10.0 STEAM AND POWER CONVERSION SYSTEM

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This chapter of the U.S. Nuclear Regulatory Commission's (NRC's) safety evaluation report (SER) provides the NRC staff evaluation and introduces the principle design features, systems, and components of the North Anna 3 Combined License (COL) steam and power conversion system of the Economic Simplified Boiling–Water Reactor (ESBWR) design. The systems discussed in this chapter include the turbine generator system used to convert energy in the steam from the nuclear steam supply system (NSSS) into electrical energy, the main steam supply system used to transport steam from the NSSS to the power conversion system and various safety related and nonsafety related auxiliaries, and other features of the steam and power conversion system.

10.1 Summary Description

Section 10.1 of the North Anna 3 COL Final Safety Analysis Report (FSAR), Revision 8, incorporates by reference Section 10.1, "Summary Description," of the ESBWR Design Control Document (DCD), Revision 10, referenced in Title10 *Code of Federal Regulations* (CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Appendix E, "Design Certification Rule for the ESBWR Design," without any departures or supplements. The staff's finding related to information incorporated by reference is in NUREG 1966, "Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling-Water Reactor Standard Design," issued April 2014, and it's Supplement 1, issued September 2014. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review[1]. The staff's review confirmed that no outstanding information related to this section is expected to be addressed in the COL FSAR. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues related to the summary description that were incorporated by reference have been resolved.

10.2 Turbine Generator

10.2.1 Introduction

This FSAR section describes the turbine generator equipment design and design bases, including programs to ensure the integrity of the turbine rotor to minimize potential impacts on safety related structures, systems, and components (SSCs).

10.2.2 Summary of Application

Section 10.2 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.2 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E. In addition, in FSAR Section 10.2, the applicant provided the following information:

COL Items

- STD COL 10.2-1-A Turbine Maintenance and Inspection Program

The applicant addressed DCD COL Item 10.2 1 A in FSAR Section 10.2.2.4, "Turbine Overspeed Protection System"; Section 10.2.2.7, "Testing"; Section 10.2.3.6, "In-service

[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 in a COL application that references a design certification.

Maintenance and Inspection of Turbine Rotors"; and Section 10.2.3.7, "In-service Inspection of Turbine Valves." In FSAR Section 10.2.3.6, the applicant stated that DCD, Tier 2, Sections 10.2.2.7, 10.2.3.5, and 10.2.3.6 and General Electric (GE) ST 56834/P, "ESBWR Steam Turbine—Low Pressure Rotor Missile Generation Probability Analysis," Revision 4, dated October 18, 2011, describe the Turbine Maintenance and Inspection Program that supports the original equipment manufacturers (OEM's) turbine missile generation probability calculation. GE ST 56834/P, Revision 4, is a bounding missile probability calculation report that sets forth the associated maintenance and inspection recommendations.

The applicant further addressed COL Item 10.2 1 A in FSAR Section 10.2.3.7. This section states that the inspection of all valves of one functional type or size will be conducted if a detrimental, unusual condition is discovered during the inspection of any single valve. This section also states that GE ST-56834/P, Revision 4, describes the Valve Inspection Program, including the valve and control system maintenance, inspections, testing, and associated frequencies.

In FSAR Sections 10.2.2.4 and 10.2.2.7, the applicant described how the information in Sections 10.2.3.6 and 10.2.3.7 applies to the turbine overspeed protection system and nonreturn valve inspection and testing.

- STD COL 10.2-2-A Turbine Missile Probability Analysis

In FSAR Section 10.2.3.8, the applicant provided information to address DCD COL Item 10.2-2-A. The applicant stated that the probability of generating a turbine missile is based on bounding material property values in the GE ST-56834/P, Revision 4 report. Because the applicant relies on this report to address the COL items described above, the staff reviewed it as part of the technical evaluation of the North Anna 3 COL application (COLA).

Supplemental Information

- STD SUP 10.2-1 Turbine Design

In FSAR Section 10.2.3.4, the applicant identified the turbine design model as N3R-6F52 from the GE nuclear steam turbine series.

10.2.3 Regulatory Basis

The regulatory basis for the information incorporated by reference is in NUREG 1966. In addition, Section 10.2, "Turbine Generator," of NUREG 0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (SRP), includes the relevant requirements of the Commission's regulations for the turbine generator and the associated acceptance criteria.

The following documents establish the applicable regulatory requirements and associated guidance for the turbine generator:

- General Design Criterion (GDC) 4, "Environmental and Dynamic Effects Design Bases," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," as it relates to SSCs important to safety being appropriately protected against the effects of missiles that may result from a turbine rotor failure

- Regulatory Guide (RG) 1.115, Revision 2, "Protection against Turbine Missiles," issued January 2012.

- NUREG–0800, SRP Section 3.5.1.3, "Turbine Missiles," and SRP Section 10.2.3, "Turbine Rotor Integrity"

10.2.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 10.2 of the certified ESBWR DCD. The staff reviewed Section 10.2 of the North Anna 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of information in the COL FSAR and information in the ESBWR DCD 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 related to the turbine generator.

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

COL Items

- STD COL 10.2-1- A Turbine Maintenance and Inspection Program

DCD COL 10.2-1-A requires the COL applicant to provide a description of the plant-specific Turbine Maintenance and Inspection Program required to satisfy the OEM's turbine missile generation probability calculation, including the acceptance criteria listed in Section II of SRP Section 3.5.1.3, and to address any valve and control system maintenance, inspections, and tests that are needed.

In Revision 1 of FSAR Section 10.2.3.6, the applicant addressed COL Item 10.2-1-A, "Turbine Maintenance and Inspection Program," which stated that "the turbine maintenance and inspection frequencies will be established upon completion of the bounding missile probability analysis." This analysis was then scheduled to be completed in the second quarter of 2009, and the FSAR would be revised to incorporate the maintenance and inspection frequencies as part of a subsequent FSAR update. The staff tracked this activity as Open Item 10.2-1 from the North Anna 3 Phase 2 SER.

In a letter dated June 24, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14199A360), the applicant submitted Revision 8 of the COL FSAR, which changed how it addressed STD COL 10.2 1 A. The applicant addressed DCD COL Item 10.2 1 A in FSAR Sections 10.2.2.4, 10.2.2.7, 10.2.3.6, and 10.2.3.7. In Section 10.2.3.6, the applicant stated that the Turbine Maintenance and Inspection Program supports the OEM's turbine missile generation probability calculation and is described in DCD Tier 2, Sections 10.2.2.7, 10.2.3.5, and 10.2.3.6 and in GE ST 56834/P, Revision 4, which is a bounding missile probability calculation report that sets forth the associated maintenance and inspection recommendations.

The applicant further addressed COL Item 10.2-1-A in FSAR Section 10.2.3.7. This section states that the inspection of all valves of one functional type or size will be conducted if a detrimental, unusual condition (as defined by the turbine Valve Inspection Program) is discovered during the inspection of any single valve. This section also states that the bounding missile probability analysis report (GE ST 56834/P, Revision 4) describes the Valve Inspection Program, including the valve and control system maintenance, inspections, testing, and associated frequencies.

In FSAR Sections 10.2.2.4 and 10.2.2.7, the applicant described how the information in Sections 10.2.3.6 and 10.2.3.7 applies to the turbine overspeed protection system and nonreturn valve inspection and testing.

In a letter dated December 6, 2013 (ADAMS Accession No. ML13346A647), the applicant provided the bounding missile probability analysis report (GE ST–56834/P Revision 4) for North Anna 3, which used Detroit Edison Company's (DTE's) responses to requests for additional information (RAIs) concerning this same technical topic on the Fermi 3 COL docket and is now part of the North Anna 3 COLA. The staff reviewed STD COL 10.2-1-A as submitted on the North Anna COL docket. Similar to the staff's review of the Fermi 3 COLA on this technical topic in the Fermi 3 docket, the review includes the bounding missile probability analysis report (ST–56834/P Revision 4). For both Fermi 3 COL Safety Evaluation Report (SER) Section 10.2.4 and this section of the North Anna 3 SER, this information satisfies the OEM's missile probability calculation called for in DCD COL Item 10.2-1-A. In addition, the applicant submitted a supplemental letter dated September 30, 2014 (ADAMS Accession No. ML14274A285), which also identifies the Fermi 3 RAI responses concerning this topic that are now submitted on the docket as part of an incorporation by reference per 10 CFR 52.8(b). The Fermi 3 RAIs referred to are 10.02.03-3, 10.02.03-7, 10.02.03-8, 10.02.03-9, and 10.02.03-10.

DCD COL Item 10.2-1-A states that "the COL applicant will provide a description of the plant specific turbine maintenance and inspection program required to satisfy the OEM's turbine missile generation probability calculation including each of the criteria identified in Section II of SRP Section 3.5.1.3, and to address any valve and control system maintenance, inspections, and tests that are needed."

The applicant addressed COL Item STD COL 10.2-1-A in the following four FSAR Sections, which also correspond to the Section numbers and titles in the DCD:

1) Section 10.2.2.4, "Turbine Overspeed Protection System," which states that "inspection programs required by the turbine missile probability analysis and implementation of the inspection, maintenance, and testing programs discussed in Section 10.2.3.6 and Section 10.2.3.7 ensure operability."

2) Section 10.2.2.7, "Testing," which states that "non-return valves are inspected and tested in accordance with vendor recommendations, as discussed in Section 10.2.3.7."

3) Section 10.2.3.6, "In-service Maintenance and Inspection of Turbine Rotors."

4) Section 10.2.3.7, "In-service Inspection of Turbine Valves." The description of the valve in-service inspection provision in this Section is consistent with the DCD and refers to the bounding missile probability analysis in the ST–56834/P Revision 4 report for the valve and control system maintenance, inspections, testing, and associated frequencies.

The staff confirmed that Section 10.2 of GE ST 56834/P, Revision 4, contains this information. The staff therefore finds that the portion of COL Item STD COL 10.2-1-A that is in FSAR Section 10.2.2.4 is acceptable. Based on its review of the turbine bounding missile probability analysis in the GE ST 56834/P, Revision 4, the staff finds the analysis acceptable. This SER further discusses this topic below under COL Item STD COL 10.2 2 A.

According to Acceptance Criterion 4 of SRP Section 3.5.1.3, an applicant obtaining a turbine from a manufacturer with an NRC-approved missile probability analysis for the turbine should meet the probabilities listed in SRP Table 3.5.1.3-1 based on the turbine orientation. This table includes the probability of a turbine failure resulting in the ejection of turbine rotor fragments through the turbine casing, P_1, of less than $1x10^{-4}$ per year for loading a favorably oriented turbine and bringing the system online. For the ESBWR, Section 10.2.1 of DCD Tier 2 states that a more conservative P_1 value of less than 10^{-5} per year will be used if the recommended inspections and tests are conducted at the recommended frequencies.

Acceptance Criterion 4 of SRP Section 3.5.1.3 also states that the turbine manufacturer should provide applicants with the relationship between the probability and the time that can be used to establish the in-service inspection and valve testing intervals that meet the missile probability criterion. Because the North Anna 3 applicant (similar to the Fermi 3 applicant) submitted a missile probability analysis from the manufacturer for NRC approval as part of the COL application, the manufacturer should also provide the inspection and valve testing intervals. In Sections 10.2.3.6 and 10.2.3.7 of the FSAR, Revision 8, the applicant stated that DCD Sections 10.2.2.7, 10.2.3.5, and 10.2.3.6 and GE ST 56834/P, Revision 4, describe this information.

The staff finds the FSAR discussions acceptable because referencing GE ST 56834/P, Revision 4, provides additional maintenance and inspection information to supplement the DCD requirements. The staff discusses its review of GE ST 56834/P, Revision 4, below under COL Item STD COL 10.2 2 A. This information therefore satisfies the OEM's missile probability calculation called for in DCD COL Item 10.2 1 A.

The staff reviewed the entire turbine missile probability analysis in GE ST 56834/P, Revision 4, as discussed below under COL Item STD COL 10.2 2 A. GE ST 56834/P addresses the maintenance and inspection of rotors in Section 10.1 and the inspection of turbine valves in Section 10.2. Section 10.1 of the report is divided into Section 10.1.1, "In service Volumetric Rotor Inspections," and Section 10.1.2, "Rotor Dovetail Inspections," and includes the following types of inspections:

- visual, magnetic particle, and ultrasonic examination of all accessible surfaces of the rotors
- visual and magnetic particle or liquid penetrant examination of all turbine blades
- visual and magnetic particle examination of couplings and coupling bolts
- rotor dovetail inspections

DCD Tier 2, Section 10.2.3.6, also lists the first three types of inspections. The description of the maintenance and inspection program in Section 10.1 of GE ST 56834/P is consistent with the DCD. In addition, for all of these inspections, GE ST 56843/P recommends an interval of no more than 12 years. This recommendation applies to the surfaces of both high pressure and low pressure rotors and rotor dovetails. The DCD identifies the inspection interval and the rotor dovetail inspections. Therefore, the staff reviewed this issue as new information that the applicant provided as part of COL Item STD COL 10.2 1 A.

The in-service inspections for the rotors consist of visual, surface, and volumetric examinations, as described above. Section 10.1.1 of GE ST 56834/P also states that performing a volumetric examination of 100 percent of the rotor is not possible because of the outside surface geometry and features. The report states that this inspection is not essential for meeting the missile probability requirements, because the growth of an internal flaw in the rotor body to the critical crack size is never the most probable missile generation mechanism. Because a 100 percent in-service volumetric examination is not possible, GE uses controls on the rotor metallurgy; the manufacturing; and the preservice inspection to limit undetected flaws in the rotor. Section 3.1.3 of the ST–56834/P report describes the preservice inspection and testing, which includes a 100 percent volumetric examination and a 100 percent surface examination (including the bore surface of the bored rotors).

As discussed in the GE ST-56834/P report, the probability of a missile generation is dominated by a turbine overspeed in the first 15 to 20 years of operation and by stress corrosion cracking (SCC) in an axial-entry dovetail slot bottom thereafter. Section 10.1.2 of the ST–56834/P report addresses the rotor dovetail inspections and recommends the following:

- magnetic particle surface examination of axial entry wheel dovetail faces
- ultrasonic examination of axial entry dovetail bottoms
- inspection of tangential entry dovetails (Stages 1 through 4) using a technique such as the phased array ultrasonic examination
- engineering disposition of flaw indications (and the possible removal of buckets for the additional surface examination)
- in-service inspection measurements used to recalculate a missile probability and to determine subsequent inspection intervals if necessary (e.g., if cracks are found)

The applicant's bounding missile probability analysis in the ST–56843/P Revision 4 report shows that the criterion of a 10^{-5} annual missile generation probability is met for both bored and solid rotors for a period longer than the proposed 12-year inspection interval. The staff finds that the applicant's proposed rotor inspection program, including the 12-year inspection interval, is consistent with the DCD and meets the missile probability criterion in SRP Section 3.5.1.3 for bounding material properties. The program is therefore acceptable.

The staff finds that the information in Section 10.2 of the COL FSAR describes the Turbine Maintenance and Inspection Program, which is used to satisfy the manufacturer's turbine missile generation probability calculation. The staff finds that the program description is consistent with the corresponding information in the DCD and meets the criteria in SRP Section 3.5.1.3, which is related to periodic inspection and testing. The applicant's information in STD COL 10.2-1-A as updated in the North Anna 3 FSAR Revision 8, is therefore acceptable with respect to valve maintenance, inspections, testing, and frequency of the Turbine Valve Inspection Program. Open Item 10.2-1, from the North Anna 3 Phase 2 SER is thus resolved and closed. The staff also evaluated these requirements and frequencies as part of the review of COL Item STD COL 10.2-2-A, the missile probability analysis, which is described below.

- STD COL 10.2-2-A		Turbine Missile Probability Analysis

DCD COL Item 10.2-2-A requires the COL applicant to provide an evaluation of the probability of a turbine missile generation using criteria in accordance with NRC requirements (based, if necessary, on bounding material property values until the actual material specimens are available).

In FSAR Revision 1 Section 10.2.3.8, the applicant provided information to address DCD COL Item 10.2-2-A. This COL item states that the COL applicant will provide an evaluation of the main turbine missile generation analysis in accordance with the acceptance criterion of SRP Section 3.5.1.3. The applicant stated that the bounding analysis would be completed in the second quarter of 2009, and the FSAR would be revised to reflect this analysis as part of a subsequent FSAR update. The staff tracked this activity from the Phase 2 North Anna 3 SER as Open Item 10.2-2.

In the letter dated December 6, 2013, the applicant provided the bounding missile probability analysis report (GE ST–56834/P, Revision 4) to address DCD COL Item 10.2-2-A. According to this COL item, "The COL applicant will provide an evaluation of the probability of a turbine missile generation using criteria in accordance with NRC requirements. If necessary, bounding material property values may be used to perform the analysis until actual material test specimens are available for testing (Section 10.2.3.8)."

The staff reviewed the applicant's information on COL Item STD COL10.2-2-A, which is related to providing the turbine missile probability analysis using the criteria and guidance in Regulatory Guide (RG) 1.115, Revision 2 and in SRP Section 3.5.1.3 and Section 10.2.3. The staff's review of the turbine missile probability analysis included the sequential RAI responses in the Fermi 3 COLA (the response dated October 5, 2010, to RAIs 10.02.03-1 through 10.02.03-11 [ADAMS Accession No. ML102800185]; the response dated July 29, 2011, to RAIs 10.02.03-12 through 10.02.03-16 [ADAMS Accession No. ML112140345]; and the response dated October 28, 2011, to RAIs 10.02.03-17 through 10.02.03-19 [ADAMS Accession No. ML113050573]), which resulted in corresponding changes to the missile analysis report as summarized in the following paragraphs.

In the letter dated December 6, 2013, the applicant provided the bounding missile probability analysis report (GE ST–56834/P, Revision 4) for North Anna 3 that uses DTE's responses to RAIs concerning the same technical topic on the Fermi 3 COL docket, which is now part of the North Anna 3 COLA. The staff reviewed STD COL 10.2-2-A as submitted on the North Anna 3 COL docket and is similar to the staff's review of the Fermi 3 COLA and this technical topic on the Fermi docket, which includes the bounding missile probability analysis report (ST–56834/P Revision 4). In addition, the applicants supplemental letter dated September, 30, 2014, also identifies that the Fermi 3 RAI responses concerning this topic are now submitted on the docket as part of an incorporation by reference per 10 CFR 52.8(b). The Fermi 3 RAIs referred to are 10.02.03-3, 10.02.03-7, 10.02.03-8, 10.02.03-9, and 10.02.03-10. For Fermi 3 COL SER, Section 10.2.4 and for this section of the North Anna 3 SER, this information provides the OEM's missile probability calculation called for in DCD COL Item 10.2-2-A.

The staff noted that Revision 4 of ST–56834/P is referenced as the applicant's turbine missile probability analysis for the GE turbine generator, model number N3R-6F52. The analysis applies to both the Fermi 3 and North Anna 3 turbine generators.

The GE ST-56834/P report provides the analysis for the probability of generating missiles for GE turbine generator model number N3R-6F52, which the COL applicant specified in Supplemental Information STD SUP 10.2-1. GE ST-56834/P, Revision 4 provides the methodology, assumptions, and results of the turbine missile generation probability, along with the manufacturer's recommendations for in-service testing and inspections. The methodology is consistent with the GE report entitled, "Probability of Missile Generation in General Electric Nuclear Turbines," issued in January 1984, as approved by the NRC in Appendix U, "Probability of Missile Generation in General Electric Nuclear Turbines," to NUREG 1048, "Safety Evaluation

Report Related to the Operation of Hope Creek Generating Station," Supplement 6, issued July 1986. GE ST–56834/P, Revision 4 also updates data such as valve failure rates to demonstrate that the destructive overspeed analysis is conservative. The methodology used consists of calculating the probability of a turbine overspeed in conjunction with the probability of a rotor burst and the probability of a turbine rotor fragment penetrating the turbine casing. The failure modes assumed in the analysis include a ductile burst (destructive overspeed), a brittle fracture of a missed internal flaw growing to a critical size due to cyclic fatigue, and SCC at the rotor dovetails.

The material used for the rotor forgings is a nickel-chromium-molybdenum-vanadium (NiCrMoV) alloy. The staff first reviewed the detailed description of the material in Revision 2 of GE ST-56834/P, which states in Section 3.1 that the rotor material will be produced in accordance with GE material specification B50A373B8. The staff determined that Revision 2 of GE ST-56834/P did not provide enough details about the material properties, including the chemistry, as required by the ESBWR DCD. In addition, the staff's SER for ESBWR DCD (NUREG-1966) Section 10.2.3.2.3 states that the COL applicant will provide the material properties (e.g., sulfur and phosphorus content) as part of the turbine missile analysis. In the responses to Fermi 3 RAI 10.02.03-4 and RAI 10.02.03-12 dated October 5, 2010, and July 29, 2011, respectively; DTE states that the rotors for the subject turbine use GE material specification B50A373B8 or an equivalent specification with a more restrictive chemistry. The responses point out that this material has been used since the 1980s for numerous integral (nonbored) rotors, with no rotor failures. The responses also state that the geometry of the buckets has been modified since the 1980s to reduce the stresses, and the use of shot-peening applies compressive forces on the surfaces of the rotor to mitigate SCC.

However, the staff requested DTE to provide the material specification for the staff's review to ensure that the material specification, including the chemistry, is adequate to meet the guidance in SRP Section 10.2.3 concerning the chemistry and processing to ensure characteristics such as adequate fracture toughness for the turbine rotor. The DTE response to Fermi 3 RAI 10.02.03-12 dated July 29, 2011, clarifies that GE material specification B50A373B8 was revised to GE material specification B50A373B12. The only change in this revision (from B8 to B12) was to restrict the nickel range to achieve the desired material properties in nuclear nonbored monoblock rotor forgings. The staff conducted an audit of the GE material specification documented in an NRC memorandum dated September 26, 2011 (ADAMS Accession No. ML112640028). The audit confirmed that the material has been used since the 1980s for turbine rotors and was only revised to restrict the nickel range. The staff also confirmed that the material is a vacuum-treated NiCrMoV alloy with the amounts of alloying impurity elements in the range of typical modern nuclear turbines, which is consistent with Section 10.2.3.1 of the ESBWR DCD and SRP Section 10.2.3. Therefore, the staff found in Section 10.2.4 of the Fermi 3 SER that the material composition included in Revision 4 of GE ST-56834/P is acceptable and will be used for the procurement of the Fermi 3 and North Anna 3 turbine rotors.

In the response to Fermi 3 RAI 10.02.03-17 dated October 28, 2011, DTE refers to bounding material properties and states that Revision 4 of ST–56834/P was updated to include the bounding assumption of the minimum tensile strength in the material specification. The bounding fracture appearance transition temperature (FATT) value of -1.1 degrees Celsius (C) (+30 degrees Fahrenheit [F]) described in the ESBWR DCD and the applicable GE material specification B50A373B12 were also used in Revision 4 of the analysis, as discussed in DTE's response to Fermi 3 RAI 10.02.03-13 dated July 29, 2011. As stated in the response to Fermi 3 RAI 10.02.03-5 dated October 5, 2010, this FATT value of -1.1 degrees C (+30 degrees F) will be determined on the site-specific rotor forgings using deep-seated impact specimens machined from radial trepans between the rotor wheels to ensure that the specified FATT value in the internal rotor region is met. In addition, the responses to Fermi 3 RAIs 10.02.03-6 and 10.02.03-7 dated October 5, 2010, show that 11 nuclear turbine rotor forgings in the past 20 years have been tested and the corresponding FATT values were well below -1.1 degrees C (+30 degrees F) throughout the rotor forgings. Statistically, the forging data resulted in a mean FATT value of -36.7 degrees C (-34 degrees F) with a plus two-sigma value (two standard deviations) of 6.1 degrees C (+11 degrees F), which demonstrates that these large monoblock forgings can achieve the specified FATT value of -1.1 degrees C (+30 degrees F). Accordingly, the staff finds that the bounding material properties of the turbine rotor were used in the analysis.

In addition, in the response to Fermi 3 RAI 10.02.03-18 dated October 28, DTE clarified that the analysis used design overspeed stresses based on the postulated conditions and events in Section 7 of GE ST-56834/P. The design overspeed was clarified to be 120 percent of the rated speed in the October 5, 2010, response to Fermi 3 RAI 10.02.03-3, which is consistent with the ESBWR design overspeed. In the response to Fermi 3 RAI 10.02.03-15 dated July 29, 2011, DTE stated that the tangential stresses at the slot bottoms of the axial entry dovetails are lower than the previous shrunk-on-wheel keyways and therefore, the use of the shrunk-on-wheel crack initiation and growth characteristics is conservative. The Fermi 3 RAI response also stated that shot-peening the rotor imparts compressive stresses to remove tensile residual stresses on the surface, thereby reducing the occurrence of SCC. Therefore, based on the above information, the staff finds that the analysis used conservative and appropriate stresses in the turbine rotor.

The cyclic propagation of an assumed internal forging defect due to tangential stresses from mechanical and thermal loading was performed in the analysis. As stated in the response to Fermi 3 RAI 10.02.03-18 dated October 28, 2011, the loading was determined based on both normal and abnormal turbine speeds with an assumed annual cyclic loading resulting from starts, stops, and load swings of the turbine. These stresses were derived using a finite element analysis based on the geometry for the N3R-6F52 rotor using corresponding startup transient thermal loadings, as clarified in the response to Fermi 3 RAI 10.02.03-9 dated October 5, 2010.

The ST–56834/P report includes an analysis of a rupture of the turbine rotor due to SCC in the slot bottoms of the rotor dovetails for the axial entry dovetails. The crack growth rate of shrunk-on-wheel keyways was used as a conservative basis, because operating experience indicates that stresses at these keyways are higher than those in the current monoblock forgings. The tangential stress of the dovetail slots in the monoblock forgings is much lower than in the previous shrunk-on-wheel keyways, as illustrated in the October 5, 2010, response to Fermi 3 RAI 10.02.03-10. Also, shot-peening of the turbine rotor surfaces reduces residual stresses and adds compressive stresses to mitigate the occurrence of SCC, as discussed in the July 29, 2011, response to Fermi 3 RAI 10.02.03-15. The analysis demonstrated that the critical crack size in the dovetail slots would be reached in approximately 40 years and the crack size is well within the nondestructive inspection capabilities, as discussed in the July 29, 2011, response to Fermi 3 RAI 10.02.03-13.

The ductile tensile burst of the rotor was analyzed using the average tangential stress of each rotor stage and the corresponding tensile strength of the material. The minimum ultimate tensile strength of the material specification was used in order to be a bounding analysis.

These three failure modes—cyclic fatigue, SCC, and ductile tensile burst—were used to calculate the probability of rupturing the rotor; and they were then combined to achieve a single probability of rupturing a turbine rotor. This probability analysis was conducted for various scenarios and turbine speeds and the resulting probabilities of rupturing a rotor, combined with the probability of the ruptured rotor fragment penetrating the turbine casing, resulted in a final probability of generating a turbine missile. Figures 9-1 and 9-2 of ST–56834/P present the results of the annual probability of generating a turbine missile.

These annual probability results in Figures 9-1 and 9-2 of ST–56834/P demonstrate that the probability of generating turbine missiles is less than 10^{-5} for an inspection interval greater than 12 years. Therefore, the proposed inspection interval of 12 years, as stated in Section 10.1 of GE ST-56834/P, Revision 4, meets the criteria in RG 1.115, Revision 2. Section 10.1 of GE ST-56834/P, Revision 4 also provides the turbine manufacturer's recommendations for the inspection and maintenance program description for the turbine rotors, which includes the following:

- visual, magnetic particle, and ultrasonic examination of all accessible rotor surfaces
- visual and magnetic particle or liquid penetrant examination of all turbine blades
- visual and magnetic particle examination of couplings and coupling bolts

These inspection methods are consistent with ESBWR DCD, Section 10.2.3.6. As clarified in the response to Fermi 3 RAI 10.02.03-19 dated October 28, 2011, the turbine manufacturer also recommends that the rotor dovetail inspections detailed in Section 10.1.2 of ST–56834/P, Revision 4 be performed within a 12-year interval; because in Section 9 of ST–56834/P, Revision 4, GE determined that SCC in the dovetail slot bottoms controls the probability of generating a turbine missile after 20 years of operation. The staff finds that the proposed description of the inspection program and the inspection interval of 12 years are acceptable because they meet the criteria of RG 1.115, Revision 2 and are consistent with the guidelines of SRP Section 10.2.3, thus ensuring that the turbine rotor integrity will be maintained to preclude the generation of a missile.

As DTE clarified in the response to RAI 10.02.03-2 dated October 5, 2010, the Fermi 3 turbine generator uses a MARK VIe turbine generator control system (TGCS). This TGCS has the same functional design and component specifications as previous GE turbine generators, with improvements made based on operating experience. Some of the improvements detailed in the response to Fermi 3 RAI 10.02.03-11 dated October 5, 2010, include the use of direct mechanical connections to the valve stem to reduce the number of moving parts and eliminate potential linkage binding on the control and intercept steam valves. These direct linkages have also been used in current operating plants on the main stop valve and on intercept stop valves. In addition, this Fermi 3 response includes the steam valve failure rates based on failure assessment data reports collected in 1993 and 2008, which were used in ST–56834/P for the main stop and control valves and the intermediate stop and intercept valves. As stated in the response to Fermi 3 RAI 10.02.03-16 dated July 29, 2011, the improvements made after 1984 effectively reduced the probability of failures. The failure rates are listed in Section 5 of GE ST-56834/P, Revision 4.

Section 5.4.1 of ST–56834/P, Revision 4 provides the hydraulic system reliability model based on the following common failure modes: water contamination caused by leaking oil coolers and corrosion of non-stainless steel mechanical and/or electrical hydraulic trip valves. After 1984, GE made improvements to the designs and materials in current operating plants, such as using titanium hydraulic oil coolers and new hydraulic fluid conditioning equipment that resolved these common failure modes. However, the analysis used the pre-1984 hydraulic failure rate model as a conservative assumption, which bounds the improved hydraulic system proposed for the North Anna 3 turbine. The overspeed probability from valve failures was calculated for valve test intervals of 90 and 120 days and resulted in similar annual missile probabilities, which were provided in the response to Fermi 3 RAI 10.02.03-16 dated July 29, 2011. The overspeed probability for a valve test interval of 120 days was well within the criteria of 10^{-5} per year specified in RG 1.115, Revision 2 and the guidance in SRP Section 3.5.1.3. The staff therefore finds the 120-day test interval acceptable because it meets the annual missile probability criteria of 10^{-5} per year in RG 1.115, Revision 2 and the specified guidelines in SRP Section 3.5.1.3 and Section 10.2.3, which ensure that the turbine rotor integrity is maintained to preclude the generation of missiles.

Based on the above discussion, the staff finds that the applicant's referenced turbine missile probability analysis in ST–56834/P, Revision 4 provides an acceptable analysis that substantiates the turbine manufacturer's recommendations, for inspecting and testing the turbine rotor and associated valves using the criteria in RG 1.115, Revision 2. The staff therefore determined that the applicant has adequately addressed COL Item STD COL 10.2-2-A, in the North Anna 3 FSAR Revision 8, with respect to evaluating the probability of a turbine missile generation using criteria in accordance with NRC requirements. Open Item 10.2-2 from the staff Phase 2 North Anna 3 SER is thus resolved and closed.

Supplemental Information

- STD SUP 10.2-1 Turbine Design

In FSAR Section 10.2.3.4, the applicant states that GE will manufacture the turbine and the generator for North Anna 3. The applicant selected turbine Model N3R-6F52, which is one of GE's N series nuclear steam turbines. The staff finds this turbine design model acceptable because GE has provided an acceptable turbine missile analysis for this model, as discussed above in the evaluation of STD COL 10.2-2-A.

10.2.5 Post Combined License Activities

There are no post COL activities related to this section.

10.2.6 Conclusion

The 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 confirmed that the applicant has addressed the required information relating to the turbine generator, 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 turbine generator that were incorporated by reference have been resolved.

In addition, the staff compared the supplemental information in the COLA to the relevant NRC regulations, the guidance in SRP Sections 10.2 and 10.2.3, and NRC RGs. The staff's review confirmed that the applicant has adequately addressed the COL license information items in the ESBWR DCD. For the reasons set forth above, the staff concluded that the information in this section of the COL FSAR is acceptable and meets the requirements of GDC 4. Specifically, the staff evaluated COL Items STD COL 10.2-1-A and STD COL 10.2-2-A according to the relevant NRC regulations and acceptance criteria in SRP Section 10.2.3 and Section 3.5.1.3. The staff finds that the applicant has satisfactorily addressed DCD COL Item 10.2-1-A, because the proposed maintenance and inspection program is consistent with the corresponding information in the DCD and meets the criteria in SRP Section 3.5.1.3 related to periodic inspection and testing. The staff also finds that the applicant has satisfactorily addressed DCD COL Item 10.2-2-A, because the turbine missile probability analysis in GE ST–56834/P, Revision 4 provides the turbine manufacturer's recommendations for inspecting and testing the turbine rotor and associated valves using the criteria in RG 1.115, Revision 2. Additionally, the staff reviewed Supplemental Information STD SUP 10.2-1, which provides the turbine model number. The staff's review finds this supplemental information acceptable because the applicant has provided an acceptable turbine missile analysis for this turbine model, as discussed in the evaluation of COL Item STD COL 10.2-2-A.

10.3 Turbine Main Steam System

Section 10.3 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.3 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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 turbine main steam supply system that were incorporated by reference have been resolved.

10.4 Other Features of Steam and Power Conversion System

This section of the COL FSAR describes other features of the steam and power conversion system.

The main condenser system (Section 10.4.1) functions as the steam cycle heat sink in receiving, condensing, and deaerating steam from the main turbine and other vents and drains in the steam cycle system.

The main condenser evacuation system (Section 10.4.2) establishes and maintains the main steam condenser vacuum and removes noncondensable gases and air from the main condenser.

The turbine gland seal system (Section 10.4.3) prevents air leakage into and steam out of the annulus space between the turbine and steam valve shafts.

The turbine bypass system (Section 10.4.4) enables a system to allow some main steam flow directly to the main condensers, thus bypassing the turbine.

The circulating water system (CWS) (Section 10.4.5) provides a continuous supply of cooling water to the main condenser.

The condensate purification system (CPS) (Section 10.4.6) purifies the condensate and minimizes corrosion/erosion products in the power conversion cycle.

The condensate and feedwater system (Section 10.4.7) supplies high-purity feedwater to the reactor at the required flow rate, pressure, and temperature.

10.4.1 Main Condenser

Section 10.4.1 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.1, "Main Condenser," of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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 main condenser that were incorporated by reference have been resolved.

10.4.2 Main Condenser Evacuation System

Section 10.4.2 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.2, "Main Condenser Evacuation System," of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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 main condenser evacuation system that were incorporated by reference have been resolved.

10.4.3 Turbine Gland Seal System

Section 10.4.3 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.3, "Gland Seal Steam System," of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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 turbine gland seal system that were incorporated by reference have been resolved.

10.4.4 Turbine Bypass System

Section 10.4.4 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.4, "Turbine Bypass System," of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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 turbine bypass system that were incorporated by reference have been resolved.

10.4.5 Circulating Water System

10.4.5.1 Introduction

The CWS provides cooling water for the removal of the power cycle heat from the main condensers and transfers this heat to the normal power heat sink.

10.4.5.2 Summary of Application

Section 10.4.5 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.5 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E. In addition, in FSAR Section 10.4.5.2.1, the applicant provides the following conceptual design information (CDI):

Site-Specific Information Replacing Conceptual Design Information

- NAPS CDI Circulating Water System

The applicant replaced the CDI in the DCD with a detailed description of the site-specific system for North Anna 3.

10.4.5.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, SRP Section 10.4.5 contains the relevant requirements of the Commission's regulations for the CWS and the associated acceptance criteria.

10.4.5.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 10.4.5 of the certified ESBWR DCD. The staff reviewed Section 10.4.5 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 the 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 related to this section.

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

Site-Specific Information Replacing Conceptual Design Information

- NAPS CDI Circulating Water System.

The staff reviewed the NAPS CDI related to the design description and operation of the CWS in FSAR Section 10.4.5. The staff's reviews of the specific CDI sections are provided below.

- NAPS CDI FSAR Section 10.4.5.2.1, "General Description"

In FSAR Section 10.4.5.2.1, the applicant described the CWS by replacing the CDI in the DCD with a more detailed general description of the site-specific system proposed for Unit 3. The applicant provided the design for the condenser water boxes, piping, and valves; condenser tube cleaning equipment; water box drain subsystem; circulating water pumps; screens; and cooling towers. The system configuration for the CWS is depicted in FSAR Figures 10.4-201 through 10.4-203, which replaces the conceptual diagram in Figure 10.4-1 of the DCD.

FSAR Section 10.4.5.2.1 describes the CWS, which consists of four motor-driven pumps, each with the capability of pumping 25 percent of the CWS design water flow; a dry-cooling tower array; one combination (hybrid) of a wet/dry mechanical draft cooling tower; and associated piping, valves, and instrumentation. The CWS and the dry- and hybrid-cooling towers provide a heat sink for waste heat exhausted from the main steam turbine. The four motor-driven pumps normally circulate the water through the condenser and back to the cooling towers. Depending on ambient conditions and heat load, one CWS pump may be taken out of operation with the flow of the remaining three pumps providing sufficient water for condenser heat removal. The four pumps are arranged in parallel and the discharge line of each pump is fitted with a remotely operated valve. This arrangement permits the isolation and maintenance of any one pump while the other pumps remain in operation and minimizes the backward flow through a tripped pump. The staff's review of the design information in FSAR Section 10.4.5.2.1 finds that the applicant has addressed the final configuration of the North Anna 3 CWS, as specified in Section 10.4.5.2.1 of ESBWR DCD, Revision 10.

Also, in FSAR Table 10.4-3R, "Circulating Water System," the applicant provides site-specific parameters to replace the values in ESBWR DCD, Table 10.4-3. The staff finds that the operating temperatures and circulating water pump information in FSAR Table 10.4-3R are acceptable, because they are bounded by the design values of these parameters in the DCD.

Furthermore, the CWS design includes vents to help fill in and remove air and other gases from the condenser water-boxes during startup and normal operations. The system includes design features such as slow-stroke, motor-operated valves; air- and vacuum-release valves; and control and interlock features that ensure proper valve lineup between the pump's discharge valves and consistency between the pump's startup and shutdown (stop signals) sequences. The staff determined that these provisions will minimize hydraulic transients, including water hammer, during startup and normal operations of the system because they are located and sized so as to be capable of performing the required functions. Accordingly, the staff finds that these vents, air releases, and vacuum relief valve provisions in the CWS adequately address the requirements of GDC 4; as it relates to the design features to accommodate the effects of discharging water, and to prevent water hammer and subsequent CWS piping or component failures from occurring at pump startup from initial system depressurization.

- NAPS CDI FSAR Section 10.4.5.2.2, "Component Description"

In FSAR Section 10.4.5.2.2, the applicant provided information regarding industry codes and standards that are applicable to the CWS design. In FSAR Section 10.4.5.2.2, Revision 0, the applicant stated that the codes and standards applicable to the CWS are in accordance with DCD Section 3.2; with the exception of large-bore piping (i.e., piping with a nominal diameter of 700 millimeters [27.6 inches] and larger). The applicant further stated that the large-bore CWS piping is constructed using American Water Works Association (AWWA) standards, and the system is designed and constructed in accordance with Quality Group D specifications.

However the staff finds that Table 3.2-3 of the DCD specifies American Society of Mechanical Engineers (ASME) Standard B31.1, "Power Piping," for Quality Group D piping. Also, RG 1.26, Revision 4, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," Revision 4, issued March 2007, recommends ASME Standard B31.1 2004. In accordance with SRP Section 10.4.5 Review Procedures Item 1, design provisions are to be incorporated that minimize the effects of hydraulic transients on the functional capability and integrity of the components of the system. Therefore, in RAI 10.4.5-1 dated June 23, 2008 (ADAMS Accession No. ML081750645), the staff asked the applicant to justify the above deviation from the DCD and its compliance with the applicable regulations. In addition, the staff asked the applicant to explain and ensure that the failure of this large-bore piping will not affect the intended functions of safety related equipment and systems.

In its response to RAI 10.4.5-1 dated August 7, 2008 (ADAMS Accession No. ML082240134), the applicant stated that it was not necessary to take an exception to DCD Section 3.2 and that it would revise FSAR Section 10.4.5.2.2 to delete this exception for large bore piping. Later, the staff confirmed that the above exception was deleted in FSAR, Revision 1. In addition, according to FSAR, Revision 8, the codes and standards in ESBWR DCD Section 3.2 are incorporated by reference into FSAR Section 10.4.5.2.2. Based on the above discussion, the staff finds that the applicant's response to RAI 10.4.5-1 is acceptable and that the staff's concerns are resolved and closed.

In FSAR Table 10.4-3R, the applicant provided site specific parameters to replace the values in ESBWR DCD Table 10.4-3. The staff finds that the operating temperatures and circulating water pump information in FSAR Table 10.4-3R are acceptable because this system does not perform any safety function and the system's failure cannot affect any safety system function.

- NAPS CDI FSAR Section 10.4.5.2.2.1, "CWS Chemical Injection"

FSAR Section 10.4.5.2.2.1 provides information about the chemical injection in the CWS that is not included in the DCD. The proposed chemical injection maintains a noncorrosive, non-scale forming condition within the CWS and ensures that any biological film growth that may affect the cooling tower and condenser heat transfer rate does not occur. Circulating water chemistry is maintained by the chemical storage and transfer system. Chemical feed equipment injects the chemicals used into the circulating water at the pump bay before water enters the circulating water pumps or into the circulating water cooling tower basin. FSAR Table 2.2-202 specifies the chemicals to be used within the system such as sodium hypochlorite, acid, bromide, dispersants, and non-oxidizing biocides, which are all compatible with selected materials or components used in the CWS. These chemicals are based upon five functions: biocide, algaecide, pH adjuster, corrosion inhibitor, and scale inhibitor. The pH adjuster, corrosion inhibitor, and scale inhibitor are metered into the system continuously or as needed to maintain proper concentrations. Biocide application frequency may vary with seasons; and algaecide is applied as needed to control algae formation in the cooling towers. Circulating water chemistry is also controlled as needed with blowdown.

The staff reviewed the information in the FSAR and finds that the applicant has adequately identified the chemicals to be used for the chemical treatment of CWS materials. The applicant also specifies the criteria that will ensure compatibility with the system materials. Furthermore, the identified chemicals will perform the appropriate functions to minimize the fouling of heat transfer surfaces and the corrosion of the CWS. Although the NRC has no specific regulatory criteria for the CWS materials and chemistry, the use of materials that are corrosion-resistant in the environment and water treatment chemicals that are compatible with system materials ensures that corrosion and biological film growth will not affect the condenser heat transfer rate.

- NAPS CDI FSAR Section 10.4.5.2.3, "System Operation"

In FSAR Section 10.4.5.2.3, the applicant described the site-specific CWS operation. The applicant stated that blowdown flow from the CWS is discharged into the plant discharge canal at a maximum temperature of 37.8 degrees C (100 degrees F). The applicant stated that leakage from the main condenser into the CWS via a condenser tube leak is not likely during power operation, because the CWS normally operates at a greater pressure than the shell (condensate) side of the condenser. The staff finds the applicant's discussion of the CWS operation acceptable.

- NAPS CDI — FSAR Section 10.4.5.5, “Instrumentation Applications”

The applicant provided the following additional measurement capability:

(1) level instrumentation in the circulating water pump forebay where the CWS pumps take suction and provide alarms in the main control room upon abnormally low or high water levels

(2) pressure indications on the CWS pump discharge and differential pressure instrumentation across the inlet and outlet to the condenser to determine the frequency of operating the condenser tube cleaning system

(3) local grab sample locations to enable periodic testing of the circulating water quality

The staff finds these additional new instrumentation and test practices acceptable, because they enhance the design and operational capability of the CWS.

- NAPS CDI — FSAR Section 10.4.5.6, “Flood Protection” and FSAR Section 10.4.5.8, “Normal Power Heat Sink”

FSAR Section 10.4.5.8 describes the site-specific normal power heat sink, which consists of the combined dry-cooling tower array and a hybrid wet/dry-cooling tower. The combination of dry- and hybrid-cooling tower arrangements supports a condenser-inlet maximum cold water temperature of 37.8 degrees C (100 degrees F). The station water system supplies makeup water to the CWS resulting from losses in evaporation and blowdown. The dry- and hybrid-cooling towers are both located at a distance from seismic Category 1 and 2 structures that is at least equal to their height. Therefore, there is no potential for the cooling towers to fall or damage safety-related structures or components. Both the dry- and the hybrid-cooling towers use fans; a failure of the fans could generate missiles. The applicant stated that the site arrangement and cooling tower construction will prevent damage to any seismic Category 1 or 2 structures or to any safety-related SSCs from possible missiles generated by the failure of a cooling tower mechanical fan, because the fans rotate at relatively slow speeds and the fan blades are made of relatively low-density material. Even if a failure of a fan could result in the generation of missiles, any damage would be confined to the cooling towers because of the site arrangement and construction of the respective towers.

However, in Revision 0 of the FSAR, the applicant did not specifically address flooding considerations from a hybrid-cooling tower failure in the application. Also, the applicant initially did not provide any information with respect to Section 10.4.5.6 of the DCD. In accordance with SRP Section 10.4.5 Acceptance Criterion Item 1, design provisions need to be provided to accommodate the effects of discharging water that may result from a failure of a component or piping in the CWS. Therefore, the staff requested the applicant in RAI 10.4.5-2 (ADAMS Accession No. ML081750645), dated June 23, 2008, to provide additional information regarding the cooling tower failure analysis. In the response to RAI 10.4.5-2 (ADAMS Accession No. ML082240134), dated August, 7, 2008, the applicant stated that a failure of a pipe or component in the hybrid-cooling tower or other CWS piping in the yard would not have an adverse impact on safety-related SSCs. The bounding piping failure for the hybrid-cooling tower is a failure of the two vertical large-bore CWS pipes that connect to the distribution header of the hybrid-cooling tower. In this failure scenario, the site grading will divert the flow of water from the ruptured pipes away from the plant to the drainage ditch on the west side of the cooling tower area. A failure of the hybrid-cooling tower basin will not lead to any discharge of water to the surface, because it is an in-ground structure. The maximum water level elevation in the basin is lower than the elevations of the surrounding areas. If a surface discharge were to occur, the water would flow away from the plant toward Lake Anna.

The staff finds that the applicant's response to RAI 10.4.5-2 provides acceptable design provisions to accommodate the effects of discharging water that may result from a failure of a component or piping in the CWS, in that a failure scenario from the cooling tower water would flow to the west side of the tower and away from the plant. The staff's concern described in RAI 10.4.5-2 is thus resolved. The staff confirmed that Revision 1 of the FSAR includes this additional information. Therefore, the staff finds that the conclusions in the ESBWR DCD FSER (NUREG–1966) regarding the requirements of GDC 4 and SRP guidance remain valid with respect to flooding.

10.4.5.5 Post Combined License Activities

There are no post COL activities related to this section.

10.4.5.6 Conclusion

The 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 related to the CWS, and that 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 CWS that were incorporated by reference have been resolved.

In addition, the staff compared the supplemental information in the COLA to the relevant NRC regulations, the guidance in SRP Section 10.4.5, and other NRC RGs. The staff's review concludes that the applicant has adequately addressed the site-specific CDI for the CWS, in accordance with the guidance in SRP Section 10.4.5 and RG 1.26 and meets the requirements of GCD 4.

10.4.6 Condensate Purification System

10.4.6.1 Introduction

This FSAR section includes information related to the purification and treatment of condensate, as needed, to maintain reactor feedwater purity. The CPS uses filtration to remove suspended solids, including corrosion products, and ion exchange to remove dissolved solids and other impurities.

10.4.6.2 Summary of Application

Section 10.4.6 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.6 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E. In addition, in FSAR Section 10.4.6, the applicant provides the following:

COL Item

- STD COL 10.4-1-A Leakage (Circulating Water into the Condenser)

The applicant provided threshold values and recommended operator actions for chemistry excursions in the condensate system to address this COL item.

10.4.6.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of Commission regulations for the CPS and associated acceptance criteria are in SRP Section 10.4.6.

The applicable regulatory requirements and associated guidance for the CPS are as follows:

- GDC 14, "Reactor coolant pressure boundary," as it relates to the reactor coolant pressure boundary being designed, fabricated, erected, and tested; so as to have an extremely low probability of an abnormal leakage, a rapidly propagating failure, and a gross rupture.

- Electric Power Research Institute (EPRI) Report NP-4947-SR, "BWR Hydrogen Water Chemistry Guidelines," 1987 Revision.

10.4.6.4 Technical Evaluation

As documented in NUREG–1966, the staff reviewed and approved Section 10.4.6 of the certified ESBWR DCD. The staff reviewed Section 10.4.6 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 the 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 related to this section.

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

COL Item

- STD COL 10.4-1-A Leakage (Circulating Water into the Condenser)

The applicant provided threshold values and recommended operator actions to address STD COL 10.4-1-A in FSAR Table 10.4-201, "Recommended Water Quality and Action Levels."

FSAR Table 10.4-201 summarizes the manufacturer's recommended threshold values of the chemistry parameters and the associated operator actions. These parameters enable the operation of the system within the EPRI Boiling-Water Reactor (BWR) water chemistry guidelines. The staff finds the applicant's information addressing COL Item STD COL 10.4-1-A acceptable, because the chemistry parameters meet the recommendations of SRP Section 10.4.6 and the EPRI BWR water chemistry guidelines.

10.4.6.5 Post Combined Operating License Activities

There are no post COL activities related to this section.

10.4.6.6 Conclusion

The 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 related to the CPS and that no outstanding information related to this section is expected to be addressed in the COL FSAR. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues related to the CPS that were incorporated by reference have been resolved.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in SRP Section 10.4.6, and other NRC RGs and industry standards. The staff's review concludes that the information in this section of the North Anna 3 COL FSAR is acceptable and meets the NRC endorsed EPRI guidelines for BWR water chemistry and the requirements of GDC 14. The staff evaluated COL Item STD COL 10.4 1 A and Supplemental Information North Anna 3 SUP 10.4 1 in this section. The staff finds that the applicant has satisfactorily addressed these items.

10.4.7 Condensate and Feedwater System

Section 10.4.7 of the North Anna 3 COL FSAR, Revision 8, incorporates by reference Section 10.4.7, "Condensate and Feedwater System," of the certified ESBWR DCD, Revision 10, without any departures or supplements. The staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The staff's review confirms that no outstanding information is expected to be addressed in the North Anna 3 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.

References

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

2. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

3. 10 CFR Part 50, Appendix A, GDC 14, "Reactor coolant pressure boundary."

4. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and dynamic effects design bases."

5. 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

6. ASME B31.1-2004, "Power Piping."

7. EPRI Report NP-4947-SR, "BWR Hydrogen Water Chemistry Guidelines," 1987 Revision.

8. GE ST-56834/P, "ESBWR Steam Turbine - Low Pressure Rotor Missile Generation Probability Analysis," Revision 4, October 18, 2011.

9. NRC RG 1.115, Revision 2, "Protection against Turbine Missiles," January 2012 (ADAMS Accession No. ML101650675).

10. NRC RG 1.26, Revision 4, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," March 2007.

11. NRC Staff NUREG 0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," March 2007 (ADAMS Accession No. ML070660036).

12. NRC Staff NUREG-1048, "Safety Evaluation Report Related to the Operation of Hope Creek Generating Station," Supplement 6, Appendix U, "Probability of Missile Generation in General Electric Nuclear Turbines," July 1986.

13. NRC Staff NUREG-1966, "Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling-Water Reactor Standard Design," and its Supplement 1, April 2014 (ADAMS Accession Nos. ML14099A519, ML14099A522, ML14099A532, ML14100A187, ML14100A190, ML14100A194, ML14265A084).