,” (ADAMS Accession No. ML16148A129)

<u>*Stability Evaluation*</u>

The staff reviewed FSAR Appendix 3G Section 3G.8.5.5 and GEH report WG3-U73-ERD-S-0003, Rev. 3 which contain the site-specific stability evaluation of the CB for overturning and sliding when subjected to the site-specific seismic loading. As stated in this GEH report, for the overturning stability evaluation, the energy approach described in DCD, Tier 2, Section 3.7.2.14 was used. This approach calculated the maximum kinetic energy imparted on the CB from the seismic event and the energy that is needed to overturn the structure. The energy needed to overturn the structure is equivalent to the maximum potential energy of the structure as it rotates about a pivot point before it tips over. The effect of buoyancy due to groundwater is included to reduce the weight of the structure, which reduces the potential energy. The staff also noted that the effects of embedment in providing some resistance to overturning were conservatively neglected in the calculations. The factor of safety was defined as the ratio of the energy needed to overturn the structure to the kinetic energy imparted on the CB.

The calculations for overturning, as well as sliding stability, dynamic bearing pressure, and lateral soil pressures, were performed for the LB, BE, and UB of the partial and full column soil profiles. Each of these calculations considered pairs of NS and vertical and then EW and vertical seismic motions, which result in a total of 12 overturning cases. The results, as presented in FSAR Appendix 3G Table 3G.8-208, show that the minimum factor of safety (FOS) for all of these cases was 519 which is substantially larger than the minimum FOS of 1.1 used as the acceptance criterion. The staff noted that the minimum FOS criterion of 1.1 and the load combination used for the overturning stability evaluation are in accordance with SRP Section 3.8.5.

During the public meeting on March 3, 2016 (ADAMS Accession No. ML16204A243) prior to the North Anna 3 Audit 2, the staff questioned the applicant about the use of the North Anna 3 site-specific seismic loading corresponding to the CB upper bound stiffness (uncracked) concrete properties and SSE damping values for the seismic demand in the various stability evaluations. The applicant explained that the analyses of models with the upper bound stiffness properties provide seismic demands that bound the effects of concrete cracking on the seismic demands on the CB foundation and below grade exterior walls. Regarding the need to consider seismic SSSI loads, the applicant indicated that with a few exceptions, the SSI analyses of the CB standalone model with full stiffness and SSE damping properties also provide seismic demands that bound the SSSI effects of RB/FB and FWSC on the CB foundation stability, foundation dynamic bearing pressures and below grade exterior wall lateral pressure demands. In the few exceptions, the exceedances in the lateral pressure demands on the CB wall facing the RB/FB have negligible effects on the results of the site-specific evaluations. Lastly, considering the very large FOS values calculated, the use of only the SSI seismic loads are considered to be acceptable.

For sliding stability evaluation, the approach used for the CB is consistent with the methodology utilized for the standard design presented in DCD Tier 2, Section 3.8.5.5. The CB sliding stability evaluations consider two critical sliding planes located at the bottom of the CB basemat and the bottom of the concrete fill block supporting the CB basemat. The sliding evaluation is performed separately for NS and vertical directions and then EW and vertical directions, using a linear time history analysis approach. At each time step the FOS is calculated, and the minimum value obtained during the duration of the site-specific ground motion is identified as the sliding stability FOS.

For the sliding stability evaluation located at the bottom of the CB basemat, the sliding evaluation considered the frictional resistance at the bottom of the basemat, and if needed, the lateral passive pressure resistance provided by the concrete fill and Zone III rock subgrade materials surrounding the CB embedded exterior walls and the CB basemat in the opposite direction of the seismic motion. The staff notes that the calculations conservatively neglected the skin friction resistance provided by the vertical surfaces of the CB embedded exterior walls and basemat sides parallel to the direction of seismic motion, as well as the lateral passive pressure resistance provided by the structural fill and in-situ saprolite material on the face of the embedded exterior wall in the opposite direction of the seismic motion.

For the sliding stability evaluation located at the bottom of the concrete fill supporting the CB foundation, the sliding evaluation considered the frictional resistance at the bottom of the concrete fill block, and if needed, the lateral passive pressure resistance provided by the surrounding concrete fill and Zone III rock subgrade materials. The staff notes that the calculations conservatively neglected the skin friction resistance provided by the vertical surfaces of the CB embedded exterior walls, basemat, and concrete fill block sides parallel to the direction of seismic motion. The calculations also conservatively neglected the lateral passive pressure resistance provided by the structural fill and in-situ saprolite material above the Zone III rock on the face of the embedded exterior wall in the opposite direction of the seismic motion.

The coefficient of friction value of 0.6 was used in the sliding evaluation which the staff confirmed is consistent with the value for the foundation to concrete fill and to rock interface presented in FSAR Section 2.5.4. The FOS was calculated as the ratio of the friction resistance force at the bottom of the CB basemat or bottom of the concrete fill to the time history results of the horizontal seismic driving force. The friction resistance force considered the seismic gravity load as the sum of the dead load and 25% of live load. In addition, the effect of buoyancy due to the ground water, in reducing the gravity load, was considered. Thus the staff concluded that all applicable loads were included in the calculation of the FOS.

At a particular instance of time, if the base friction resistance beneath the basemat and beneath the concrete fill block alone was not sufficient to develop the minimum FOS of 1.1 against sliding, the additional lateral resistance force acting on the embedded exterior wall and basemat opposite to the direction of motion was calculated.

As in the overturning stability evaluations discussed above, the sliding stability evaluations were also performed for the LB, BE, and UB of the partial and full column soil profiles. The results, as presented in FSAR Appendix 3G Table 3G.8-209, show that the minimum factor of safety (FOS) of 1.1 is satisfied in all 12 cases analyzed; however, to achieve this, passive lateral pressure resistance is needed to maintain the FOS of 1.1. As discussed below in this SER Section, these lateral passive pressures are enveloped by the corresponding standard design loads.

Based on the above discussion, the staff concluded that the seismic overturning and sliding stability evaluations are acceptable.

Dynamic Bearing Pressures

The staff reviewed FSAR Appendix 3G Section 3G.8.5.5 and GEH report WG3-U73-ERD-S-0003 Rev. 3 which contain the site-specific evaluation of the CB for developing the dynamic bearing pressures on the concrete fill block and on the Zone III-IV rock beneath the concrete fill. As stated in the above FSAR Section and the GEH report, the maximum site-specific dynamic bearing pressure demands from the CB basemat on the concrete fill and the Zone III-IV rock are evaluated using the EB/MEB method consistent with the methodology used in the standard design. The SASSI2010 analysis results for the spring forces at the bottom of the CB basemat from the SSI analyses of CB for the partial and full column LB, BE, and UB subsurface profiles were used to determine the dynamic bearing pressures. he dynamic bearing pressure evaluation considered the seismic weight of the CB that consists of the building dead load and 25% of the design live loads. Since this method of analysis is consistent with the standard design and the criteria in SRP 3.8.5, the staff considers this approach acceptable.

As shown in FSAR Appendix 3G Table 3G.8- 211a, for the case of the maximum dynamic bearing pressure demand of the CB basemat on the concrete fill block, the maximum calculated toe bearing pressure demand of 1.46 MPa (30.5 ksf) is lower than the maximum toe bearing pressure demand of 2.19 MPa (45.7 ksf) determined by the standard design. In addition, the maximum calculated dynamic bearing pressure demand is also lower than the allowable dynamic bearing pressure of 8.0 MPa (167 ksf) for the concrete fill material based on ACI 318-05.

As shown in FSAR Appendix 3G Table 3G.8- 211b, for the case of the maximum dynamic bearing pressure demand of the CB and the concrete fill block on the underlying Zone III-IV rock, the maximum calculated toe bearing pressure demand of 0.73 MPa (15.2 ksf) is lower than the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock. The staff confirmed that the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock matches the allowable value given in FSAR Section 2.5.4.

Therefore, the staff concluded that the calculated maximum site-specific dynamic bearing pressure demands of the CB are acceptable, with large margins against allowable values.

Lateral Pressures on Exterior Embedded Walls

The staff reviewed FSAR Appendix 3G Section 3G.8.5.6 and GEH report WG3-U73-ERD-S-0003, Rev. 3 which contain the site-specific evaluation of the CB for developing the lateral soil pressures on below grade exterior walls. The plots of the vertical distribution of lateral pressures acting on the various walls due to the at-rest static pressure, seismic dynamic pressure, sum of the static and dynamic pressure, as well as the passive pressure distributions are shown in

FSAR Appendix 3G Figures 3G.8-203 through 3G.8-210. These figures also show the lateral pressure distributions from the standard design to enable comparisons to be made.

The GEH report indicates that the site-specific lateral pressure demands on the embedded exterior walls were developed following the same approach that was used for the standard design. The distribution of the static pressure includes the at-rest static soil pressure and the hydrostatic pressure from the groundwater using the North Anna 3 site-specific values of the at-rest soil coefficients and the groundwater level depth.

The dynamic pressure distributions are developed based on the SSI analysis results for horizontal forces of the contact springs located at the wall-subgrade interfaces. FSAR Appendix 3G Figures 3G.8-203 through 3G.8-210 show the envelope of the lateral pressure results obtained from the SSI analyses of the LB, BE and UB subgrade profiles. The site-specific static and dynamic lateral pressure demands are compared with the corresponding static and dynamic lateral pressure loads used for the standard design of the CB.

In addition, total lateral pressures corresponding to the sum of the site-specific static and dynamic lateral pressures are presented in FSAR Appendix 3G Figures 3G.8-203 through 3G.8-210 and the GEH report. These plots also present the distributions of the maximum site-specific passive lateral pressures that are determined from the results of the sliding stability evaluation discussed above in order to satisfy the sliding FOS of 1.1. These two sets of site-specific lateral pressures are compared with the corresponding total lateral soil pressures calculated in the standard design and the standard design wall capacity passive resistance pressures.

The comparisons of the lateral soil pressure distributions presented in FSAR Appendix 3G Figures 3G.8-203 through 3G.8-210 show that near the floor slab at El. 267.9 ft and near the top of the CB basemat, the site-specific total lateral pressures exceed the total lateral pressures used for the standard design. The comparisons also indicate that the lateral passive pressures needed to ensure the stability of the CB against sliding in the EW direction exceed the pressures used in the standard design of the CB wall capacity check. Therefore, the North Anna 3 site-specific seismic demand pressures were used for the site-specific structural evaluation. The lateral passive pressures, needed to maintain sliding stability, were also considered in the structural evaluations. For the static lateral pressures, the higher standard design pressure loads were used.

Based on the above discussion, the staff considers that the approach to calculate the lateral soil pressures is acceptable, and where the lateral pressures exceed the pressures used in the standard design, these higher demand loads are also acceptable because they are used in the site-specific design evaluations.

Foundation Evaluation of FWSC

The foundation for the FWSC is included in the modeling, analysis, and design of the FWSC structure. Therefore, the staff evaluation of the analytical model; site design loads, load combinations, and material properties; structural analysis; and structural design of the foundation for the FWSC is provided in SER Section 3.8.4.4.

The staff evaluation of other aspects of the site-specific structural evaluations for the FWSC foundation is described in this SER Section. These include site-specific evaluations performed for stability and dynamic bearing pressure beneath the foundation as described in FSAR Appendix 3G Section 3G.10.5.5 and the GEH report identified below:

1. WG3-U63-ERD-S-0002, Rev. 1, “Firewater Service Complex Stability Analysis Report,” (ADAMS Accession No. ML15362A011)

Stability Evaluation

The staff reviewed FSAR Appendix 3G Section 3G.10.5.5 and GEH report WG3-U63-ERD-S-0002, Rev. 1 which contain the site-specific stability evaluation of the FWSC for overturning and sliding when subjected to the North Anna 3 seismic loading. As stated in FSAR Appendix 3G Section 3G.10.5.5 and this GEH report, for the overturning stability evaluation, the energy approach described in DCD, Tier 2, Section 3.7.2.14 was used. This approach calculated the maximum kinetic energy imparted on the FWSC from the seismic event and the energy that is needed to overturn the structure. The energy needed to overturn the structure is equivalent to the maximum potential energy of the structure as it rotates about a pivot point before it tips over. The factor of safety was defined as the ratio of the energy needed to overturn the structure to the kinetic energy imparted on the FWSC.

The calculations for overturning stability, as well as sliding stability and dynamic bearing pressure were performed for the site-specific SSI analysis stand-alone model and separately for the site-specific SSSI analysis of the FWSC-CB combined model. For each of these two cases, the evaluation considered full (uncracked concrete) stiffness properties and SSE damping values for the LB, BE, and UB subgrade profiles using the deep input control motion applied at the bottom of the underlying concrete fill block. The overturning evaluations considered pairs of NS and vertical and then EW and vertical seismic motions, which result in a total of 12 overturning cases. The results, as presented in FSAR Appendix 3G Table 3G.10-214(a), show that the minimum factor of safety (FOS) against overturning for all of these cases was 902 which is substantially larger than the minimum FOS of 1.1 used as the acceptance criterion. The staff noted that the minimum FOS criterion of 1.1 and the load combination used for the overturning stability evaluation are in accordance with SRP Section 3.8.5.

During the public meeting on March 3, 2016 (ADAMS Accession No. ML16204A243) prior to the North Anna 3 Audit 2, the staff questioned the applicant about the use of the North Anna 3 site-specific seismic loading corresponding to the FWSC upper bound stiffness (uncracked) concrete properties and SSE damping values for the seismic demand in the various stability evaluations. The applicant explained that the analyses of models with the upper bound stiffness properties provide seismic demands that bound the effects of concrete cracking on the seismic demands on the FWSC foundation. Also, the staff noted the very large FOS values calculated, and thus this approach is considered to be acceptable.

For sliding stability evaluation, the approach used for the FWSC is consistent with the methodology utilized for the standard design presented in DCD Tier 2, Section 3.8.5.5. The FWSC sliding stability evaluations consider two critical sliding planes; one located at the bottom of the FWSC basemat and the other at the bottom of the concrete fill block supporting the FWSC basemat. The sliding evaluation is performed separately for NS and vertical directions and then EW and vertical directions, using a linear time history analysis approach. At each time step the FOS is calculated, and the minimum value obtained during the duration of the site-specific ground motion is identified as the sliding stability FOS.

For the sliding stability evaluation at the critical sliding plane located at the bottom of the FWSC basemat, the sliding evaluation considered the frictional resistance between the bottom of the basemat and the top of the supporting concrete fill, and the lateral resistance provided by the shear keys which are embedded in the concrete fill placed under the FWSC. The staff notes that the calculations conservatively neglected the (a) skin friction resistance provided by the sides of the basemat parallel to the direction of the seismic motion, (b) lateral passive resistance provided by the structural fill along the face of the basemat perpendicular to the direction of motion, and (c) skin friction provided by the shear key side parallel to the direction of motion.

For the sliding stability evaluation at the critical sliding plane located at the bottom of the concrete fill supporting the FWSC foundation, the sliding evaluation considered the frictional resistance at the bottom of the underlying concrete fill block, and if needed, the lateral passive pressure resistance provided by the surrounding concrete fill and Zone III rock. The staff notes that the calculations conservatively neglected the lateral resistance provided by the (a) structural fill and in-situ saprolite acting on the FWSC basemat and concrete fill block under the basemat perpendicular to the direction of motion, (b) skin friction resistance acting on the vertical surfaces of the basemat and concrete fill block sides parallel to the direction of motion, and (c) pull-out resistance of the shear keys that contribute to the base friction resistance by resisting the upward forces that would reduce the base friction.

The coefficient of friction value of 0.6 was used in the sliding evaluation which the staff confirmed is consistent with the value for the foundation to concrete fill and concrete fill to Zone III-IV rock interfaces presented in FSAR Section 2.5.4. The FOS was calculated as the ratio of the friction resistance force at the bottom of the FWSC basemat or bottom of the concrete fill to the time history results of the horizontal seismic driving force. The friction resistance force considered the seismic gravity load as the sum of the dead load and 25% of live load. In addition, the effect of buoyancy due to the ground water, in reducing the gravity load, was considered. Thus the staff concludes that all applicable loads were included in the calculation of the FOS.

For sliding at the bottom of the FWSC basemat, if the base friction resistance beneath the basemat alone was not sufficient to develop the minimum FOS of 1.1 against sliding, the additional lateral resistance force provided by the shear keys is calculated. Similarly, at the bottom of the concrete fill, if the base friction resistance beneath the concrete fill alone was not sufficient to develop the minimum FOS of 1.1 against sliding, the additional lateral resistance provided by Zone III rock is calculated.

As in the overturning stability evaluations discussed above, the sliding stability evaluations also were performed for a total of 12 cases (combinations of SSI/SSSI, LB/BE/UB subgrade conditions, and NS/EW directions). The lateral resistance force demands on the shear keys or subgrade surrounding the concrete fill under the FWSC are computed if, at a particular instance of time, the friction resistance on a sliding plane analyzed is not sufficient to achieve a minimum factor of safety of 1.1 against sliding.

Sliding stability calculations showed that the separation between the concrete fill and surrounding soil can amplify the lateral force demands on the FWSC keys. The staff confirmed that the site-specific structural evaluation of the FWSC shear keys used amplified lateral pressure loads that bound the effects of soil separation. FSAR Appendix 3G Table 3G.10-

214(b) presents a summary of the sliding stability analysis at the bottom of the FWSC basemat based on the site-specific lateral force demands on the FWSC shear keys under fully bonded conditions between the concrete fill and surrounding soil. FSAR Appendix 3A Table 3A.17.14.5-202 presents similar results but under the condition of separation between the concrete fill and surrounding soil. FSAR Appendix 3A Table 3A.17.14.5-202 further shows that the maximum lateral resistance pressure demand on the concrete fill from the shear key is 1.26 MPa, which is below the allowable lateral bearing pressure of the concrete fill of 8.0 MPa.

FSAR Appendix 3G Table 3G.10-214(c) presents a summary of the calculations of the FWSC sliding stability at the critical sliding plane at the bottom of the concrete fill. For the instances of time the friction resistance at the bottom of the concrete fill alone is not sufficient, the lateral passive pressure demand required to achieve a minimum factor of safety of 1.1 against sliding is calculated. FSAR Appendix 3G Table 3G.10-214(c) shows that the maximum site-specific lateral passive pressure demand on the surrounding subgrade is 0.89 MPa, which is below the allowable dynamic lateral bearing pressure of 1.44 MPa of Zone III rock at the FWSC location as specified in FSAR Appendix 3G Table 3G.10-201.

The results of the evaluations of sliding stability for the FWSC show that the minimum factor of safety (FOS) of 1.1 is satisfied in all 12 cases analyzed, taking into account the lateral resistance force demands (1) on the shear keys at the critical sliding plane at the bottom of the FWSC basemat, and (2) on the surrounding subgrade at the critical sliding plane at the bottom of the concrete fill. The staff noted that the maximum lateral pressure demand on the concrete fill exerted by the shear keys and the maximum passive pressure demand on the subgrade surrounding the concrete fill are below their respective allowable bearing pressures.

Based on the above discussion, the staff concludes that the seismic overturning and sliding stability evaluations for the FWSC foundation are acceptable.

Dynamic Bearing Pressures

The staff reviewed FSAR Appendix 3G Section 3G.10.5.5 and GEH report WG3-U63-ERD-S-0002, Rev. 1 which contain the site-specific evaluation of the FWSC for developing the dynamic bearing pressures on top of the concrete fill block and on the Zone III-IV beneath the concrete fill. As stated in the above FSAR Section and the GEH report, the maximum site-specific dynamic bearing pressure demands from the FWSC basemat on the concrete fill and on the Zone III-IV rock are evaluated using the EB/MEB method consistent with the methodology used in the standard design. The SASSI2010 analysis results for the spring forces at the bottom of the FWSC basemat from the SSI FWSC standalone model and the SSSI analyses of the FWSC-CB combined model for the LB, BE, and UB subsurface profiles were used to determine the dynamic bearing pressures. The dynamic bearing pressure evaluation considered the seismic weight of the FWSC that consists of the building dead load and 25% of the design live loads. Since this method of analysis is consistent with the standard design and the acceptance criteria in SRP 3.8.5, the staff considers this approach acceptable.

As shown in FSAR Appendix 3G Table 3G.10-215 for the case of the maximum dynamic bearing pressure demand of the FWSC basemat on the concrete fill block, the maximum calculated site-specific toe bearing pressure demand of 0.89 MPa (18.6 ksf) is lower than the maximum toe bearing pressure demand of 1.2 MPa (25.1 ksf) determined by the standard design. In addition, the maximum calculated dynamic bearing pressure demand is also lower than the allowable dynamic bearing pressure of 8.0 MPa (167 ksf) for the concrete fill material based on ACI 318-05.

As shown in FSAR Appendix 3G Table 3G.10-215 for the case of the maximum dynamic bearing pressure demand of the FWSC and the concrete fill block on the underlying Zone III-IV rock, the maximum calculated toe bearing pressure demand of 1.85 MPa (38.6 ksf) is lower than the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock. The staff confirmed that the allowable dynamic bearing pressure of 12.4 MPa (259 ksf) for the Zone III-IV rock matches the allowable value given in FSAR Section 2.5.4.

The staff review of the adequacy of the concrete fill as foundation material, including its bearing and shear capacities, is presented in SER Section 2.5.4.

Therefore, the staff concluded that the calculated maximum site-specific dynamic bearing pressure demands of the FWSC are acceptable, with large margins against allowable values.

Lateral Pressures on Exterior Embedded Walls

Since the FWSC is a surface mounted structure there are no embedded walls, and thus, there is no lateral soil pressures that need to be evaluated.

3.8.5.5 Post Combined License Activities

There are no post COL activities related to this Section.

3.8.5.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966 (ADAMS Accession No. ML14100A304). NRC 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 North Anna 3 FSAR related to this Section. All nuclear safety issues relating to foundations that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.5 of NUREG–0800, and other NRC RGs. The staff found that the applicant has addressed the areas related to foundations in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concluded that the applicant has satisfied the relevant requirements of the regulations delineated in Section 3.8.5.3 of this SER.

3.9 Mechanical Systems and Components

3.9.1 Introduction

This Section addresses the structural integrity and functional capability of safety related and non-safety related mechanical SSCs for seismic Category I components and supports, including both those designated as ASME Boiler and Pressure Vessel (B&PV) Code, Section III and those not covered by the ASME B&PV Code as discussed in Section 3.9.1 of NRC NUREG-0800 SRP. The design includes issues such as load combinations, allowable stresses, methods of analysis, summary of results, and preoperational testing. The evaluation of this section focuses on determining whether there is adequate assurance that mechanical systems and components will perform their safety-related functions under all postulated combinations of normal operating conditions, system operating transients, postulated pipe breaks, and seismic events.

Following the issuance of the ESBWR FSER on March 9, 2011, the NRC staff identified issues applicable to the ESBWR steam dryer structural analysis based on information obtained during the NRC review of a license amendment request for a power uprate at an operating boiling-water reactor nuclear power plant. As a result of resolving those issues, General Electric–Hitachi (GEH) revised the DCD to withdraw the licensing topical reports (LTRs) addressing the ESBWR steam dryer structural evaluation, and to reference new engineering reports that describe the updated ESBWR steam dryer analysis methodology. The staff reviewed the revised DCD sections, the new GEH engineering reports, and the RAI responses. NUREG-1966, Supplement 1, the Supplemental FSER related to the certified ESBWR DCD, Tier 2, Section 3.9.5 replaces in its entirety Section 3.9.5, "Reactor Pressure Vessel Internals," of the DCD FSER issued on March 9, 2011. Information related to ESBWR reactor pressure vessel (RPV) internals other than the steam dryer (such as core support structures) was copied from the FSER and placed in the Supplemental FSER to provide the description of the staff's review of all ESBWR RPV internals in one location.

3.9.2 Summary of Application

Section 3.9, "Mechanical Systems and Components," of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 3.9, "Mechanical Systems and Components," of the ESBWR DCD, Revision 10.

In addition, in North Anna 3 COL FSAR, Revision 8, the applicant provides the following:

COL Items

- CWR COL 3.9.9-1-A — Reactor Internals Vibration Analysis, Measurement and Inspection Program

To address COL Item 3.9.9-1-A, the North Anna 3 COL applicant provides the following supplemental information in FSAR Section 3.9.2.4:

> For reactor internals other than the steam dryer, the vibration assessment program, as specified in Regulatory Guide (RG) 1.20, is provided in DCD Appendix 3L and the following referenced GEH Report:

- NEDE-33259P-A, “Reactor Internals Flow Induced Vibration Program”

The classification of the North Anna 3 reactor internals in accordance with RG 1.20 is dependent on ESBWR status, i.e., if North Anna 3 is the initial ESBWR to perform testing of the reactor internals, or if testing is performed at another reactor prior to North Anna 3 testing. There are two different scenarios:

a. A valid prototype for the Unit 3 reactor internals does not exist. Under this scenario, Unit 3 reactor internals classification is a prototype per RG 1.20.

b. A valid prototype for Unit 3 reactor internals does exist. If the prototype testing is performed outside the United States, the guidance in RG 1.20, Revision 3, Regulatory Position 1.2, would need to be satisfied in order for this reactor to be considered a “valid prototype.” Assuming that Unit 3 reactor internals are substantially similar to the valid prototype and that the valid prototype does not experience inservice problems that result in component or operational modifications, Unit 3 reactor internals will be classified as non-prototype Category I. If a change to the classification for Unit 3 reactor internals is later determined to be necessary, the classification change will be addressed at the time the change is proposed with proper evaluation/justification and documented in a revision to the FSAR.

Specific to the steam dryer, the comprehensive vibration assessment program, as specified in RG 1.20, is provided in DCD Appendix 3L and the following referenced GEH reports:

- NEDE-33312P, “ESBWR Steam Dryer Acoustic Load Definition”
- NEDE-33313P, “ESBWR Steam Dryer Structural Evaluation”
- NEDE-33408P, “ESBWR Steam Dryer- Plant Based Load Evaluation Methodology, PBLE01 Model Description”

The steam dryer is definitively classified as a prototype according to RG 1.20, Revision 3. Section 10.2 of NEDE-33313P provides four elements of a steam dryer Comprehensive Vibration Assessment Program that must be addressed. The following describes the approach for the steam dryer Comprehensive Vibration Assessment Program elements, consistent with RG 1.20 and Section 10.2 of NEDE-33313P:

a. The ESBWR steam dryer Comprehensive Vibration Assessment Program is described in DCD Section 3.9, DCD Appendix 3L, and NEDE-33313P, Section 10.0, which includes a description for preparing and submitting to the NRC a Steam Dryer Monitoring Plan no later than 90 days before startup.

b. The detailed design of the steam dryer will follow the methodology described in DCD Appendix 3L and the incorporated engineering reports. As described in NEDE-33313P, Section 10.2(b), an example of a steam dryer predicted analysis that concludes the steam dryer will not exceed stress limits with applicable bias and uncertainties and the minimum alternating stress ratio of 2.0 is provided in NEDE-33408P. The final detailed design of the ESBWR steam dryer has not yet been completed. Therefore, the example of an as-designed steam dryer that has been subject to the predicted analysis process and successful startup testing described in NEDE-33408P serves as the design analysis report for the steam dryer and provides sufficient information for licensing. The post licensing commitments in Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) and license conditions will confirm the acceptability of the ESBWR steam dryer design.

c. The startup program and associated license conditions that include appropriate notification points during power ascension, providing data to the NRC at certain hold points and at full power, and providing to the NRC a full stress analysis report and evaluation within 90 days of reaching the full power level, are established in accordance with NEDE-33313P, Section 10.2(c).

d. Periodic steam dryer inspection during refueling outages is as described in NEDE-33313P, Section 10.2(d), and associated license conditions.

In addition, in FSAR Section 3.9.2.4, the applicant identifies a comprehensive vibration assessment program that will be developed as described in DCD Appendix 3L with no departures and that will comply with guidance specified in RG 1.20, Revision 3. These programs will be prepared as stated in this Section of the North Anna 3 FSAR.

- STD COL 3.9.9-2-A — ASME Class 2 or 3 or Quality Group D Components with 60-Year Design Life

To address COL 3.9.9-2-A, the North Anna 3 COL applicant adds the following discussion in FSAR Section 3.9.3.1:

> The equipment stress reports identified in this DCD section will be completed within six months of completion of DCD ITAAC Table 3.1-1 [following plant construction]. The FSAR will be revised as necessary in a subsequent update to address the results of this analysis [on the as-built North Anna 3 power station].

- STD COL 3.9.9-3-A — Inservice Testing of Pumps and Valves

To address COL Item 3.9.9-3-A, the North Anna 3 COL applicant specifies FSAR provisions to supplement ESBWR DCD, Tier 2, Section 3.9.6, "Inservice Testing of Pumps and Valves." For example, the North Anna 3 FSAR specifies that in addition to the provisions in ESBWR DCD, Tier 2, Section 3.9.6, milestones for implementing the ASME Code for Operation and Maintenance of Nuclear Power Plants (OM Code) preservice and inservice testing programs are defined in FSAR Section 13.4.

In addition to the provisions in ESBWR DCD, Tier 2, Section 3.9.6.1,"Inservice Testing of Valves," the North Anna 3 FSAR specifies that valves are subject to preservice testing. In addition to the provisions in ESBWR DCD, Tier 2, Section 3.9.6.1.4, "Valve Testing," the North Anna 3 FSAR provides additional provisions for valve exercise tests.

The North Anna 3 FSAR also specifies additional provisions for the design and qualification process for explosively actuated valves. In addition to the power-operated valve test provisions in ESBWR DCD, Tier 2, Section 3.9.6.1.5, "Specific Valve Test Requirements," the North Anna

3 FSAR refers to Section 3.9.6.8 for additional (non-Code) testing of power-operated valves as discussed in Regulatory Issue Summary (RIS) 2000-03, “Resolution of Generic Safety Issue 158: Performance of Safety-Related Power-Operated Valves Under Design Basis Conditions.” In addition to the check valve exercise test provisions in ESBWR DCD, Tier 2, Section 3.9.6.1.5, the North Anna 3 FSAR specifies that check valve testing includes verification that obturator movement is in the direction required for the valve to perform its safety function. The North Anna 3 FSAR also includes additional check valve test provisions for (1) acceptance criteria, (2) a disassembly examination program where test methods are impractical, (3) nonintrusive diagnostic techniques, (4) post-maintenance testing, (5) preoperational testing, and (6) data collection for testing and inspections. In addition to the provisions in ESBWR DCD, Tier 2, Section 3.9.6.5, “Valve Replacement, Repair and Maintenance,” the North Anna 3 FSAR provides additional provisions for determining new reference values.

In addition to the provisions in ESBWR DCD, Tier 2, Section 3.9.6.8, “Non-Code Testing of Power-Operated Valves,” the North Anna 3 FSAR provides additional provisions for performing periodic tests of power-operated valves that are consistent with the guidance in NRC RIS 2000-03.

- STD COL 3.9.9-4-A Snubber Inspection and Test Program

To address COL Item 3.9.9-4-A, the North Anna 3 COL applicant specifies FSAR provisions that will supplement ESBWR DCD, Tier 2, Section 3.9.3.7.1(3)e, “Snubber Preservice and Inservice Examination and Testing.” For example, the North Anna 3 FSAR provides additional provisions to supplement the provisions for preservice examination and testing, and inservice examination and testing, of snubbers in ESBWR DCD, Tier 2, Section 3.9.3.7.1(3)e. In addition, the North Anna 3 FSAR provides additional provisions for listing snubber information to supplement ESBWR DCD, Tier 2, Section 3.9.3.7.1(3)f, “Snubber Support Data.”

In addition, in FSAR Section 3.9.3.7.1(3)3, the applicant states that as part of the system specific post COL ITAAC for piping and component design a plant-specific table will include snubber information as part of a subsequent FSAR update for ASME Class 1, 2 and 3 systems.

Supplemental Information

- STD SUP 3.9-1 10 CFR 50.55a Relief Requests and Code Cases

The North Anna 3 FSAR supplements ESBWR DCD, Tier 2, Section 3.9.6.6, “10 CFR 50.55a Relief Requests and Code Cases,” by specifying that no relief from or alternative to the ASME OM Code is being requested.

- STD SUP 3.9-2 Risk-Informed Inservice Testing

The North Anna 3 FSAR supplements ESBWR DCD, Tier 2, Section 3.9.7, “Risk-Informed Inservice Testing,” by specifying that risk informed inservice testing is not being utilized.

- STD SUP 3.9-3 Risk-Informed Inservice Inspection of Piping

The North Anna 3 FSAR supplements ESBWR DCD, Tier 2, Section 3.9.8, "Risk-Informed Inservice Inspection of Piping," by specifying that risk informed inservice inspection is not being utilized.

North Anna 3 Departure 3.7-1 related to reactor internals

In the North Anna 3 COL, Part 7, "Departures Report," Revision 6, the applicant identifies DCD departure NAPS DEP 3.7-1 for the plant specific FIRS which exceeds the CSDRS, as discussed in Section 3.7 of this SER. The staff has evaluated this departure and its related effect on the North Anna 3 reactor internals.

License Conditions

Part 10, Revision 7, of the North Anna 3 COL application specifies proposed license conditions related to Mechanical Sytems and Components in the following topic areas: steam dryer, explosively actuated valves, and the operational program implementation schedule.

3.9.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG–1966, the FSER related to the certified ESBWR DC and NUREG-1966, Supplement 1.

In addition, acceptance criteria associated with the relevant requirements of the Commission regulations are given in Section 3.9.2 of NUREG-0800 SRP, which include the following:

- The guidance associated with the reactor internals startup testing is given in RG 1.20, (Revision 3), "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing."

- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," GDC 1, "Quality standards and records," which requires (in part) that components important to safety be designed, fabricated, erected, and, tested to quality standards commensurate with the importance of the safety functions to be performed..

- GDC 2, "Design bases for protection against natural phenomena," which requires (in part) that components important to safety be designed to withstand seismic events without a loss of capability to perform their safety functions.

- GDC 4, "Environmental and dynamic effects design bases," which requires that SSCs important to safety be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operations, maintenance, testing, and postulated pipe ruptures including loss-of-coolant accidents.

- GDC 14, "Reactor coolant pressure boundary," which requires that the RCPB be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage; rapidly propagating failures; and gross ruptures.

- GDC 15, "Reactor coolant system design," which requires that the reactor coolant system and associated auxiliary, control, and protection systems be designed with sufficient margins to assure that the design conditions of the RCPB are not exceeded during any condition of normal operation, including anticipated operational occurrences.

- 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” as it relates to the suitability of the plant design bases for mechanical components established in consideration of site seismic characteristics.

The regulatory basis for the staff’s review of the North Anna 3 FSAR is provided by 10 CFR Parts 50 and 52. Specifically, the NRC regulations in 10 CFR 52.79(a)(11) require that a COL application provide a description of the programs and their implementation necessary to ensure that the systems and components meet the requirements of the ASME Boiler and Pressure Vessel Code (BPV Code) and the ASME OM Code, in accordance with 10 CFR 50.55a. As discussed in the ESBWR DCD FSER, GDC 1, 2, 4, 14, 15, 37, “Testing of emergency core cooling system”; 40, “Testing of containment heat removal system”; 43, “Testing of containment atmospheric cleanup system”; 46, “Testing of cooling water system”; and 54, “Piping systems penetrating containment”; in Appendix A to 10 CFR Part 50 establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public. The quality assurance (QA) criteria in 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” provide assurance that the design, tests, and documentation related to functional design, qualification, and inservice testing (IST) programs for pumps, valves, and dynamic restraints will comply with established standards and criteria; thereby ensuring that such equipment will be capable of performing the intended functions.

RG 1.206 provides guidance for a COL applicant in preparing and submitting the COL application in accordance with NRC regulations. For example, Section C.IV.4 in RG 1.206 discusses the requirement in 10 CFR 52.79(a) that descriptions of operational programs need to be included in the FSAR for a COL application to allow reasonable assurance for a finding of acceptability. In particular, a COL applicant should fully describe the IST and other operational programs defined in Commission Paper SECY-05-0197, “Review of Operational Programs in a Combined License Application and Generic Emergency Planning Inspections, Tests, Analyses, and Acceptance Criteria,” to avoid the need for ITAAC for operational programs. The term “fully described” for an operational program should be understood to mean that the program is clearly and sufficiently described in terms of scope and level of detail to allow a reasonable assurance finding. Further, operational programs should be described at a functional level with an increasing level of detail, where implementation choices could materially and negatively affect the program’s effectiveness and acceptability. In the SRM for SECY-05-0197 dated February 22, 2006, the Commission approved the SECY including the use of a license condition for operational program implementation milestones that are fully described or referenced in the FSAR.

The staff’s review of the North Anna 3 COL application followed the applicable guidance in SRP Section 3.9. North Anna 3 FSAR Table 1.9-201, “Conformance with Standard Review Plan,” specifies that the COL application conform to the subsections in SRP Section 3.9. The staff also compared the North Anna 3 FSAR information with the guidance in RG 1.206, as listed in North Anna 3 FSAR Table 1.9-203, “Conformance with the FSAR Content Guidance in RG 1.206.”

3.9.4 Technical Evaluation

As documented in NUREG-1966, the NRC staff reviewed and approved Section 3.9 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.9 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD that represent the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the required information related to the "Mechanical Systems and Components."

The staff's review of the information contained in the North Anna 3 COL FSAR is as follows:

<u>*COL Items*</u>

- CWR COL 3.9.9-1-A — Reactor Internals Vibration Analysis, Measurement and Inspection Program

This COL Information Item states the following.

DCD COL Item 3.9.9-1-A in Section 3.9.9 of the ESBWR DCD states that the COL applicant will perform the following:

1. For the reactor internals, other than steam dryer, classify its reactor per the guidance in RG 1.20 and provide a milestone for submitting a description of the inspection and measurement programs to be performed (including measurement locations and analysis predictions) and the results of the vibration analysis, measurement and test program (Section 3.9.2.4).

2. For the steam dryer, which is classified as a prototype per the guidance in RG 1.20, (a) provide a milestone of no later than 90 days before startup to prepare and provide to the NRC a Steam Dryer Monitoring Plan as described in NEDE-33313P, Section 10; (b) submit or reference a steam dryer predicted analysis (for the plant-specific or a sample steam dryer) that concludes the steam dryer will not exceed stress limits with applicable bias and uncertainties and the minimum alternating stress ratio (MASR) of 2.0; (c) describe startup program (with proposed license conditions) that includes appropriate notification points during power ascension, and submittal of the completed analysis of steam dryer data within 90 days following completion of the power ascension testing and monitoring of the steam dryer; and (d) specify periodic steam dryer inspections during refueling outages (Section 3.9.2.4).

To address COL Information Item 3.9.9-1-A, the North Anna 3 COL applicant specified that the vibration assessment program for reactor internals other than the steam dryer, as discussed in RG 1.20, is provided in DCD Appendix 3L and NEDE-33259P-A (ADAMS Accession No. ML091660434). In addition, the classification of the North Anna 3 reactor internals in accordance with RG 1.20 is dependent on ESBWR plant start-up testing status, that is, if North Anna 3 is the initial ESBWR to perform testing of the reactor internals, or if testing is performed at another reactor prior to North Anna 3 testing.

Specific to the steam dryer, the comprehensive vibration assessment program, as specified in RG 1.20 is provided in ESBWR DCD Appendix 3L, NEDE-33312P (ADAMS Accession No. ML13344B157; ML13344B163 Non-Public), NEDE-33313P (ADAMS Accession No. ML13344B158; ML13344B164 Non-Public), and NEDE-33408P (ADAMS Accession No. ML13344B159; (ML13344B175 and ML13344B176 Non-Public)).

The steam dryer is classified as a prototype according to RG 1.20, Revision 3, and the applicant presents an approach that is consistent with RG 1.20 and Section 10.2 of NEDE-33313P, including four elements of a steam dryer Comprehensive Vibration Assessment Program (CVAP) that must be addressed.

The staff reviewed the classification of the North Anna 3 reactor internals. The North Anna 3 classification of the reactor internals has two scenarios. In the first scenario, the North Anna 3 reactor internals are classified as the ESBWR prototype for testing the reactor internals. In the second scenario, should a CVAP for an ESBWR unit other than North Anna 3 be completed and approved by the NRC as a valid prototype before the initiation of startup testing at North Anna 3, the North Anna 3 reactor internals will be classified as non-prototype Category I. As described in NUREG-1966, Supplement 1, the Supplemental FSER related to the certified ESBWR DCD, Tier 2, Section 3.9.5, the steam dryer will be classified as a prototype regardless of the presence of another ESBWR unit. The staff finds the classification approach for the North Anna 3 reactor internals to be acceptable because the classification of the reactor internals for North Anna 3 is consistent with RG 1.20, and the classification of the steam dryer as a prototype regardless of the presence of another ESBWR unit is conservative.

For reactor internals (other than the steam dryer) to be installed in North Anna 3, the staff finds the review and acceptance of the CVAP specified in the ESBWR DCD to be acceptable as described in NUREG-1966, Supplement 1, the supplemental FSER related to the certified ESBWR DCD, Tier 2, Section 3.9.5. Therefore, the staff finds the portion of COL Item 3.9.9-1-A related to the reactor internals (other than the steam dryer) for North Anna 3 to be satisfied.

For the steam dryer, a description of the staff's review and acceptance of the ESBWR steam dryer evaluation methodology is in NUREG-1966, Supplement 1, the Supplemental FSER related to the certified ESBWR DCD, Tier 2, Section 3.9.5. The North Anna 3 FSAR specifies the COL applicant's actions that are necessary to satisfy the portion of COL Item 3.9.9-1-A related to the steam dryer. For the North Anna 3 steam dryer Item (a) of COL Item 3.9.9-1-A, the CVAP to be applied is described in ESBWR DCD, Tier 2, Section 3.9 and Appendix 3L and in NEDE-33313P, Section 10.0. The CVAP includes preparing and submitting to the NRC a Steam Dryer Monitoring Plan (SDMP) no later than 90 days before startup. For Item (b) of COL Item 3.9.9-1-A, the detailed design of the North Anna 3 steam dryer will follow the methodology described in DCD Appendix 3L and in the incorporated engineering reports. As described in NEDE-33313P, Section 10.2(b), an example of a steam dryer predictive analysis that concludes the steam dryer will not exceed stress limits with the applicable bias and uncertainties and the minimum alternating stress ratio of 2.0 is provided in NEDE-33408P. The example of an as designed steam dryer that was subject to the predictive analysis process and successful startup testing described in NEDE-33408P serves as the design analysis report for the steam dryer and provides sufficient information for licensing. For Item (c) of COL Item 3.9.9-1-A, the North Anna 3 startup program is based on NEDE-33313P, Section 10.2(c), which includes (1) providing appropriate notification points during power ascension; (2) providing data to the NRC at certain hold points and at full power; and (3) providing a full stress analysis report and evaluation to the

NRC within 90 days of reaching the full power level. For Item (d) of COL Item 3.9.9-1-A, the periodic steam dryer inspection program for North Anna 3 during refueling outages is described in NEDE-33313P, Section 10.2(d). Part 10 of the North Anna 3 COL application provides a proposed license condition for the steam dryer startup program and the periodic inspection program.

The NRC staff has reviewed the actions specified in the North Anna 3 FSAR for each of the individual portions of COL Item 3.9.9-1-A regarding the steam dryer. The staff determined that the North Anna 3 FSAR actions related to the steam dryer satisfy the provisions in ESBWR DCD, Tier 2 and NEDE-33312P, NEDE-33313P, and NEDE-33408P incorporated in the ESBWR DCD as accepted in NUREG-1966, Supplement 1 on ESBWR DCD, Tier 2, Section 3.9.5. These North Anna 3 actions include application of the CVAP for the steam dryer described in the ESBWR DCD, Tier 2 and NEDE-33313P, reference of the example steam dryer predictive analysis in NEDE-33408P, preparation of a North Anna 3 startup program that incorporates the steam dryer monitoring plan in NEDE-33313P, and specification of a periodic steam dryer inspection program consistent with NEDE-33313P. The North Anna 3 steam dryer monitoring and inspection program will be verified by the license condition specified in this SER Section. The staff notes that the license condition proposed in this SER, as compared to the model condition proposed in NEDE-33313P, has been reformatted to better conform with standard license condition format and has been rewritten for clarity and to remove redundancy. Some of these changes resulted in minor changes in substance, such as more clearly specifying power levels for steam dryer monitoring and methods for informing the NRC of the results of monitoring. The staff reviewed and accepted the ESBWR DCD and its referenced engineering reports on the steam dryer as part of the NRC review of the ESBWR design certification application. Therefore, the staff finds that the actions specified by the North Anna 3 COL applicant satisfy the steam dryer portion of COL Item 3.9.9-1-A.

The staff notes that the ESBWR DCD identifies specific portions of the information on the structural integrity and functional capability of mechanical systems and components to be Tier 2* information. As part of this identification of Tier 2* information, the ESBWR DCD identifies Tier 2, Section 3.9.2.3 as well as the GEH engineering reports NEDE-33312P, NEDE-33313P, and NEDE-33408P on the ESBWR steam dryer incorporated by reference in the DCD as Tier 2* in their entirety. Therefore, the North Anna 3 steam dryer evaluation methodology will be implemented as Tier 2* information in accordance with the ESBWR design certification.

Based on its review described above, the staff finds that the North Anna 3 COL applicant has satisfied the provisions in COL Information Item COL 3.9.9-1-A. The staff discusses the applicable license conditions and FSAR provisions related to reactor internals for North Anna 3 in this SER section under “Post Combined License Activities.” The staff finds that the information related to reactor internals classification and testing is adequate in meeting NRC regulatory requirements and RG 1.20 guidance, and is therefore acceptable.

- STD COL 3.9.9-2-A — ASME Class 2 or 3 or Quality Group D Components with 60-Year Design Life

DCD COL Item 3.9.9-2-A in Section 3.9.9 of the ESBWR DCD states the following:

> The COL Applicant will provide a milestone for completing the required equipment stress reports, per ASME BPV Code, Subsection NB, for equipment segments that are subject to loadings that could result in thermal or dynamic fatigue and for updating the FSAR, as necessary, to address the results of the analysis (Section 3.9.3.1).

North Anna 3 COL FSAR, Revision 8, Section 3.9.3.1, "Loading Combinations, Design Transients and Stress Limits," states that the required equipment stress reports will be completed within 6 months of the completion of DCD ITAAC Table 3.1-1 for the as-built piping systems and components. In addition, the North Anna 3 FSAR specifies that the FSAR will be revised as necessary in a subsequent update to address the results of this analysis. The staff observes that in order to complete the referenced ITAAC related to the pipe break analyses listed in DCD Tier 1, Table 3.1-1, the applicant will first perform equipment and piping stress analyses that support the determination of pipe break locations based on the as-built conditions. Additional ITAAC related to the completion of component and piping stress analyses in accordance with ASME BPV Code requirements are in DCD Tier 1. Dominion clarified in a subsequent letter dated April 17, 2014 (ADAMS Accession No. ML14100A508) that there are currently no non-Class 1 components for North Anna 3 that are subjected to cyclic loadings of a magnitude and/or duration so severe that the 60-year design life cannot be assured. Therefore, the staff finds that no supplemental information that provides an analysis or design per the Tier 2* provisions of ESBWR DCD, Tier 2, Section 3.9.3.1, is necessary. The staff also observes that the original basis for including these requirements in the ESBWR DCD related to the NRC staff's concerns regarding environmentally assisted fatigue, which have been resolved through the final staff position in RG 1.207, "Guidelines for Evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components Due To the Effects of the Light-Water Reactor Environment for New Reactors," which is committed to in ESBWR DCD, Tier 2, Section 3.9.1. Therefore, the applicant has provided an acceptable milestone related to the development of the required equipment stress reports, as requested in the COL item. These milestone activities are acceptable to the staff, as they address one detail of the overall stress analysis that will be confirmed through completion of ITAAC related to ASME BPV Code requirements, as well as periodic FSAR updates required by the regulations. Post licensing and inspection processes are already in place to provide final verification of these overall activities. Based on the provision of the required evaluation and FSAR updates in response to this COL item and the associated ITAAC, the staff thus finds the applicant's response to COL Item 3.9.9-2-A acceptable.

- STD COL 3.9.9-3-A Inservice Testing Programs

This COL item is related to the functional design, qualification, and IST Programs for pumps, valves, and dynamic restraints. COL Item 3.9.9-3-A in Section 3.9.9 of the ESBWR DCD states the following:

> The COL Applicant shall provide a full description of the IST Program and a milestone for full program implementation as identified in Section 3.9.6.1.

ESBWR DCD Section 3.9.3.5, "Valve Operability Assurance," describes the process for the functional design and qualification of valves to be used in the ESBWR. Section 3.9.3.5 in ESBWR DCD, Tier 2 specifies that valve designs not previously qualified will meet the requirements of ASME Standard QME-1-2007, "Qualification of Active Mechanical Equipment

In COL item 3.9.9.3-A, the applicant provided supplemental information on the North Anna 3 IST Program which provides the overall preservice testing, of pumps, valves and restraints. The North Anna 3 COL FSAR does not identify any additional plant-specific valves to be included in the IST Program beyond those listed in ESBWR DCD, Tier 2, Table 3.9-8. ESBWR DCD, Tier 2, Section 3.9.6.1.4, "Valve Testing," references NUREG–1482 (Revision 1), "Guidelines for Inservice Testing at Nuclear Power Plants." Following the issuance of the North Anna 3 COL, the guidance in NUREG–1482, (Revision 2 issued in October 2013) can be used to develop the IST Program for North Anna 3, including the specific information to be included in Program documentation and tables utilized for NRC inspection. The staff reviewed the description of the ASME OM Code requirements in the North Anna 3 FSAR on the IST Program that supplements the provisions in the ESBWR DCD including the prohibition of preconditioning that undermines the purpose of the IST activities. The staff finds the North Anna 3 FSAR to be consistent with Subsection ISTC, "Inservice Testing of Valves in Light-Water Reactor Nuclear Power Plants," of the ASME OM Code incorporated by reference in 10 CFR 50.55a, and therefore, the FSAR description of the use of ASME OM Code, Subsection ISTC, is acceptable.

The ESBWR DCD specifies that the ESBWR reactor design does not require the use of pumps to mitigate the consequences of design-basis accidents or to achieve or maintain a safe-shutdown condition. The post-accident long-term decay heat removal for the ESBWR is performed by nonsafety-related systems as accepted in Commission paper SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Nonsafety Systems [RTNSS] in Passive Plant Designs." The availability of systems relied on after 72 hours that is addressed under the RTNSS Program is discussed in Chapter 19.0, "Probabilistic Risk Assessment and Severe Accidents," of this SER.

Adverse Flow Affects

Nuclear power plant operating experience has revealed the potential for adverse flow effects from vibration caused by hydrodynamic loads and acoustic resonance within reactor coolant, steam, and feedwater systems, as well as reactor internal components such as steam dryers. Therefore in RAI 03.09.02-1, dated August 19, 2008 (ADAMS Accession No. ML082320133), the staff requested that Dominion describe the planned implementation of the program to address potential adverse flow effects on safety-related valves and dynamic restraints within the IST Program in the reactor coolant, steam, and feedwater systems at North Anna Unit 3 from hydraulic loading and acoustic resonance during plant operation.

In response to RAI 03.09.02-1 dated October 2, 2008 (ADAMS Accession No. ML082810405), the applicant presented a plan to use the overall Initial Test Program, which includes preoperational and startup testing, to address potential adverse flow effects on safety-related valves and dynamic restraints. The program will confirm attributes of the component design described in the ESBWR DCD, with implementation described in FSAR Section 14.2 and Table 13.4-201. As part of ESBWR DCD Tier 2, Section 3.9.2, the COL applicant referred to ESBWR DCD Tier 2, Section 3.9.2.1, "Piping Vibration, Thermal Expansion and Dynamic Effects," which states that the overall test program is divided into the preoperational test phase and the initial startup test phase with piping vibration, thermal expansion, and dynamic effects testing performed during both phases and described in ESBWR DCD Tier 2, Chapter 14. The COL applicant also referred to ESBWR DCD Tier 2, Section 3.9.2.1.1, "Vibration and Dynamic Effects Testing," which states that the purpose of these tests is to confirm that the piping, components, restraints, and supports of specified high- and moderate-energy systems have been designed to withstand the dynamic effects of steady-state, flow induced vibration (FIV) and anticipated operational transient conditions.

The North Anna 3 COL applicant referenced ESBWR DCD Tier 2, Section 3.9.3.5, which requires valve specifications to incorporate lessons learned from nuclear power plant operations and research programs, including applicable load combinations. The COL applicant also referred to ESBWR DCD Tier 2, Sections 3.9.3.7 and 3.9.3.8, which require analyses or tests for component supports to assure their structural capability to withstand seismic and other dynamic excitations. With respect to reactor internals, ESBWR DCD Section 3.9.2.3 states that the major reactor internal components within the vessel are subjected to extensive testing, coupled with dynamic system analyses, to properly evaluate the resulting FIV phenomena during normal reactor operation and from anticipated operational transients. The preoperational and startup tests are described in DCD Section 14.2.8.1.42, “Expansion, Vibration and Dynamic Effects Preoperational Test,” and in DCD Section 14.2.8.2.10, “System Vibration Test,” which describe the applicable preoperational and startup tests. Based on this information, the staff found the COL applicant’s description of plans to implement the provisions in the ESBWR DCD to address potential adverse flow effects for safety-related valves and dynamic restraints at North Anna 3 to reflect nuclear power plant operating experience. In particular, the COL applicant plans to address the effects of steady-state FIV and operational transients, including lessons learned from operating experience and research programs as part of equipment qualification. Further, the COL applicant plans to address potential adverse flow effects by monitoring piping vibration during the Initial Test Program for North Anna 3. The staff’s review of the qualification provisions for potential adverse flow effects as part of the review of design and procurement specifications is documented in SER Section 3.9.6. The implementation of the provisions in ESBWR DCD Tier 2, Chapter 14 will be reviewed as part of future NRC inspections at North Anna 3. The staff finds the North Anna 3 COL applicant’s plans acceptable because they recognize the safety significance of potential adverse flow effects with future regulatory activities to monitor the details of those plans. Therefore, RAI 03.09.02-1 is resolved and closed.

The staff issued RAI 03.09.02-2, dated August 19, 2008 (ADAMS Accession No. ML082140136) requesting North Anna 3 COL applicant to indicate when it proposed to submit to the staff an implementation schedule to review the comprehensive FIV assessment program for reactor internals, in accordance with RG 1.20 Revision 3 and SRP Sections 3.9.2 and 3.9.5. In response to RAI 03.09.02-2 dated October 2, 2008 (ADAMS Accession No. ML082810405), the COL applicant stated that the comprehensive FIV assessment program for reactor internals was submitted by GEH to the staff as part of the ESBWR DCD review; this is now reflected in the ESBWR DCD, Revision 10. The reactor internals vibration analysis, measurement and inspection program is addressed under COL Information Item 3.9.9-1-A. The response of the North Anna 3 COL applicant to this COL Information Item has been evaluated by the staff as discussed above in this SER section. Therefore, RAI 03.09.02-02 is resolved and closed.

Special Tests

As part of STD COL 3.9.9-3-A the COL applicant in FSAR Section 3.9.6.1.4 (4), provided the following additional information for development of the IST program for explosively actuated (i.e., squib) valves.

> Industry and regulatory guidance is considered in development of IST program for explosively actuated valves. In addition, the IST program for explosively actuated valves incorporates lessons learned from the design and qualification process for these valves such that surveillance activities provide reasonable assurance of the operational readiness of explosively actuated valves to perform their safety functions.

Subsection ISTC-5260, “Explosively Actuated Valves,” in the ASME OM Code specifies that at least 20 percent of the charges in squib valves shall be fired and replaced at least once every 2 years. If a charge fails to fire, the ASME OM Code states that all charges with the same batch number shall be removed, discarded, and replaced with charges from a different batch. In light of the updated design and safety significance of squib valves in new reactors, the need for improved surveillance activities for squib valves is being considered by the ASME.

In RAI 03.09.06-1 for the Fermi 3 RCOL application, the staff requested Detroit Edison to describe its plans for addressing the surveillance of squib valves that will provide reasonable assurance of the operational readiness of those valves to perform their safety functions in support of the Fermi 3 COL application. In a letter dated November 9, 2010 (ADAMS Accession No. ML103140611), Detroit Edison submitted a planned revision to Fermi 3 COL FSAR Section 3.9.6 to specify that industry and regulatory guidance will be considered in the development of the IST Program for squib valves. Detroit Edison indicated that the FSAR would also state that the IST Program for squib valves will incorporate lessons learned from the design and qualification process for these valves, such that surveillance activities provide reasonable assurance of the operational readiness of squib valves to perform their safety functions. The staff found that the planned changes to the Fermi 3 COL FSAR were sufficient to describe the IST Program for squib valves for incorporating the lessons learned from the design and qualification process in developing surveillance activities that will provide reasonable assurance of the operational readiness for squib valves to perform their safety functions.

Dominion, following its COLA revision to the ESBWR on April 25, 2013, adopted the response to this RAI in a letter dated, August 30, 2013 (ADAMS Accession No. ML13247A394) and provided the FSAR updated information as part of FSAR Revision 6, July 2013. The staff finds that this supplemental information for development of the squib valve IST program for North Anna 3 is acceptable.

As discussed later in this SER section, North Anna 3 incoroporated the FERMI License Condition directing the implementation of a surveillance program for squib valves in the gravity-driven cooling system and the automatic depressurization system for North Anna 3 prior to fuel load to supplement the IST requirements in the ASME OM Code, consistent with the licensing of other passive design new reactors. The staff considers the application of the ASME OM Code as incorporated by reference in 10 CFR 50.55a prior to startup of North Anna 3 to be sufficient for squib valves in the standby liquid control (SLC) system for North Anna 3, without the additional provisions of License Condition 3.9 that are necessary for the gravity driven cooling system and the automatic depressurization system, based on operating experience with SLC squib valves in current boiling-water reactor nuclear power plants.

- STD COL 3.9.9-4-A Snubber Inspection and Test Program

DCD COL Item 3.9.9-4-A in Section 3.9.9 of the ESBWR DCD states the following:

> The COL Applicant shall provide a full description of the snubber preservice and inservice inspection and testing programs, and a milestone for program implementation, including development of a data table identified in Subsection 3.9.3.7.1(3)f (Subsection 3.9.3.7.1(3)e).

The staff reviewed the applicant's information related to the snubber preservice and inservice examination and testing programs included under Section 3.9.3.7.1(3)e of the North Anna 3 COL FSAR, which states the following:

> A preservice thermal movement examination is also performed; during initial system heatup and cooldown, for systems whose design operating temperature exceeds 121°C (250°F), snubber thermal movement is verified.
>
> Additionally, preservice operational readiness testing is performed on all snubbers. The operational readiness test is performed to verify the parameters of ISTD-5120. Snubbers that fail the preservice operational readiness test are evaluated to determine the cause of failure, and are retested following completion of corrective action(s).
>
> Snubbers that are installed incorrectly or otherwise fail preservice testing requirements are re-installed correctly, adjusted, modified, repaired or replaced, as required. Preservice examination and testing is re-performed on installation-corrected, adjusted, modified, repaired or replaced snubbers as required.
>
> The preservice inspection and testing programs for snubbers will be completed in accordance with milestones described in Section 13.4.
>
> Inservice examination and testing of all safety-related snubbers is conducted in accordance with the requirements of the ASME OM Code, Subsection ISTD. Inservice examination is initially performed not less than two months after attaining 5 percent reactor power operation and will be completed within 12 calendar months after attaining 5 percent reactor power. Subsequent examinations are performed at intervals defined by ISTD-4252 and Table ISTD-4252-1. Examination intervals, subsequent to the third interval, are adjusted based on the number of unacceptable snubbers identified in the then current interval.
>
> An inservice visual examination is performed on all snubbers to identify physical damage, leakage, corrosion, degradation, indication of binding, misalignment or deformation and potential defects generic to a particular design. Snubbers that do not meet visual examination requirements are evaluated to determine the root cause of the unacceptability, and appropriate corrective actions (e.g., snubber is adjusted, repaired, modified, or replaced) are taken. Snubbers evaluated as unacceptable during visual examination may be accepted for continued service by successful completion of an operational readiness test.
>
> Snubbers are tested inservice to determine operational readiness during each fuel cycle, beginning no sooner than 60 days before the scheduled start of the applicable refueling outage. Snubber operational readiness tests are conducted with the snubber in the as-found condition, to the extent practical, either in place or on a test bench, to verify the

test parameters of ISTD-5210. When an in-place test or bench test cannot be performed, snubber subcomponents that control the parameters to be verified are examined and tested. Preservice examinations are performed on snubbers after reinstallation when bench testing is used (ISTD-5224), or on snubbers where individual subcomponents are reinstalled after examination (ISTD-5225).

Defined test plan groups (DTPG) are established and the snubbers of each DTPG are tested according to an established sampling plan each fuel cycle. Sample plan size and composition are determined as required for the selected sample plan, with additional sampling as may be required for that sample plan based on test failures and failure modes identified. Snubbers that do not meet test requirements are evaluated to determine root cause of the failure, and are assigned to failure mode groups (FMG) based on the evaluation, unless the failure is considered unexplained or isolated. The number of unexplained snubber failures not assigned to an FMG determines the additional testing sample. Isolated failures do not require additional testing. For unacceptable snubbers, additional testing is conducted for the DTPG or FMG until the appropriate sample plan completion criteria are satisfied.

Unacceptable snubbers are adjusted, repaired, modified, or replaced. Replacement snubbers meet the requirements of ISTD-1600. Post-maintenance examination and testing, and examination and testing of repaired snubbers, is done to ensure that test parameters that may have been affected by the repair or maintenance activity are verified acceptable.

Service life for snubbers is established, monitored and adjusted as required by ISTD-6000 and the guidance of ASME OM Code Nonmandatory Appendix F.

The inservice inspection and testing programs for snubbers will be completed in accordance with milestones described in Section 13.4.

In the North Anna 3 FSAR Section 3.9.3.7.1(3)e, “Snubber Support Data,” it is stated that for the ASME Class 1, 2, and 3 systems listed in DCD Tier 1, Section 3.1, that contain snubbers, a plant specific table will be prepared in conjunction with the closure of the system-specific ITAAC for piping and component design and will include specific snubber information. This information will be included in the FSAR as part of a subsequent FSAR update.

The staff finds that the provisions specified in the North Anna 3 FSAR on the snubber inspection and test program together with the ESBWR DCD provisions incorporated by reference in the North Anna 3 FSAR adequately describe the snubber inspection and test program as consistent with the 3-87 ASME OM Code provisions in accordance with Commission policy to review a description of the operational programs (including the snubber IST program) in support of the COL application review. As indicated in a License Condition specified later in this SER section, the licensee will submit a schedule that supports planning and conducting NRC inspections of operational programs. During inspections of the North Anna 3 operational programs, the staff will confirm that the Preservice Testing (PST) and IST Operational Programs (including the snubber program) have been established consistent with the North Anna 3 FSAR and this SER section, including completion of the applicable requirements specified in the North Anna 3 FSAR. Therefore, COL Item 3.9.9-4-A is satisfied.

Supplemental Information

The North Anna 3 COL application also provides three instances of standard supplemental information in Section 3.9. In Section 3.9.6.6, STD SUP 3.9-1 states that no relief from or alternative to the ASME OM Code is being requested. In Section 3.9.7, STD SUP 3.9-2 states that risk-informed IST is not being utilized, replacing a statement in the ESBWR DCD that risk-informed IST initiatives, if any, are included in IST Program implementation plans. Similarly, in Section 3.9.8, STD SUP 3.9-3 states that risk-informed inservice inspection is not being utilized, replacing a statement in the ESBWR DCD that initiatives for risk-informed inservice inspection of piping, if any, are included in inservice inspection implementation plans. All three of these supplemental statements confirm that the North Anna 3 applicant intends to follow the processes for ASME OM Code implementation, IST Program implementation, and inservice inspection implementation described in the ESBWR DCD, as supplemented in the North Anna 3 COL application and evaluated as described in this SER section. Therefore, the staff finds this supplemental information acceptable.

North Anna 3 Departure 3.7-1 related to reactor internals

The loads due to earthquake and other RBV acting on the structure within the reactor vessel are based on a dynamic analysis methods described in Section 3.7 of this SER.

In the North Anna 3 COL, Part 7, "Departures Report," Revision 6, the applicant identifies DCD departure NAPS DEP 3.7-1 for the plant specific FIRS which exceeds the CSDRS, as discussed in Section 3.7 of this SER.

In ESBWR DCD 3.9, “Mechanical Systems and Components,” it states that, in accordance with GDC 2 and 10 CFR 50 Appendix S, the RPV assembly and its safety related internal components are designed to withstand seismic events with site specific seismic characteristics. In response to RAI 03.09.02-3 dated August 1, 2014 (ADAMS Accession No. ML14217A472), Dominion verified that the North Anna 3, “ASME Code Design and Purchase Specification,” that all components designed and purchased, to ASME Code, Section III, Class 1, 2, and 3 and related ASME code subsections requirements; including the RPV assembly and its safety related internal components including the core support structures, will include the requirements for loads and load combinations and will include both the CSDRS and the Unit 3 site specific FIRS for establishing the SSE ground motion response spectra, as defined in FSAR Section 3.7.1. The applicant further stated that according to the Unit 3 COLA, Part 7, departure NAPS DEP 3.7-1, and FSAR Section 3.7.1, the Unit 3 SSE design ground motion in FSAR Section 3.7.1 applies to the seismic design, analysis, and qualification of North Anna 3 plant SSCs, including the ASME Code related reactor internal components. The applicant’s response also stated that the RPV evaluation which is described in FSAR Section 3.7.2.4 is performed utilizing both CSDRS and Unit 3 site specific FIRS. The staff reviewed FSAR, Revision 8, Section 3.7.1, “Seismic Design Parameters,” NAPS DEP 3.7-1 and verified that according to this section for each structure and each equipment location within the buildings, the site-specific ISRS that exceed the standard design ISRS, are used in conjunction with the standard design ISRS for seismic design and qualification of equipment and components. In addition the staff reviewed FSAR 3.7.2.4.1.8, “Site-Specific Seismic Design and Analysis of Structures, Systems, and components,” which confirms that the seismic capability of the RPV subsystem is verified through the DCD Tier 1, Table 2.1.1-3, “ITTAC For the Reactor Pressure Vessel and Internals,” using SSE loads developed from the results of site-specific SSI analysis of the RB/FB model.

Based on its review above, the staff finds the applicant's response acceptable because it demonstrated that the GDC 2 and 10 CFR 50 Appendix S requirements that the RPV assembly and its safety related internal components will be designed to withstand seismic events of the evaluated site specific seismic characteristics have been satisfied.

Interfaces for Standard Design

ESBWR DCD, Tier 2, Section 1.8, "Interfaces with Standard Design," identifies site-specific interfaces with the standard ESBWR design. DCD Table 1.8-1, "Matrix of NSSS Interfaces," references Section 3.9 for the supporting interface areas of mechanical SSCs. The staff reviewed the North Anna 3 COL application for interface requirements with the ESBWR standard design regarding the functional design, qualification, and IST Programs for safety-related valves and dynamic restraints using the review procedures described in SRP Section 3.9.6. The staff finds that the applicant's consideration of design interface items is acceptable based on compliance with NRC regulations discussed in this SER section.

3.9.5 Post Combined License Activities

With respect to the ESBWR steam dryer, NEDE-33313P specifies Tier 2* provisions for the COL holder to complete the design and construction of the steam dryer for an ESBWR nuclear power plant. For example, Section 9.1, "Instrumentation for Monitoring Steam Dryer Response," in NEDE-33313P describes the process to meet ITAAC 12, 13, and 14 in DCD Tier 1, Table 2.1.1-3, for the installation of pressure sensors, strain gages, and accelerometers on the as-built steam dryer to monitor its performance during power ascension. Section 10.1.1, "Steam Dryer Design Analysis Report," in NEDE-33313P specifies the elements for the as-designed ESBWR steam dryer analysis report. Section 10.1.2, "Steam Dryer As-Built Analysis Report," in NEDE-33313P specifies the process to satisfy ITAAC 16 in DCD Tier 1, Table 2.1.1-3, in verifying that the as-built steam dryer fatigue analysis provides at least a minimum alternating stress ratio (MASR) of 2.0 to the allowable alternating stress intensity of 93.7 MPa (13,600 psi). Appendix A, "ITAAC for Reactor Pressure Vessel Internals," to NEDE-33313P describes the process to meet ITAAC 8.b in DCD Tier 1, Table 2.1.1-3, to provide assurance that the reactor internal structures will meet the provisions of ASME BPV Code, Subsection NG-3000, except for the weld quality and fatigue factors for secondary structural non-load bearing welds. Appendix B, "ITAAC for Main Steam Line [MSL] and [Safety Relief Valve] SRV/Safety Valve [SV] Branch Piping Acoustic Resonance," to NEDE-33313P describes the process to meet ITAAC 36 in DCD Tier 1, Table 2.1.2-3, to provide assurance that the MSL and SRV/SV branch piping geometry will preclude first and second shear layer wave acoustic resonance conditions from occurring and avoids excessive pressure loads on the steam dryer at plant normal operating conditions. These post-combined license activities for the ESBWR steam dryer will be performed by the COL holder for North Anna 3 as described by the Tier 2* provisions in the ESBWR DCD and its referenced engineering reports unless the COL holder obtains regulatory approval for an alternative process.

Section 3.9.2.4 of the North Anna 3 FSAR provides the following provisions for the submittal of reports regarding reactor internals after receipt of the COL:

- For reactor internals other than the steam dryer, the comprehensive vibration assessment program will be developed and implemented as described in DCD

Appendix 3L with no departures. The vibration measurement and inspection programs will comply with the guidance specified in RG 1.20, Revision 3, consistent with the Unit 3 reactor internals classification. A summary of the vibration analysis program and description of the vibration measurement (including measurement locations and analysis predictions) and inspection phases of the comprehensive vibration inspection program will be submitted to the NRC six months prior to implementation.

- For reactor internals other than the steam dryer, the preliminary and final reports (as necessary), which together summarize the results of the vibration analysis, measurement and inspection programs will be submitted to the NRC within 60 and 180 days, respectively, following the completion of the programs.

The NRC staff finds these provisions for the submittal of a summary of the vibration analysis program, a description of the vibration measurement and inspection phases of the comprehensive vibration inspection program, and the preliminary and final reports of the vibration analysis, measurement, and inspection programs for reactor internals other than the steam dryer to be acceptable as consistent with the provisions of the ESBWR DCD and R-COLA FSAR. For the steam dryer, these actions are addressed in the license condition specified below.

License Conditions:

FSAR Section 13.4 indicates that FSAR Table 13.4-201 lists each operational program, the regulatory source for the program, the associated implementation milestones, and the FSAR section where the operational program is fully described, as discussed in RG 1.206. RG 1.206, Regulatory Position Section C.IV.4.3 states that the COL will contain a license condition that requires the licensee to submit to the NRC a schedule that supports planning and conducting NRC inspections of operational programs including pre-service testing, IST, reactor material surveillance and containment leakage testing. The schedule must be submitted 12 months after the NRC issues the COL. The schedule will be updated every 6 months, until 12 months before scheduled fuel loading, and every month thereafter until either the operational programs in FSAR Table 13.4-201 have been fully implemented or the plant has been placed in commercial service, whichever comes first.

3.6 Operational Program Readiness

The licensee shall submit to the Director of NRO, a schedule, no later than 12 months after issuance of the COL, for implementation of the operational programs listed in FSAR Table 13.4-201. The schedule shall be updated every 6 months until 12 months before scheduled fuel loading, and every month thereafter until the operational programs in the FSAR table have been fully implemented. This schedule shall also address:

- The implementation of site-specific Severe Accident Management Guidelines

- The spent fuel rack coupon monitoring program implementation

The NRC staff has determined that a license condition is required, for safety significant squib valves based on its review of the North Anna 3 COL application and as evaluated by the staff in Section 3.9.4 under the heading “Special Tests,” as follows:

3.9 Explosively Actuated Valves

Before initial fuel load, the licensee shall implement a surveillance program for explosively actuated valves (squib valves) in the Gravity-Driven Cooling System and the Automatic Depressurization System at Unit 3 that includes the following provisions in addition to the requirements specified in the ASME Code for Operation and Maintenance of Nuclear Power Plants (OM Code) as incorporated by reference in 10 CFR 50.55a.

a. Preservice Testing (PST)

All explosively actuated valves shall be preservice tested by verifying the operational readiness of the actuation logic and associated electrical circuits for each explosively actuated valve with its pyrotechnic charge removed from the valve. This must include confirmation that sufficient electrical parameters (voltage, current, resistance) are available at the explosively actuated valve from each circuit that is relied upon to actuate the valve. In addition, a sample of at least 20 percent of the pyrotechnic charges in all explosively actuated valves shall be tested in the valve or a qualified test fixture to confirm the capability of each sampled pyrotechnic charge to provide the necessary motive force to operate the valve to perform its intended function without damage to the valve body or connected piping. The sampling must select at least one explosively actuated valve from each redundant safety train. Corrective action shall be taken to resolve any deficiencies identified in the operational readiness of the actuation logic or associated electrical circuits, or the capability of a pyrotechnic charge. If a charge fails to fire or its capability is not confirmed, all charges with the same batch number shall be removed, discarded, and replaced with charges from a different batch number that has demonstrated successful 20 percent sampling of the charges.

b. Operational Surveillance

Explosively actuated valves shall be subject to the following surveillance activities after commencing plant operation:

(1) At least once every 2 years, each explosively actuated valve shall undergo visual external examination and remote internal examination (including evaluation and removal of fluids or contaminants that may interfere with operation of the valve) to verify the operational readiness of the valve and its actuator. This examination shall also verify the appropriate position of the internal actuating mechanism and proper operation of remote position indicators. Corrective action shall be taken to resolve any deficiencies identified during the examination with post-maintenance testing conducted that satisfies the PST requirements.

(2) At least once every 10 years, each explosively actuated valve shall be disassembled for internal examination of the valve and actuator to verify the operational readiness of the valve assembly and the integrity of individual components and to remove any foreign material, fluid, or corrosion. The examination schedule shall provide for each valve design used for explosively actuated valves at the facility to be included among the explosively actuated valves to be disassembled and examined every 2 years. Corrective action shall be taken to resolve any deficiencies identified during the examination with post-maintenance testing conducted that satisfies the PST requirements.

(3) For explosively actuated valves selected for test sampling every 2 years in accordance with the ASME OM Code, the operational readiness of the actuation logic and associated electrical circuits shall be verified for each sampled explosively actuated valve following removal of its charge. This must include confirmation that sufficient electrical parameters (voltage, current, resistance) are available for each valve actuation circuit. Corrective action shall be taken to resolve any deficiencies identified in the actuation logic or associated electrical circuits.

(4) For explosively actuated valves selected for test sampling every 2 years in accordance with the ASME OM Code, the sampling must select at least one explosively actuated valve from each redundant safety train. Each sampled pyrotechnic charge shall be tested in the valve or a qualified test fixture to confirm the capability of the charge to provide the necessary motive force to operate the valve to perform its intended function without damage to the valve body or connected piping. Corrective action shall be taken to resolve any deficiencies identified in the capability of a pyrotechnic charge in accordance with the PST requirements.

This license condition supplements the current requirements in the ASME OM Code for explosively actuated valves, and sets forth requirements for preservice testing and operational surveillance, as well as any necessary condition. The license condition will expire either when (1) the license condition is incorporated into the Unit 3 Inservice Testing (IST) program; or (2) the updated ASME OM Code requirements for squib valves in new reactors (i.e., plants receiving a construction permit, or a combined license for construction and operation, after January 1, 2000), as accepted by the NRC in 10 CFR 50.55a, are incorporated into the Unit 3 IST program. For the purpose of satisfying the license condition, the licensee retains the option of including in its IST program either the requirements stated in this condition, or including updated ASME OM Code requirements.

The NRC staff has determined that a license condition related to the steam dryer for North Anna 3 is needed, based on its review of the North Anna 3 COL application and as evaluated by the staff in Section 3.9.4, CWR COL 3.9.9-1-A item, as follows:

3.10 Steam Dryer License Conditions

The licensee shall implement the following license conditions using supporting information in GE Hitachi Nuclear Energy Reports NEDE-33312P, “ESBWR Steam Dryer Acoustic Load Definition,” Revision 5, December 2013, and NEDE-33313P, “ESBWR Steam Dryer Structural Evaluation,” Revision 5, December 2013.

1.a A Steam Dryer Monitoring Plan (SDMP) for the steam dryer shall be prepared and provided to the NRC no later than 90 days before initial fuel load.

1.b Power Ascension Test (PAT) procedures for the steam dryer testing shall be provided to NRC inspectors no later than 10 days before initial fuel load. The PAT procedures shall include the following:

- Level 1 and Level 2 acceptance limits, for on-dryer strain gage and on-dryer accelerometer measurements to be used up to 100 percent power;
- Specific hold points and their duration during 100% power ascension;
- Activities to be accomplished during hold points;
- Plant parameters to be monitored;
- Actions to be taken if acceptance criteria are not satisfied
- Verification of the completion of commitments and planned actions.

2. An initial hold point during the first power ascension shall be at no more than 75 percent of full power. At this hold point, the licensee shall complete the actions specified in item 2 of the model license condition specified in paragraph (c) of Section 10.2, “Comprehensive Vibration Program Elements for a COL Applicant,” in NEDE-33313P, Revision 5
3. Continue power ascension: The licensee shall complete the actions specified in item 3 of the model license condition specified in paragraph (c) of Section 10.2 in NEDE-33313P, Revision 5
4. Power ascension monitoring: The licensee shall complete the actions specified in item 4 of the model license condition specified in paragraph (c) of Section 10.2 in NEDE-33313P, Revision 5.
5. Flow-induced resonances: The licensee shall complete the actions specified in item 5 of the model license condition specified in paragraph (c) of Section 10.2 in NEDE-33313P, Revision 5.
6. Limit curve modifications: The licensee shall complete the actions specified in item 6 of the model license condition specified in paragraph (c) of Section 10.2 in NEDE-33313P, Revision 5.

7. At the initial hold point and the hold points at approximately 85 and 95 percent power, power ascension shall not proceed for at least 72 hours after making the steam dryer data analysis and results available to the NRC by facsimile or electronic transmission to the NRC project manager.

8. During the Power Maneuvering in the Feedwater Temperature Operating Domain testing, pressures, strains, and accelerations shall be recorded from the on-dryer mounted instrumentation across the expected range of normal steady state plant operating conditions. An evaluation of the dryer structural response over the range of steady state plant operating conditions shall be included in the stress analysis report described in license condition 3.10.9 (below).

9. Full power achievement: The licensee shall complete the actions specified in item 9 of the model license condition specified in paragraph (c) of Section 10.2 in NEDE-33313P, Revision 5.

10. A periodic steam dryer inspection program will be implemented as follows:

    a. During the first two scheduled refueling outages after reaching full power conditions, a visual inspection shall be conducted of all accessible areas and susceptible locations of the steam dryer in accordance with accepted industry guidance on steam dryer inspections. The results of these baseline inspections shall be provided to the NRC within 60 days following startup after each outage.

    b. At the end of the second refueling outage following full power operation, an updated SDMP reflecting a long-term inspection plan based on plant-specific and industry operating experience shall be provided to the NRC within 180 days following startup from the second refueling outage.

In addition to the above three license conditions, the NRC staff notes that, as discussed earlier in this SER section, Part 10 of the North Anna 3 COL application lists a detailed license condition for the initial test program (ITP) that includes activities to address COL Item STD COL 14.2.3-A, "Preoperational and Startup Test Procedures." This license condition will ensure that the COL licensee implements the ITP, which includes the reactor internals initial start-up FIV testing.

ITAAC

ESBWR DCD, Tier 1 includes numerous ITAAC to verify the acceptability of the as-built mechanical systems and components at North Anna 3. A sample of the ITAAC related to the North Anna 3 steam dryer includes the following:

ESBWR DCD, Tier 1, Table 2.1.1-3, "ITAAC for the Reactor Pressure Vessel and Internals"

ITAAC Item 8b. The RPV internal structures listed in Table 2.1.1-1 (chimney and partitions, chimney head and steam separators assembly, and steam dryer assembly) meet the requirements of ASME BPV Code, Subsection NG-3000, except for the weld quality and fatigue factors for secondary structural non-load bearing welds.

ITAAC Item 12. The number and locations of pressure sensors installed on the steam dryer for startup testing ensure accurate pressure predictions at critical locations.

ITAAC Item 13. The number and locations of strain gages and accelerometers installed on the steam dryer for startup testing are capable of monitoring the most highly stressed components, considering accessibility and avoiding discontinuities in the components.

ITAAC Item 14. The number and locations of accelerometers installed on the steam dryer for startup testing are capable of identifying potential rocking and of measuring the accelerations resulting from support and vessel movements.

ITAAC Item 16. The as-built steam dryer predicted peak stress is below the fatigue limitation. ESBWR DCD, Tier 1, Table 2.1.2-3, "ITAAC for the Nuclear Boiler System"

ITAAC Item 36. The main steam line and SRV/SV [safety relief valve/safety valve] branch piping geometry precludes first and second shear layer wave acoustic resonance conditions from occurring and avoids pressure loads on the steam dryer at plant normal operating conditions.

With respect to the ESBWR steam dryer, NEDE-33313P specifies Tier 2* provisions for the COL licensee to complete the design and construction of the steam dryer for an ESBWR nuclear power plant. For example, Section 9.1, "Instrumentation for Monitoring Steam Dryer Response," in NEDE-33313P describes the process to meet ITAAC Items 12, 13, and 14 in DCD Tier 1, Table 2.1.1-3, for the installation of pressure sensors; strain gages; and accelerometers on the as-built steam dryer to monitor its performance during power ascension. Section 10.1.1, "Steam Dryer Design Analysis Report," in NEDE-33313P specifies the elements for the as-designed ESBWR steam dryer analysis report. Section 10.1.2, "Steam Dryer As-Built Analysis Report," in NEDE-33313P specifies the process to satisfy ITAAC Item 16 in DCD Tier 1, Table 2.1.1-3, for verifying that the as-built steam dryer fatigue analysis provides at least a minimum alternating stress ratio (MASR) of 2.0 to the allowable alternating stress intensity of 93.7 MPa (13,600 psi). Appendix A, "ITAAC for Reactor Pressure Vessel Internals," to NEDE-33313P describes the process to meet ITAAC Item 8b in DCD Tier 1, Table 2.1.1-3, so as to provide assurance that the reactor internal structures will meet the provisions of ASME BPV Code, Subsection NG-3000, except for the weld quality and fatigue factors for secondary structural non-load bearing welds. Appendix B, "ITAAC for Main Steam Line and SRV/Safety Valve Branch Piping Acoustic Resonance," to NEDE-33313P describes the process to meet ITAAC 36 in DCD Tier 1, Table 2.1.2-3, to provide assurance that the main steam line and SRV/SV branch piping geometry will preclude first and second shear layer wave acoustic resonance conditions from occurring and avoids excessive pressure loads on the steam dryer at plant normal operating conditions. These post COL activities for the ESBWR steam dryer will be performed by the COL licensee for North Anna 3, as described by the Tier 2* provisions in the ESBWR DCD and its referenced engineering reports, unless the COL licensee obtains regulatory approval for an alternative process.

3.9.6 Conclusion

NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to the dynamic testing and analysis of SSCs, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

The NRC staff reviewed North Anna 3 FSAR Section 3.9 and the provisions specified in ESBWR DCD, Tier 2, Section 3.9 that are incorporated by reference in the North Anna 3 FSAR for structural integrity and functional capability of mechanical systems and components for the North Anna 3 nuclear power plant. The staff review of the information provided in Section 3.9 of the ESBWR DCD, Tier 2 is provided in the FSER on the ESBWR design certification applicant as modified by NUREG-1966, Supplement 1 on Section 3.9.5 of the ESBWR DCD, Tier 2. Based on its review, the staff concludes that the North Anna 3 COL applicant has provided reasonable assurance that mechanical systems and components to be installed in North Anna 3 will have the structural integrity and functional capability to perform their design functions for the safe operation of the North Anna 3 nuclear power plant.

North Anna 3 Departure 3.7-1 related to reactor internals

The staff, by its above review, finds that the applicant has adequately addressed NAPS DEP 3.7-1 as it relates to reactor internals and has provided sufficient information to meet GDC 2 and 10 CFR 50 Appendix S.

In addition, based on the staff's review discussed in this SER section, the staff concluded that the North Anna 3 COL application, together with incorporation by reference of the ESBWR DCD, provides an acceptable description of the Dynamic and Analysis and Testing Program to be used at North Anna 3 considering the site-specific SSE as defined in FSAR Section 3.7.1. The staff has determined that the North Anna 3 COL applicant has provided sufficient information to satisfy the requirements of 10 CFR Parts 50 and 52 for the dynamic testing and analysis of North Anna 3 SSCs using the site-specific SSE specifically related to reactor internals.

3.10 Seismic and Dynamic Qualification of Mechanical and Electrical Equipment

3.10.1 Introduction

Seismic and dynamic qualification of seismic Category I equipment include the following types:

- Safety-related active mechanical equipment that performs a mechanical motion while accomplishing a system safety-related function. Examples include pumps, valves, and valve operators.

- Safety-related, non-active mechanical equipment whose mechanical motion is not required while accomplishing a system safety-related function, but whose structural integrity must be maintained in order to fulfill its design safety-related function.

- Safety-related instrumentation and electrical equipment and certain monitoring equipment.

Mechanical and electrical equipment (including instrumentation and controls and where applicable, their supports) classified as seismic Category I must demonstrate that they are capable of performing their intended safety-related functions under the full range of normal and seismic loadings. This equipment includes devices associated with seismic loadings. This equipment includes devices associated with systems that are essential to safe shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing a significant release of radioactive material into the environment or in mitigating the consequences of accidents.

3.10.2 Summary of Application

Section 3.10 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 3.10 of the ESBWR DCD, Revision 10. In addition, in FSAR Section 3.10, the applicant provided the following:

<u>*COL Items*</u>

- STD COL 3.10.4-1-A Dynamic Qualification Report

In FSAR Section 3.10.1.4, the applicant described its implementation schedule for completing ITAAC to be provided to the NRC no later than one year after issuance of the COL or the start of construction as defined in 10 CFR 50.10(a), whichever is later.

Supplemental Information

- STD SUP 3.10-1 Quality Assurance Program for Equipment Qualification

In FSAR Section 3.10.1.4, the applicant states that the North Anna 3 QA Program is in FSAR Section 17.5, including requirements for handling safety-related quality records; control of purchased material, equipment, and services; test control; and other quality related processes.

3.10.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966, the FSER related to the certified ESBWR DCD. In addition, the relevant requirements of the Commission regulations for the seismic and dynamic qualification of mechanical and electrical equipment, and the associated acceptance criteria are in Section 3.10 of NUREG-0800. Specific requirements include the following:

- GDC 1 and GDC 30, “Quality of reactor coolant pressure boundary,” as they relate to qualifying equipment to appropriate quality standards commensurate with the importance of the safety functions to be performed.

- GDC 2 and Appendix S to 10 CFR Part 50, as they relate to designing equipment to withstand the effects of natural phenomena such as earthquakes.

- GDC 4 as it relates to qualifying equipment as capable of withstanding the dynamic effects associated with external missiles and internally generated missiles, pipe whip, and jet impingement forces.

- GDC 14, “Reactor coolant pressure boundary,” as it relates to qualifying equipment associated with the reactor coolant boundary so that there is an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

- 10 CFR Part 50, Appendix B, as it relates to qualifying equipment using the quality assurance criteria.

- 10 CFR Part 50, Appendix B, Criterion III, as it relates to verifying and checking the adequacy of a design by the performance of a suitable test program (among other options), which specifically requires that a test program used to verify the adequacy of a specific design feature shall include suitable qualification testing of a prototype unit under the most adverse design conditions.

- 10 CFR 52.80(a), which requires that a COL application to contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and NRC’s regulations.

3.10.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.10 of the certified ESBWR DCD. The staff reviewed Section 3.10 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD to ensure that the combination of the information in the ESBWR DCD and the information in the North Anna 3 COL FSAR appropriately represents the complete scope of information relating to this review topic.[1] The staff’s review confirms that the information in the application and the information incorporated by reference address the relevant information related to this section.

The staff reviewed the information in the North Anna 3 COL FSAR, Revision 8, as follows:

COL Items

- STD COL 3.10.4-1-A Dynamic Qualification Report

The staff reviewed the applicant’s information related to the dynamic qualification report that was included under Section 3.10.1.4 of the North Anna 3 COL FSAR. In this North Anna 3 Section the applicant stated the following:

> An implementation schedule for completing ITAAC will be provided to the NRC no later than 1 year after issuance of the combined license or at the start of construction as defined in 10 CFR 50.10(a), whichever is later. Dominion shall submit updates to the ITAAC schedules every 6 months thereafter and, within 1 year of its scheduled date for initial loading of fuel, and shall submit updates to the ITAAC schedules every 30 days until the final notification is provided to the NRC under paragraph 10 CFR 52.99(c)(1).

> The Dynamic Qualification Report and documentation that describe the seismic and dynamic qualification methods will be made available for NRC staff review, inspection, and audit. Information that verifies the seismic and dynamic qualification will be made available to the NRC to facilitate reviews, inspections, and audits throughout the process. FSAR information will be revised, as necessary, as part of a subsequent FSAR update

The staff's review finds that the applicant's response adequately addresses COL Item STD COL 3.10.4-1-A per the guidance in RG 1.206.

<u>Supplemental Information</u>

- STD SUP 3.10-1 — Quality Assurance Program for Equipment Qualification

The staff reviewed the applicant's information related to the QA Program for equipment qualification included under FSAR Section 3.10.1.4, which states the following:

> Section 17.5 defines the Quality Assurance Program requirements that are applied to equipment qualification files, including requirements for handling safety-related quality records, control of purchased material, equipment and services, test control, and other quality related processes.

The staff reviewed the conformance of Section 3.10 of the North Anna COL FSAR to the guidance in RG 1.206, Chapter 3, Sections C.I.3.10 and C.III.1.3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment." The staff's review of Section 3.10 of the North Anna COL FSAR found that the applicant has appropriately incorporated by reference Section 3.10 of the ESBWR DCD, Revision 10. In addition to meet the guidance in Section C.I.3.10.4 and C.III.3.10.4 of RG 1.206 the applicant should provide the results of tests and analyses to demonstrate adequate seismic qualification of equipment. However, RG 1.206 acknowledges that this level of detail may not be available and provides an alternative provision for an implementation plan that includes milestones and completion dates. The information included with this plan should address those details not addressed in the DCD. Those details include, for example, a listing of the equipment to be qualified, the method of qualification, and who will be performing the qualification. The expectation is that all information for these planning phases would be completed before component procurement and would be available for inspection by the staff as necessary.

Therefore the staff in RAI 3.10-1 requested that the applicant provide an implementation plan that includes the level of detail that will be completed prior to procurement and the plan for completing equipment qualification as called for in RG 1.206. This information is necessary for the staff to make a reasonable assurance safety finding for licensing (i.e., to find that the design is in accordance with the regulations). It is expected that this information would be available to be audited by the staff prior to equipment installation. In its response to RAI 3.10-1, the applicant provided its qualification plan including its ITAAC implementation schedule as well as stating in Section 3.10.1.4 of North Anna 3, FSAR Revision 8 the following:

> The Dynamic Qualification Report and documentation that describe the seismic and dynamic qualification methods will be made available for NRC staff review, inspection,

and audit. Information that verifies the seismic and dynamic qualification will be made available to the NRC to facilitate reviews, inspections, and audits throughout the process. FSAR information will be revised, as necessary, as part of a subsequent FSAR update.

As described in the North Anna 3 COL FSAR, Revision 8, Section 3.10, the applicant provided requirements that meet the alternative provision for an implementation plan that includes applicable ITAAC and milestones and completion dates as required in RG 1.206. Therefore, RAI 3.10-1 is resolved and closed and the staff finds the North Anna 3 FSAR Supplemental Information Item STD SUP 3.10-1 acceptable.

3.10.5 Post Combined License Activities

The applicant identifies the following FSAR requirements related to safety related seismic and dynamic equipment qualification:

- An implementation schedule for completing ITAAC will be provided to the NRC no later than 1 year after issuance of the combined license or at the start of construction as defined in 10 CFR 50.10(a), whichever is later. Dominion shall submit updates to the ITAAC schedules every 6 months thereafter and, within 1 year of its scheduled date for initial loading of fuel, and shall submit updates to the ITAAC schedules every 30 days until the final notification is provided to the NRC under paragraph 10 CFR 52.99(c)(1).

- The Dynamic Qualification Report and documentation that describe the seismic and dynamic qualification methods will be made available for NRC staff review, inspection, and audit. Information that verifies the seismic and dynamic qualification will be made available to the NRC to facilitate reviews, inspections, and audits throughout the post COL construction process.

- FSAR information will be revised, as necessary, as part of a subsequent post COL FSAR update.

3.10.6 Conclusion

The staff’s finding related to information incorporated by reference is in NUREG–1966. The NRC staff reviewed the application and checked the referenced DCD. The NRC 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 section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E ,Section VI.B.1, all nuclear safety issues relating to the seismic and dynamic qualification of mechanical and electrical equipment that were incorporated by reference have been resolved.

In addition, the staff compared the additional COL information in the application to the relevant NRC regulations, the guidance in Section 3.10 of NUREG–0800, and other NRC RGs. The staff’s review concluded that the applicant has adequately addressed COL Item STD COL 3.10.4-1-A and Supplemental Item STD SUP 3.10-1. Therefore, the staff finds that North Anna 3 COL FSAR, Revision 7, Section 3.10, is acceptable and meets the NRC regulatory requirements and acceptance criteria in Section 3.10 of NUREG-0800 and RG 1.206 including GDC 1, GDC 2, GDC 4, GDC 14 and GDC 30; Appendix S to 10 CFR Part 50, 10 CFR Part 50,

Appendix B, Criterion III, and 10 CFR 52.80(a).

3.11 Environmental Qualification of Mechanical and Electrical Equipment

3.11.1 Introduction

This FSAR section describes the Environmental Qualification (EQ) Program to be used at North Anna 3 for the electrical and mechanical safety related equipment. The objective of the EQ Program is to reduce the potential for common failures resulting from specified environmental events and to demonstrate that the equipment within the scope of the EQ Program is capable of performing its intended design function under all conditions, including environmental stresses resulting from design-basis events. During plant operation, the COL licensee implements the EQ Program, which specifies the replacement frequencies of affected safety-related equipment in harsh environments. The EQ Program also addresses non-safety-related equipment failures under the postulated environmental conditions that could prevent the satisfactory performance of the safety function requirements of the specified safety-related equipment, and certain post-accident monitoring equipment.

The safety related equipment must perform its safety functions under all normal environmental conditions, abnormal operational occurrences, design-basis events, post-design- basis events, and containment test conditions. This capability is demonstrated through qualification testing and analysis of similar equipment under the temperature, pressure, humidity, chemical effects, radiation, and submergence conditions in which the equipment will be expected to operate. The qualification information shall include identification of the equipment required to be environmentally qualified. Each component shall have onsite and in an auditable form, the designated functional requirements; the definition of the applicable environmental parameters; the periodic maintenance to support the qualified life; the accident that the component is required to mitigate; the required operation time; and the documentation of the qualification process employed to demonstrate the required environmental capability. This information shall be maintained and remain current.

3.11.2 Summary of Application

Section 3.11 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 3.11 of the ESBWR DCD, Revision 10. In addition, in FSAR Section 3.11 the applicant provides the following:

COL Items

- STD COL 3.11-1-A Environmental Qualification Documentation

In FSAR Section 3.11.4.4 the applicant provides additional information to address COL Item 3.11-1-A. The applicant states that the EQ Program consists of the equipment and certain post-accident monitoring devices that are in scope and that must be environmentally qualified for use in a harsh environment as identified in the ESBWR DCD, Tier 2, Section 3.11, Table 3.11.1. This EQ Master Equipment List (EQMEL) consists of equipment that is essential to emergency reactor shutdown, containment isolation, reactor core cooling, or containment and reactor heat removal or that is otherwise essential in preventing a significant release of radioactive material to the environment. The North Anna 3 FSAR also specifies that the implementation of the EQ

Program, including the development of the Environmental Qualification Document (EQD), will be in accordance with the milestone schedule in FSAR Section 13.4, "Operational Program Implementation."

3.11.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is discussed in NUREG–1966.

The relevant requirements of the Commission regulations for the EQ operational program and EQD and the associated acceptance criteria are in Section 3.11 of NUREG-0800.

The applicable regulatory requirements for the EQD are as follows:

- 10 CFR 50.49, "Environmental qualification of electrical equipment important to safety for nuclear plants," requires an applicant for a nuclear power plant license to establish a program that qualifies electrical equipment for environmental effects.

- GDC 1 requires components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- GDC 2 requires components important to safety be designed to withstand the effects of natural phenomena without loss of capability to perform their safety function.

- GDC 4 requires components important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss of coolant accidents.

- GDC 23, "Protection system failure modes," requires protection systems to be designed to fail in a safe state, or in a state demonstrated to be acceptable on some other defined basis, if conditions such as postulated adverse environments occur (e.g., extreme heat or cold, pressure, steam, water, or radiation).

- 10 CFR Part 50, Appendix B, Criterion III, "Design Control," requires measures to be established to ensure that applicable regulatory requirements and the associated design bases are correctly translated into specifications, drawings, procedures, and instructions. These measures should include provisions to ensure that appropriate quality standards are included in design documents and deviations from established standards are controlled. A process should also be established to determine the suitability of equipment that is essential to safety-related functions and to identify, control, and coordinate design interfaces between participating design organizations. Where a testing program is used to verify the adequacy of a specific design feature, the test shall include suitable qualification testing of a prototype unit under the most adverse design conditions.

- 10 CFR Part 50, Appendix B, Criterion XI, "Test Control," requires a test control plan to be established to ensure that all tests needed to demonstrate a component's performance capability are identified in accordance with required procedures and acceptance limits in the applicable design documents.

- 10 CFR Part 50, Appendix B, Criterion XVII, "Quality Assurance Records," requires sufficient records to be maintained to furnish evidence of activities affecting quality. The records must include inspections, tests, audits, work performance monitoring, and materials analyses. Records must be identifiable and retrievable.

The related acceptance criteria are as follows:

- In accordance with SECY-05-0197, "Review of Operational Programs in a Combined License Application and Generic Emergency Planning Inspections, Tests, Analyses, and Acceptance Criteria," as accepted in the Commission's SRM dated February 22, 2006, equipment qualification is an Operational Program that will be reviewed in the COL application. The staff reviews this program to make a reasonable assurance finding on the program. A COL applicant should fully describe the EQ and other Operational Programs as defined in SECY-05-0197 to avoid the need for ITAAC to implement those programs. The term "fully described" for an operational program should be understood to mean that the program is clearly and sufficiently described in terms for scope and level of detail to allow a reasonable assurance finding of acceptability. Further, Operational Programs should be described at a functional level and an increasing level of detail where implementation choices could materially and negatively affect the program effectiveness and acceptability. The Commission approved the use of a license condition for operational program implementation milestones that are fully described or referenced in the FSAR as discussed in the SRM for SECY-05-0197, dated February 22, 2006.

3.11.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.11 of the certified ESBWR DCD, Revision 10. The staff reviewed Section 3.11 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD to ensure that the combination of the information in the ESBWR DCD and the information in the North Anna 3 COL FSAR, appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the relevant information related to this section.

The NRC staff reviewed the North Anna 3 COL application and the applicable sections in the ESBWR DCD incorporated by reference into the North Anna 3 FSAR for the description of the EQ Program for mechanical and electrical equipment to determine whether the North Anna 3 COL application meets the regulatory requirements to provide reasonable assurance that the applicable equipment at North Anna 3 will be capable of performing their intended functions.

The staff reviewed the following information in the North Anna 3 COL FSAR as follows:

COL Items

- STD COL 3.11-1-A Environmental Qualification Documentation

The staff reviewed the additional information related to the environmental qualification documentation under Section 3.11.7 of the North Anna 3 COL FSAR, Revision 8, which states the following:

> This COL item is addressed in Section 3.11.4.4.

In ESBWR DCD, Tier 2, Section 3.11.7, COL Item 3.11-1-A states that the COL applicant will provide a full description and a milestone for implementing the EQ Program that will include completion of the plant-specific EQD per Section 3.11.4.4, "Environmental Qualification Documentation." In FSAR Section 3.11.4.4, the applicant states that a description of the EQ Program is provided in ESBWR DCD, Tier 2, Section 3.11. The applicant also states that the implementation of the EQ Program, including the development of the EQD will be in accordance with the milestone schedule in FSAR Section 13.4. The NRC staff reviewed the applicant's resolution to ESBWR COL Item 3.11-1-A in FSAR Section 3.11.4.4. In addition to reviewing the North Anna 3 COL application, the staff reviewed the information in the ESBWR DCD. Provisions in the ESBWR DCD support the North Anna 3 COL application by fully describing the EQ Operational Program for North Anna 3.

North Anna 3 FSAR Section 3.11 incorporates by reference ESBWR DCD, Tier 2, Section 3.11 with supplemental information. In RAI 03.11-1 the staff requested Dominion provide or reference certain information related to the EQ Program for safety-related mechanical equipment or indicate the status of and the schedule for its availability. In Dominion's RAI response dated September 11, 2008 (ADAMS Accession No. ML082730754), which noted that the ESBWR DCD, Tier 2, Section 3.11, Revision 5, COL Item 3.11-1-A, had been revised requiring a full description of the environmental qualification program along with a milestone for program implementation by the COL applicant. The North Anna 3 FSAR Section 3.11, Revision 8, reflects this change. For example, ESBWR DCD, Tier 2, Table 3.11-1, "Electrical and Mechanical Equipment for Environmental Qualification," identifies the environment in which a component within the scope of the EQ Program will be located. The RAI response stated that no site-specific, safety-related equipment will be used beyond that described in the ESBWR DCD. Section 3.11.4.1, "Harsh Environment Qualification," in ESBWR DCD, Tier 2, indicates that the qualification of mechanical equipment includes materials that are sensitive to environmental effects (e.g., seals, gaskets, lubricants, and fluids for hydraulic systems). The RAI response stated that the completion of the plant-specific EQD will be accomplished as specified in FSAR Section 3.11.4.4. Furthermore, the RAI response indicated that the completion of the EQ Program for plant equipment will be confirmed by the close-out of the ITAAC, which is specified in ESBWR DCD, Tier 1, Table 3.8-1, "ITAAC for Environmental Qualification of Mechanical and Electrical Equipment." As noted in Section 3.9.4 of this SER, GEH is responsible for the design and qualification of mechanical equipment, and the GEH procurement specifications and processes were made available for NRC to review.

In RAI 03.11-3 the staff requested Dominion to clarify whether the FSAR would be updated to include additional equipment not identified in ESBWR DCD, Tier 2, Table 3.11-1. In Dominion's RAI response dated September 11, 2008, the applicant stated that there is no safety-related equipment or safe shutdown equipment outside the scope of the ESBWR design. As a result, there is no additional equipment covered by the EQ Program that is not identified in DCD Table 3.11-1. Therefore, RAI 03.11-3 is resolved and closed.

In RAI 03.11-5 the staff requested that Dominion describe consideration of FIV in the qualification of safety-related mechanical equipment, including acoustic resonance and hydraulic loading. In Dominion's RAI response dated September 11, 2008, the applicant stated that ESBWR DCD, Tier 2, Section 3.9.3.5 requires the ESBWR general valve requirement specification to include requirements related to the design and functional qualification of safety-related valves that incorporate lessons learned from nuclear power plant operations and research programs. ESBWR DCD, Tier 2, Section 3.10 addresses methods of testing and analysis employed to ensure the capability of mechanical and electrical equipment under the full range of normal and accident loadings. The RAI response indicated that testing, as described in ESBWR DCD, Tier 2, Section 3.9.2 and FSAR Section 14.2, will provide confidence in the capability of safety-related equipment to perform their safety functions. For example, ESBWR DCD, Tier 2, Section 3.9.2.1.1 discusses vibration and dynamic effects testing that will be performed during the ITP, as described in DCD Sections 14.2.8.1.42 and 14.2.8.2.10. The objective of these tests will be to confirm that the piping, components, restraints, and supports of specified high and moderate-energy systems were designed to withstand the dynamic effects of steady-state FIV and anticipated operational transient conditions. The staff considers that the actions specified in the ESBWR DCD will address potential adverse flow effects on safety-related valves and dynamic restraints including the consideration of lessons learned from nuclear power plant operating experience. Therefore, RAI 03.11-5 is resolved and closed.

In the North Anna 3 FSAR Section 13.4, Table 13.4-201, "Operational Programs Required by NRC Regulations," lists each operational program, the regulatory source for the program, the FSAR section where the operational program is described and the associated implementation milestones. This Table specifies the implementation milestone for the EQ Program as "prior to fuel load." In RAI 03.11-6 the staff requested that Dominion further clarify the commencement of the EQ Program and its transition into an operating reactor program. Dominion's RAI response dated September 11, 2008, stated that the COL application will contain a license condition that will require the COL licensee to submit a schedule to the NRC 12 months after the issuance of the COL, which will support planning and conducting NRC inspections of operational programs including the EQ Program, with periodic updating of the schedule. This schedule will address additional program implementation details, such as commencement of the EQ Program. The transition of the EQ Program into an operating program will occur as part of the plant turnover process. The staff finds that the RAI response clarified plans for the implementation and turnover of the EQ Program during plant construction and startup. Therefore, RAI 03.11-6 is resolved and closed.

ESBWR DCD, Tier 1, Revision 10, Section 3.8, "Environmental Qualification of Mechanical and Electrical Equipment," specifies the EQ ITAAC for safety-related mechanical and electrical equipment in Table 3.8-2. The inspections, tests, and analyses for safety-related or RTNSS mechanical equipment located in a harsh environment state that type tests, or a combination of type tests and analyses will be performed. In RAI 03.11-7 that staff requested the applicant to describe the plan for the implementation of the ITAAC for safety-related mechanical equipment located in a harsh environment, as specified in ESBWR DCD, Tier 1. Dominion's response to the staff RAI 03.11-7, dated September 11, 2008, stated that ESBWR DCD, Tier 1, Section 1.1.2.2 provides the description of ITAAC implementation. Part 10 of the North Anna 3 COL application incorporates the DCD ITAAC by reference. With respect to specific ITAAC implementation, the NRC regulations in 10 CFR 52.99, "Inspection during construction," require the licensee to submit a schedule for completing the inspections, tests, or analyses in the ITAAC, no later than 1 year after COL issuance or the start of construction as defined in 10 CFR

50.10(b) with subsequent updates to the ITAAC schedule. The RAI response stated that plans and schedules for implementing the ITAAC will be provided in accordance with 10 CFR 52.99. The staff finds that these provisions for addressing the EQ ITAAC are consistent with the regulations and are acceptable. Therefore, RAI 03.11-7 is resolved and closed.

ESBWR DCD, Tier 2, Section 3.11 describes the program for the initial EQ of electrical and mechanical equipment within the EQ Program for nuclear power plants applying the ESBWR reactor design. An NRC audit at the GEH office in Wilmington, NC, in July 2009, found that the ESBWR DCD does not address the transition from the initial EQ program to the operational aspects of the EQ Program. As discussed in RG 1.206 and Commission Paper SECY-05-0197, COL applicants must fully describe their operational programs to avoid the need for ITAAC regarding those programs. Therefore, the staff requested in RAI 03.11-8 that Dominion address the operational aspects of the EQ Program in the FSAR. Dominion's RAI response dated February 4, 2010 (ADAMS Accession No. ML100470588), which provided a proposed revision to the FSAR to enhance the EQ Program description and to address the operational aspects of the program. The staff found that the planned revision to the COL FSAR which is included in Revision 8 provides an acceptable description of the transition from the initial EQ Program to the operational aspects of the EQ Program. The North Anna 3 FSAR, Revision 8 describes the EQ Master Equipment List (EQMEL) that identifies the electrical and mechanical equipment that must be environmentally qualified for use in a harsh environment. The FSAR describes the control of revisions to the EQ files and the EQMEL. The FSAR specifies that the operational aspect of the EQ Program will include: (1) evaluation of EQ results for design life to establish activities to support continued EQ; (2) determination of surveillance and preventive maintenance activities based on EQ results; (3) consideration of EQ maintenance recommendations from equipment vendors; (4) evaluation of operating experience in developing surveillance and preventive maintenance activities for specific equipment; (5) development of plant procedures that specify individual equipment identification, appropriate references, installation requirements, surveillance and maintenance requirements, post-maintenance testing requirements, condition monitoring requirements, replacement part identification, and applicable design changes and modifications; (6) development of plant procedures for reviewing equipment performance and EQ operational activities, and for trending the results to incorporate lessons learned through appropriate modifications to the EQ operational program; and (7) development of plant procedures for the control and maintenance of EQ records. Therefore, since the applicant meets the intent of the EQ and other Operational Programs as defined in SECY-05-0197, RAI 03.11-8 is resolved and closed. Based on the above evaluation, the staff finds that the applicant has adequately addressed COL Item STD COL 3.11-1-A, and it is therefore acceptable.

Interfaces for Standard Design

ESBWR DCD, Tier 2, Section 1.8, "Interfaces with Standard Design," identifies site-specific interfaces with the standard ESBWR design. DCD Table 1.8-1, "Matrix of NSSS Interfaces," references Section 3.11 for the supporting interface of the design of mechanical and electrical equipment in accordance with its potential operational environmental conditions. The staff reviewed the North Anna 3 COL application for interfacing requirements with the ESBWR standard design regarding the EQ of mechanical and electrical equipment using the review procedures described in SRP Section 3.11. The NRC staff finds the applicant's consideration of design interface items to be acceptable based on compliance with 10 CFR 50.49 as discussed above.

3.11.5 Post Combined License Activities

The following items were identified as the responsibility of the COL licensee:

License Conditions

Dominion has proposed the following license conditions to address the North Anna 3 EQ programs as follows:

> 3.6 Operational Program Readiness
>
> The licensee shall submit to the Director of NRO, a schedule, no later than 12 months after issuance of the COL, for implementation of the operational programs listed in FSAR Table 13.4-201. The schedule shall be updated every 6 months until 12 months before scheduled fuel loading, and every month thereafter until the operational programs in the FSAR table have been fully implemented. This schedule shall also address:
>
> - The implementation of site-specific Severe Accident Management Guidelines
> - The spent fuel rack coupon monitoring program implementation

License Condition 3.6, "Operational Program Implementation," in Part 10 of the North Anna 3 COL application includes the EQ Program in FSAR table 13.4-201. This license condition will require the EQ Program to be implemented prior to initial fuel load. The schedule for implementation of the EQ program must be available to the NRC staff no later than 12 months after issuance of the COL. The condition will also require that the schedule be updated every 6 months until 12 months before scheduled fuel load, and every month thereafter until the operational programs listed in the North Anna 3 COL FSAR Table 13.4-201 have been fully implemented or the plant has been placed in commercial service, whichever comes first.

3.11.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG-1966. The staff reviewed the application and checked the referenced DCD. The NRC 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 section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to the EQ of the mechanical and electrical equipment that were incorporated by reference have been resolved.

In addition, the staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.11 of NUREG-0800, and other NRC RGs. The staff's review concluded that the applicant has provided sufficient information to satisfy the NRC requirements. Therefore, the staff concludes that the North Anna 3 COL FSAR, with the incorporation by reference of the ESBWR DCD, provides an acceptable description of the EQ of electrical and mechanical equipment to be used at North Anna 3, which provides reasonable assurance that the electrical and mechanical equipment within the scope of the North Anna 3

EQ Program will be capable of performing their safety functions in accordance with NRC regulations.

3.12 Piping Design Review

3.12.1 Introduction

This FSAR section covers the design of the metallic piping system and piping support for seismic Category I, Category II, and nonsafety systems. The discussion also includes the adequacy of the structural integrity, and the functional capability of the safety-related piping system, piping components, and their associated supports. The design of the piping systems should ensure that they perform their safety-related functions under all postulated combinations of normal operating conditions, system operating transients, postulated pipe breaks, and seismic events. This includes pressure retaining piping components and their supports, buried piping, instrumentation lines, and the interaction of NS Category I piping and associated supports with seismic Category I piping and associated supports. This section also covers the design transients and resulting loads and load combinations with appropriate specified design and service limits for seismic Category I piping and piping supports - including those designated as ASME Code Class 1, 2, and 3.

3.12.2 Summary of Application

Section 3.12 of the North Anna 3 COL FSAR, Revision 8, references the related sections of Chapter 3 and Chapter 5 of the ESBWR DCD, Revision 10 for the information on seismic Category I and II and NS piping analyses. In addition in FSAR Section 3.12, the applicant provides the following:

Supplemental Information

- CWR SUP 3.12-1 Piping Design Review

In FSAR Section 3.12, the applicant states the following:

> Information on seismic Category I and II, and non-seismic piping analysis and their associated supports is presented in DCD Sections 3.7, 3.9, 3D, 3K, 5.2 and 5.4.

3.12.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966.

In addition, the relevant requirements of the Commission regulations for the piping and support design, and the associated acceptance criteria, are in Section 3.12 of NUREG-0800.

3.12.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Chapters 3 and 5 of the ESBWR DCD. The staff reviewed Section 3.12 of the North Anna 3 COL FSAR, Revision 8, and checked the referenced ESBWR DCD to ensure that the combination of the information in the ESBWR DCD and the information in the North Anna 3 COL FSAR appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the relevant information related to this section.

The staff reviewed the following information in the North Anna 3 COL FSAR:

Supplemental Information

- CWR SUP 3.12-1 Piping Design Review

The staff reviewed Supplemental Information STD SUP 3.12-1. The ESBWR DCD does not have Section 3.12. Therefore, this supplemental information is being considered as an editorial change to provide a map for the piping design information. The staff finds this change acceptable.

The staff also reviewed COL application FSAR Section 3.7 to verify that the site-specific structural response spectra has been used to evaluate North Anna 3 seismic Category I and II and NS piping. This evaluation is documented in Section 3.7.2 of this SER. On the basis that site-specific response spectra was used for the piping design evaluation as evaluated under North Anna 3 departure NAPS DEP 3.7-1, in this SER, Sections 3.7 and 3.8, the staff finds that the ESBWR standard plant design as modified by NAPS DEP 3.7-1 is acceptable at the North Anna 3 site.

In addition to the piping design acceptance criteria (DAC) ITAAC in ESBWR DCD, Tier 1, the staff also reviewed COL Item NAPS COL 14.3A-1-1 which provides a schedule for completing the piping DAC ITAAC. On the basis that the applicant's proposed DAC are sufficient to provide reasonable assurance in meeting the requirements of 10 CFR 52.80(a), the staff finds this acceptable.

3.12.5 Post Combined License Activities

The following activities will be implemented following issuance of the COL:

Piping DAC

1. The ASME Code piping and support design reports are completed on a system-by-system basis for applicable systems in order to support closure of the DAC ITACC.

2. Reconciliation of the as-built piping to the design analysis requirements.

3.12.6 Conclusion

NRC staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the relevant information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. In addition, the staff compared the additional COL information in the application to the relevant NRC regulations and the guidance in Section 3.12 of NUREG-0800. The staff's review concludes that the applicant is in compliance with NRC regulations. The applicant has adequately addressed the COL information item involving the completion of the piping DAC ASME Design Reports. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 requirements by providing reasonable assurance that the piping system will be designed and built in accordance with the certified ESBWR design.

3.13 Threaded Fasteners – ASME BPV Code Class 1, 2 and 3

3.13.1 Introduction

This FSAR section covers the selection of the materials and design, and the inspecting and testing for threaded fasteners before initial service and during service and is limited to threaded fasteners in the ASME Boiler and Pressure Vessel Code Class 1, 2 or 3 systems.

ESBWR DCD, Revision 10 does not contain Section 3.13 because the DCD application was submitted before the new SRP Section 3.13 was issued in March 2007. However, ESBWR DCD, Tier 2, Section 3.9.3.9, "Threaded Fasteners - ASME B&PV Code Class 1, 2 and 3," provides sufficient information for the staff to conclude that the selection of the materials and design, and inspecting and testing for threaded fasteners before initial service and during service are acceptable. Therefore, North Anna 3 FSAR, Revision 8, Section 3.13 provides supplemental information that references ESBWR DCD, Tier 2, Section 3.9.3.9.

3.13.2 Summary of Application

Section 3.13 of the North Anna 3 FSAR, Revision 8, references Section 3.9.3.9 of the ESBWR DCD, Revision 10. Section 3.9 of North Anna 3 FSAR incorporates by reference Section 3.9.3.9 of the ESBWR DCD. In addition, in FSAR Section 3.13 the applicant provides the following:

Supplemental Information

- STD SUP 3.13-1 Threaded Fasteners – ASME Code Class 1, 2, and 3

In FSAR Section 3.13, the applicant states the following:

> Criteria applied to the selection of materials, design, inspection and testing of threaded fasteners (i.e., threaded bolts, studs, etc.) are presented in DCD Section 3.9.3.9, with supporting information in DCD Sections 4.5.1, 5.2.3, and 6.1.1.

3.13.3 Regulatory Basis

The relevant requirements of the Commission regulations for the piping and support design, and the associated acceptance criteria, are in Section 3.13 of NUREG–0800. Specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 1 and 30, as they relate to the requirement that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- GDC 4, as it relates to the compatibility of components with environmental conditions.

- GDC 14, as it relates to the requirement that the RCPB be designed, fabricated, erected, and tested in a manner that provides assurance of an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture.

- GDC 31, "Fracture prevention of reactor coolant pressure boundary," as it relates to the requirement that the RCPB be designed with a sufficient margin to ensure that when stressed under operating, maintenance, testing, and postulated accident conditions the boundary behaves in a non-brittle manner and the probability of rapidly propagating fracture is minimized.

- 10 CFR Part 50, Appendix B, as it relates to controlling the cleaning of material and equipment to prevent damage or deterioration.

- 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements," as it relates to materials testing and acceptance criteria for fracture toughness of reactor pressure boundary components.

- 10 CFR 50.55a incorporates by reference the design criteria of ASME BPV Code, Section III, Class 1, 2, and 3 components. The selection of materials, design, testing, fabrication, installation and inspection of threaded fasteners and mechanical joints are acceptable if they meet the criteria of ASME BPV Code, Section III Class 1, 2, and 3 components. However, 10 CFR 50.55a(b)(4) permits the use of code cases that have been adopted by the staff in RG 1.84 in lieu of applicable criteria in ASME BPV Code, Section III, Class 1, 2, and 3 component.

- 10 CFR 52.47(b)(1), which requires a DC application to contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and NRC's regulations.

- 10 CFR 52.80(a), which requires that a COL application to contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the NRC's regulations.

3.13.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.9.3.9 of the certified ESBWR DCD. The staff reviewed Section 3.13 of the North Anna 3 COL FSAR, Revision 8, which references ESBWR Section 3.9.3.9, and checked the referenced ESBWR DCD to ensure that the combination of the information in the ESBWR DCD and the information in the North Anna 3 COL FSAR, Revision 8, appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirms that the information in the application and the information incorporated by reference address the relevant information related to this section.

The staff reviewed the following information in the North Anna 3 COL FSAR:

Supplemental Information

- STD SUP 3.13-1 — Threaded Fasteners – ASME Code Class 1, 2, and 3

The staff reviewed STD SUP 3.13-1 related to the criteria for the selection of materials, design, inspection, and testing of threaded fasteners included under Section 3.13 of the North Anna 3 COL FSAR. STD SUP 3.13-1 which points to ESBWR DCD Tier 2, Sections 4.5.1, 5.2.3, and 6.1.1. Those Sections provide additional and specific requirements concerning threaded fasteners used in reactor internals, the reactor coolant system, and other engineered safety features. The staff found that STD SUP 3.13-1 appropriately points out the DCD Sections that identify the specific use of threaded fasteners in reactor internals, the reactor coolant system, and other engineered safety features. The staff reviewed the conformance of Section 3.13 of the North Anna 3 COL FSAR to the guidance of RG 1.206, Section C.III.1, Chapter 3, C.I.3.13, "Threaded Fasteners." The staff's review of Section 3.13 of the North Anna 3 COL FSAR found that the applicant has appropriately incorporated by reference Section 3.9.3.9 of ESBWR DCD, Revision 10. The staff considers the applicant's Supplemental Information Item STD SUP 3.13-1 to adequately address threaded fasteners and is therefore acceptable.

3.13.5 Post Combined License Activities

There are no post COL activities related to this section.

3.13.6 Conclusion

NRC staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the relevant information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional COL information in the application to the relevant NRC regulations, the guidance in Section 3.13 of NUREG-0800, and other NRC RGs. The staff's review concludes that the information in North Anna 3 COL FSAR, Section 3.13 is within the scope of the design certification and adequately incorporates by reference Section 3.9.3.9 of the ESBWR DCD, which addresses SRP Section 3.13. The information is thus acceptable and meets the NRC regulations.