10.0 STEAM AND POWER CONVERSION SYSTEM

This chapter introduces the principal design features, systems, and components of the steam and power conversion system. The components of this system are designed to produce electric power using the steam generated by the reactor; condense the steam into water; and return water to the reactor as heated feedwater with a major portion of its gaseous, dissolved, and particulate impurities removed to maintain reactor water quality.

The steam and power conversion system includes the turbine main steam system (TMSS), main turbine generator, main condenser, main condenser evacuation system, turbine gland seal system (TGSS), turbine bypass system (TBS), condensate purification system, condensate and feedwater system (C&FS), and circulating water system. The majority of the steam and power conversion system piping and components are located in the turbine building.

10.1 Summary Description

Section 10.1 of the Fermi 3 combined license (COL) Final Safety Analysis Report (FSAR), Revision 7, incorporates by reference Section 10.1 of the certified Economic Simplified Boiling-Water Reactor (ESBWR) Design Control Document (DCD), Revision 10, referenced in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Appendix E, "Design Certification Rule for the Economic Simplified Boiling-Water Reactor," with no departures or supplements. The U.S. Nuclear Regulatory Commission (NRC) 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." NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The NRC staff's review confirms 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 summary description that were incorporated by reference are 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 turbine rotor integrity to minimize potential impacts on safety-related structures, systems, and components (SSCs).

10.2.2 Summary of Application

Section 10.2 of the Fermi 3 COL FSAR, Revision 7, 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 provides the following:

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[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.

COL Items

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

The applicant addresses DCD COL Item 10.2-1-A in FSAR Subsections 10.2.2.4, 10.2.2.7, 10.2.3.6, and 10.2.3.7. In Subsection 10.2.3.6, the applicant states that the Turbine Maintenance and Inspection Program that supports the original equipment manufacturer's (OEM) turbine missile generation probability calculation is described in DCD Subsections 10.2.2.7, 10.2.3.5, 10.2.3.6, and in General Electric (GE) ST-56834/P, "ESBWR Steam Turbine – Low Pressure Rotor Missile Generation Probability Analysis," Revision 4. ST-56834/P, Revision 4 is a bounding missile probability calculation that contains the associated maintenance and inspection recommendations.

The applicant further addressed COL Item 10.2-1-A in FSAR Subsection 10.2.3.7. This subsection 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 subsection also states that the description of the Valve Inspection Program, including valve and control system maintenance, inspections, testing, and associated frequencies, is provided in ST-56834/P, Revision 4.

In FSAR Subsections 10.2.2.4 and 10.2.2.7, the applicant describes how the information in Subsections 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 Subsection 10.2.3.8, the applicant provided information to address DCD COL Item 10.2-2-A. The applicant states that the probability of generating a turbine missile is based on bounding material property values in the ST-56834/P, Revision 4 report. Since 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 Fermi 3 COL application.

Supplemental Information

- STD SUP 10.2-1 Turbine Design

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

10.2.3 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 turbine generator, and the associated acceptance criteria, are in Sections 10.2 and 10.2.3 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 and associated guidance for the turbine generator are established in:

- 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 1, "Protection Against Low-Trajectory Turbine Missiles"

- NUREG–0800, Subsection 3.5.1.3 and Section 10.2.3

10.2.4 Technical Evaluation

As documented in NUREG–1966, NRC staff reviewed and approved Section 10.2 of the certified ESBWR DCD. The staff reviewed Section 10.2 of the Fermi 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 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 Fermi 3 COL FSAR as follows:

<u>COL Items</u>

- 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 Subsection 3.5.1.3, and to address any valve and control system maintenance, inspections, and tests that are needed.

The applicant addresses COL Item STD COL 10.2-1-A in four FSAR Subsections: 10.2.2.4, "Turbine Overspeed Protection System"; 10.2.2.7, "Testing"; 10.2.3.6, "Inservice Maintenance and Inspection of Turbine Rotors"; and 10.2.3.7, "Inservice Inspection of Turbine Valves." These subsection numbers and titles correspond to subsections in the DCD.

Subsection 10.2.2.4 states that "inspection programs required by the turbine missile probability analysis and implementation of the inspection, maintenance, and testing programs discussed in Subsection 10.2.3.6 and Subsection 10.2.3.7 ensure operability." Subsection 10.2.2.7 states that "non-return valves are inspected and tested in accordance with vendor recommendations, as discussed in Subsection 10.2.3.7." The description of the valve inservice inspection requirement in Subsection 10.2.3.7 is consistent with the DCD, and it 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 ST-56834/P, Revision 4, (Section 10.2) provides this information. The staff therefore found that

[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.

the portion of COL Item STD COL 10.2-1-A that is in FSAR Subsection 10.2.2.4 is acceptable. The staff's review of the turbine missile probability analysis in the ST-56834/P, Revision 4 report is discussed below under COL Item STD COL 10.2-2-A.

According to Acceptance Criterion 4 of SRP Subsection 3.5.1.3, an applicant obtaining the turbine from a manufacturer with an NRC-approved missile probability analysis is required to meet the probabilities listed in Table 3.5.1.3-1. 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 10^{-4} per year for loading a favorably oriented turbine and bringing the system online. For the ESBWR, Section 10.2.1 of the 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 Subsection 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 inservice inspection and valve testing intervals that meet the missile probability criterion. Because the Fermi 3 applicant submitted a missile probability analysis from the manufacturer for NRC approval as part of the COL application, the inspection and valve testing intervals are also expected to be provided by the manufacturer. In FSAR Revision 3, Subsections 10.2.3.6 and 10.2.3.7, the applicant stated that this information is described in DCD Subsections 10.2.2.7, 10.2.3.5, and 10.2.3.6. The staff had previously reviewed these DCD subsections and determined that additional information (i.e., COL 10.2-1-A and 10.2-2-A) is required from a COL applicant.

The staff determined that by only listing DCD subsections as the basis for the inspection and maintenance program, the applicant was not providing new information from the manufacturer as required by the DCD COL Item 10.2-1-A, specifically, the turbine missile probability analysis recommended rotor dovetail inspection and extraction nonreturn valve testing that are not included in the DCD. Therefore, in Request for Additional Information (RAI) 10.02.03-19, the staff requested that the applicant include a requirement for these inspections in the COL FSAR. In the response to this RAI, dated October 28, 2011 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML11305A214), the applicant proposed revising Subsection 10.2.3.6 of the FSAR as follows, with the revised portion identified by the underlined text:

> The turbine maintenance and inspection program that supports the Original Equipment Manufacturer's turbine missile generation probability calculation is described in DCD Subsections 10.2.2.7, 10.2.3.5, and 10.2.3.6, and in GE-ST, "ESBWR Steam Turbine – Low Pressure Rotor Missile Generation Probability Analysis," ST-56834/P, Revision 4.

The staff found this response acceptable because referencing the ST-56834/P, Revision 4 report provides additional maintenance and inspection information to supplement the DCD requirements. The staff's review of the ST-56834/P, Revision 4 report is discussed below under COL Item STD COL 10.2-2-A. This information thereby satisfies the OEM's missile probability calculation, as required by DCD COL Item 10.2-1-A. The staff confirmed that the applicant has included this change in Revision 4 of the COL FSAR. Therefore, this issue is resolved.

The staff reviewed the entire turbine missile probability analysis in the ST-56834/P, Revision 4 report, as discussed below under COL Item STD COL 10.2-2-A. The ST-56834/P report 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

The first three inspections are also listed in DCD Tier 2, Subsection 10.2.3.6. The description of the maintenance and inspection program in Section 10.1 of the ST-56834/P report is consistent with the DCD. In addition, for all of these inspections, the ST-56843/P report 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 inspection interval and the rotor dovetail inspections are not identified in the DCD. Therefore, the staff reviewed this issue as new information provided by the applicant as part of COL Item STD COL 10.2-1-A.

For the rotors, the inservice inspections consist of visual, surface, and volumetric examinations, as described above. Section 10.1.1 of ST-56834/P also states that it is not possible to perform a volumetric examination of 100 percent of the rotor 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 inservice volumetric examination is not possible, GE uses controls on rotor metallurgy, manufacturing, and preservice inspection to limit undetected flaws in the rotor. Section 3.1.3 of the ST-56834/P report describes preservice inspection and testing, which includes a 100 percent volumetric examination and a 100 percent surface examination (including the bore surface of bored rotors).

As discussed in the ST-56834/P report, the probability of a missile generation is dominated by 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 phased array ultrasonic examination
- engineering disposition of flaw indications (and possible removal of buckets for additional surface examination)
- the use of inservice inspection measurements to recalculate missile probability and 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 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. Since the applicant's proposed rotor inspection program, including the 12-year inspection interval, is consistent with the DCD and meets the missile probability requirement in SRP Subsection 3.5.1.3 for bounding materials properties, the staff found the program acceptable. This finding is based, in part, on the staff's detailed review of COL Item STD COL 10.2-2-A, the missile probability analysis.

Section 10.2 of the ST-56834/P report describes the recommended inservice inspection of valves. This section supplements the following statement in FSAR Subsection 10.2.3.7:

> Inspection of all valves of one functional type or size (i.e., stop, control, intercept, non-return) are conducted for any detrimental unusual condition (as defined by the turbine valve inspection program) if one is discovered during the inspection of any single valve.

In the response to RAI 10.02.03-19, the applicant also proposed a revision to FSAR Subsection 10.2.3.7 to address the valve testing requirements in STD COL 10.2-1-A as follows, showing additions (underlined) and deletions (strike-throughs):

> The turbine valve inspection program, including ~~Associated~~ valve and control system maintenance, inspections, testing, and associated frequencies, is described ~~and test frequencies are established in the bounding missile probability analysis~~ in GE-ST, "ESBWR Steam Turbine – Low Pressure Rotor Missile Generation Probability Analysis," ST-56834/P, Revision 4 ~~2, submitted in Reference 10.2-201~~.

In the same response, the applicant proposed deleting FSAR Section 10.2.6, "References," which contained ST-56834/P as the only entry, and correcting the revision number of ST-56834/P to Revision 4 in four places. The staff found these changes acceptable because Revision 4 of ST-56834/P is the latest revision reviewed by the staff, and FSAR Subsections 10.2.3.6 and 10.2.3.7 provide the reference information that makes Section 10.2.6 unnecessary. The staff confirmed that the applicant has included these changes in Revision 4 of the Fermi 3 COL FSAR. Therefore, this issue is resolved.

The staff found that the information in Section 10.2 of the COL FSAR describes the Turbine Maintenance and Inspection Program, which is required to satisfy the manufacturer's turbine missile generation probability calculation. This program is based on the information being consistent with the corresponding information in the DCD and meets the criteria in SRP Subsection 3.5.1.3 related to periodic inspection and testing. Therefore, the staff determined that COL Item STD COL 10.2-1-A is acceptable with respect to providing the valve testing requirements and frequencies. 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).

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 RG 1.115 and in SRP Subsection 3.5.1.3 and Section 10.2.3. In Revision 3 of the COL FSAR, the applicant addressed this COL Item by referencing a bounding analysis in ST-56834/P. Revision 2 of the FSAR referenced Revision 1 of ST-56834/P, dated July 2009. The staff's review of the turbine missile probability analysis included sequential requests for additional information, which resulted in corresponding changes to the missile analysis report and the FSAR (summarized in the following paragraph). This process culminated in Revision 4 of the FSAR referencing Revision 4 of ST-56834/P. The staff's review is described in detail below.

As a result of the responses to RAIs 10.02.03-1 through 10.02.03-11, dated October 5, 2010 (ADAMS Accession No. ML102800185); the responses to RAIs 10.02.03-12 through 10.02.03 16, dated July 29, 2011 (ADAMS Accession No. ML112140345); and the responses to RAIs 10.02.03-17 through 10.02.03-19, dated October 28, 2011 (ADAMS Accession No. ML113050573), the applicant submitted a revised turbine missile analysis, ST-56834/P, Revision 4, in a letter dated October 28, 2011 (ADAMS Accession No. ML11305A217 [public version]). The staff found that the revision to the analysis in ST-56834/P addresses the staff's concerns described below and is therefore acceptable. In addition, the staff noted that Revision 4 of the Fermi 3 COL FSAR was revised to reference the updated Revision 4 of ST-56834/P as the applicant's turbine missile probability analysis for the GE model number N3R-6F52 turbine generator. The staff finds this acceptable since the updated analysis was found to be acceptable as discussed below and is applicable to the Fermi 3 turbine generator.

ST-56834/P provides the analysis for the probability of generating missiles for the GE model number N3R-6F52 turbine generator specified by the COL applicant in Supplemental Information STD SUP 10.2-1. ST-56834/P, Revision 4 provides the methodology, assumptions, and results of the turbine missile generation probability, along with the manufacturer's recommendations for inservice 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 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," issued in July 1986. ST-56834/P, Revision 4 also provides updated data, such as valve failure rates, to demonstrate that the destructive overspeed analysis is conservative. The methodology used consists of calculating the probability of turbine overspeed in conjunction with the probability of 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), brittle fracture of a missed internal flaw growing to 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 material requirements in Revision 2 of 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 ST-56834/P did not provide enough detail about the material properties, including the chemistry, as required by the ESBWR DCD. In addition, Subsection 10.2.3.2.3 of NUREG–1966 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 response to RAI 10.02.03-4, dated October 5, 2010, and the response to RAI 10.02.03-12, dated July 29, 2011, the applicant states that the rotors for the subject turbine use the GE material specification B50A373B8 or equivalent specification with more restrictive chemistry. The applicant points out that this material has been used since the 1980s for numerous integral (nonbored) rotors, with no rotor failures. The applicant also states in these responses 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 the applicant to provide the material specification for the staff's review to ensure that the material specification, including chemistry, is adequate to meet the guidance in SRP Section 10.2.3 concerning chemistry and processing to ensure adequate fracture toughness for the turbine rotor. The applicant's response to RAI 10.02.03-12, dated July 29, 2011, clarifies that the 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 required 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 Subsection 10.2.3.1 of the ESBWR DCD and SRP Section 10.2.3. Therefore, the staff found that the material composition included in Revision 4 of ST-56834/P is acceptable and will be used for the procurement of the Fermi 3 turbine rotor.

Concerning the use of the bounding material properties, the applicant's response to RAI 10.02.03-17, dated October 28, 2011, 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 the July 29, 2011, response to RAI 10.02.03-13. As stated in the response to 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 a 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 RAI 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 were tested, and the corresponding FATT values were well below +30 degrees F (-1.1 degrees C) 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 of -12 degrees C (+11 degrees F), which demonstrates that these large monoblock forgings can achieve the required FATT value of -1.1 degrees C (+30 degrees F). Therefore, the staff found that the bounding material properties of the turbine rotor were used in the analysis.

In addition, in the response to RAI 10.02.03-18, dated October 28, 2011, the applicant clarified that the analysis used design overspeed stresses based on the postulated conditions and events in Section 7 of ST-56834/P. The design overspeed was clarified to be 120 percent of rated speed in the October 5, 2010, response to RAI 10.02.03-3, which is consistent with the ESBWR design overspeed. In the July 29, 2011, response to RAI 10.02.03-15, the applicant states 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. Also, this response provides information 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 found that the analysis used conservative and appropriate stresses in the turbine rotor.

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 RAI 10.02.03-18, dated October 28, 2011, the loading was determined based on both normal and abnormal turbine speed, with assumed annual cyclic loading due to starts, stops, and load swings of the turbine. These stresses were derived using finite element analysis based on the geometry for the N3R-6F52 rotor using corresponding startup transient thermal loadings, as clarified in the applicant's October 5, 2010, response to RAI 10.02.03-9.

The 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, due to the higher stresses at these keyways from past operating experience when compared to the current monoblock forgings. The tangential stress of the dovetail slots in the monoblock forgings are much less than in the previous shrunk-on-wheel keyways, as illustrated in the October 5, 2010, response to 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 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 that the crack size is well within the nondestructive inspection capabilities, as discussed in the July 29, 2011, response to 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 so the analysis would be bounding.

These three failure modes—cyclic fatigue, SSC, and ductile tensile burst—were used to calculate the probability of rupturing the rotor and were then combined to achieve a single probability of rupturing a turbine rotor. This was conducted for various scenarios and turbine speeds, and these 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 result 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 ST-56834/P, Revision 4, meets the criteria in RG 1.115. Section 10.1 of ST-56834/P, Revision 4 also provides the turbine manufacturer's recommendations for the inspection and maintenance program description of 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, Subsection 10.2.3.6. As clarified in the response to RAI 10.02.03-19, dated October 28, 2011, the turbine manufacturer also recommends that 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 dovetail slot bottoms controls the probability of generating a turbine missile after 20 years of operation. The staff found that the proposed description of the inspection program and inspection interval of 12 years is acceptable because it meets the criteria of RG 1.115 and is consistent with the guidelines of SRP Section 10.2.3: to ensure that the turbine rotor integrity is maintained to preclude the generation of a missile.

As clarified by the applicant's response to RAI 10.02.03-2, dated October 5, 2010, a MARK VIe turbine generator control system (TGCS) is used for the ESBWR turbine generator at Fermi 3. This TGCS has the same functional design and component requirements of previous GE turbine generators, with improvements made based on operating experience. Some of the improvements that are detailed in the response to 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 intercept stop valves. In addition, this RAI response includes the steam valve failure rates based on failure assessment data reports collected in 1993 and 2008 and 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 RAI 10.02.03-16, dated July 29, 2011, the improvements made after 1984 were effective in reducing the probability of failures. The failure rates are listed in Section 5 of 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 ESBWR turbine. The overspeed probability from valve failures was performed for valve test intervals of 90 and 120 days, resulting in similar annual missile probabilities, which were provided in the July 29, 2011, response to RAI 10.02.03-16. 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 and the guidance in SRP Subsection 3.5.1.3. Therefore, the staff found the 120-day test interval acceptable because it meets the annual missile probability criteria of 10^{-5} per year in RG 1.115 and the specified guidelines in SRP Subsection 3.5.1.3 and Section 10.2.3 to ensure that the turbine rotor integrity is maintained to preclude the generation of missiles.

Based on the above discussion, the staff found the applicant's referenced turbine missile probability analysis, 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. In addition, the applicant's description of the turbine maintenance and inspection program, which includes the turbine manufacturer's recommendations for inspecting and testing the turbine rotor and associated valves, is consistent with the guidance in SRP Section 10.2.3 and Section 10.2.3 of the ESBWR DCD. Therefore, the staff determined that the applicant has adequately addressed COL Item STD COL 10.2-2-A.

With respect to the review of COL Items STD COL 10.2-1-A and STD COL 10.2-2-A, the staff determined that RAIs 10.02.03-1 through 10.02.03-19 are resolved.

Supplemental Information:

- STD SUP 10.2-1 Turbine Design

In FSAR Subsection 10.2.3.4, the applicant states that GE will manufacture the turbine and generator for the Fermi 3 site. The applicant selected the N3R-6F52 turbine model, which is one of GE's N series nuclear steam turbines. The staff found 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 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 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 are resolved.

In addition, the staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Sections 10.2 and 10.2.3 of NUREG–0800, and other NRC RGs. The staff's review concludes that the information in this section of the COL FSAR is acceptable and meets the requirements of GDC 4. 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 Section 10.2.3 and Subsection 3.5.1.3 of NUREG–0800. 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 Subsection 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, 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. Additionally, the staff reviewed Supplemental Information STD SUP 10.2-1, which provides the turbine model number. The staff 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 Supply System

Section 10.3 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.3 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, with no departures or supplements. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The NRC staff's review confirms 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 turbine main steam supply system that were incorporated by reference are resolved.

10.4 Other Features of Steam and Power Conversion System

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

- Section 10.4.1: The main condenser system 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.

- Section 10.4.2: The main condenser evacuation system establishes and maintains the main steam condenser vacuum and removes non-condensable gases and air from the main condenser.

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

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

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

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

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

- Section 10.4.8: The steam generator blowdown system for pressurized-water reactors (PWRs) is not applicable to the ESBWR design.

- Section 10.4.9: The auxiliary feedwater system for PWRs is not applicable to the ESBWR design.

[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.

10.4.1 Main Condenser

Section 10.4.1 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.4.1 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, with no departures or supplements. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The NRC staff's review confirms 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 main condenser that were incorporated by reference are resolved.

10.4.2 Main Condenser Evacuation System

Section 10.4.2 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.4.2 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, with no departures or supplements. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remains for review.[1] The NRC staff's review confirms 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 main condenser evacuation system that were incorporated by reference are resolved.

10.4.3 Turbine Gland Seal System

Section 10.4.3 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.4.3 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, with no departures or supplements. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The NRC staff's review confirms 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 turbine gland seal system that were incorporated by reference are resolved.

10.4.4 Turbine Bypass System

Section 10.4.4 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.4.4 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E, with no departures or supplements. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue related to this section remains for review.[1] The NRC staff's review confirms 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 turbine bypass system that were incorporated by reference are resolved.

10.4.5 Circulating Water System

[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.

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 Fermi 3 COL FSAR, Revision 7, 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, the applicant provides the following conceptual design information (CDI):

<u>Site-Specific Information Replacing Conceptual Design Information</u>

The applicant replaces the CDI in the DCD with a detailed description of the site-specific system for Fermi 3 as follows:

- EF3 CDI — FSAR Subsection 10.4.5.2.1, "General Description"

The applicant describes the CWS by replacing the design information in the DCD with a more detailed general description of the site-specific system proposed for Fermi 3.

- EF3 CDI — FSAR Subsection 10.4.5.2.2, "Component Description"

In FSAR Table 10.4-3R, the applicant provides site-specific parameters to replace the values in ESBWR DCD, Table 10.4-3, "Circulating Water System."

- EF3 CDI — FSAR Subsection 10.4.5.2.2.1, "CIRC Chemical Injection"

In FSAR Subsection 10.4.5.2.2.1, the applicant provides information on the CWS chemical injection system and water chemistry that is not included in the DCD.

- EF3 CDI — FSAR Subsection 10.4.5.2.3, "System Operation"

In FSAR Subsection 10.4.5.2.3, the applicant provides supplemental information describing the Fermi 3 site-specific CWS operation.

- EF3 CDI — FSAR Subsection 10.4.5.5, "Instrumentation Applications"

In FSAR Subsection 10.4.5.5, the applicant provides instrumentation and test practices in addition to those in the ESBWR DCD, Revision 10.

- EF3 CDI FSAR Subsections 10.4.5.6, "Flood Protection," and 10.4.5.8, "Normal Power Heat Sink"

In FSAR Subsections 10.4.5.6 and 10.4.5.8, the applicant describes the Fermi 3 site-specific cooling tower failure analysis related to flood protection and the normal power heat sink, which is a hyperbolic natural draft cooling tower (NDCT).

10.4.5.3 *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 CWS, and the associated acceptance criteria, are in Section 10.4.5 of NUREG–0800.

The applicable regulatory requirement and associated guidance for the CWS are as follows:

- GDC 4, as it relates to design provisions provided to accommodate the effects of discharging water that may result from a failure of a component or piping in the CWS

10.4.5.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 10.4.5 of the certified ESBWR DCD. The staff reviewed Section 10.4.5 of the Fermi 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 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 CWS.

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

Site-Specific Information Replacing Conceptual Design Information:

- EF3 CDI FSAR Subsection 10.4.5.2.1, "General Description"

In FSAR Subsection 10.4.5.2.1, the applicant provides supplemental information that replaces the design information in the DCD with a more detailed general description of the site-specific CWS proposed for Fermi 3. The supplemental information includes the design and arrangement of the CWS, which consists of (a) one hyperbolic NDCT; (b) four 25-percent capacity circulating water pumps; (c) condenser water boxes; (d) related piping and valves; (e) the water box drain subsystem; and (f) condenser tube cleaning equipment. The system configuration for the Fermi 3 CWS is depicted in FSAR Figures 10.4-201 and 10.4-202, which replace the conceptual diagram in Figure 10.4-1 of the DCD. The staff reviewed the design information in FSAR Subsection 10.4.5.2.1 and found that the applicant has addressed the final configuration of the Fermi 3 CWS, as specified in Subsection 10.4.5.2.1 of the ESBWR DCD, Revision 10. Also, the staff found that the configuration and piping and valve arrangement of the CWS are in agreement with the conceptual design—as recommended in the DCD—and are therefore acceptable.

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[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.

Furthermore, the CWS design includes vents to help fill in and remove air and other non-condensable gases from the condenser water boxes during startup and normal operations. The system includes design features such as the slow-stroke, motor-operated valves; air- and vacuum-release valves; control and interlock features that ensure the proper valve lineup before pump startup; and discharge isolation valves that open and close with pump start and stop signals. These provisions will minimize pressure transients during startup and normal operations of the system. The staff found that these vents, air releases, and vacuum-relief valve provisions in the CWS adequately address the requirements of GDC 4 as it relates to design features that accommodate the effects of discharging water and prevent water hammer and subsequent CWS piping or component failures from occurring at pump startup due to initial system pressurization.

- EF3 CDI FSAR Subsection 10.4.5.2.2, "Component Description"

In FSAR Table 10.4-3R, the applicant provides site-specific parameters to replace the values in ESBWR DCD, Table 10.4-3. The staff found that the operating temperatures and circulating water pump information in FSAR Table 10.4-3R are acceptable because they are bounded by the values in the ESBWR DCD.

- EF3 CDI FSAR Subsection 10.4.5.2.2.1, "CIRC (CWS) Chemical Injection"

FSAR Subsection 10.4.5.2.2.1 provides information on the CWS chemical injection system and water chemistry that is not included in the ESBWR DCD. The proposed chemical injection maintains a noncorrosive, non-scale-forming condition. This condition ensures that biological film growth that may affect the condenser heat transfer rate does not occur. This section also provides the chemicals used, as specified by plant chemistry, to control the circulating water chemistry. In addition, the section states that the selected chemicals are compatible with the selected materials or components used in the CWS.

The staff reviewed the information in the FSAR and found that the applicant has adequately identified the chemicals to be used for chemical treatment of the 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 there are 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.

- EF3 CDI FSAR Subsection 10.4.5.2.3, "System Operation"

In FSAR Subsection 10.4.5.2.3, the applicant provides supplemental information describing the Fermi 3 site-specific CWS operation that is not included in the ESBWR DCD. The applicant states that leakage from the main condenser into the CWS through a condenser tube leak is not likely to occur during power operation because the CWS normally operates at a greater pressure than the shell (condensate) side of the condenser. This pressure difference prevents radioactive releases into the circulating water, and the staff therefore found the applicant's supplemental information describing the CWS operation acceptable.

Furthermore, the applicant states that the analysis of routine cooling tower grab samples will detect events that could lead to unmonitored and uncontrolled radioactive releases into the environment. The applicant adds that this action satisfies the requirements of Inspection and Enforcement (IE) Bulletin (BL) No. 80-10, "Contamination of Nonradioactive System and Resulting Potential for Unmonitored, Uncontrolled Release of Radioactivity to Environment." Consistent with BL 80-10, FSAR Sections 11.2, "Liquid Waste Management Systems," and 11.4, "Solid Waste Management Systems," address the issue of preventing and monitoring for cross-contamination of systems not normally radioactive that could become contaminated through interactions with the operating conditions in radioactive systems. Sections 11.2 and 11.4 of this SER provide the staff's evaluation of this issue.

- EF3 CDI FSAR Subsection 10.4.5.5, "Instrumentation Applications"

The applicant provides the following instrumentation and test practices in addition to those in the ESBWR DCD, Revision 10:

a. Level instrumentation in the circulating water pump pit to control makeup flow from the station water system to the NDCT basin, including alarms in the main control room for an abnormally low or high water level

b. 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

c. Local grab samples used to periodically test the circulating water quality

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

- EF3 CDI FSAR Subsection 10.4.5.6, "Flood Protection," and Subsection 10.4.5.8, "Normal Power Heat Sink"

In FSAR Subsection 10.4.5.8, the applicant describes the Fermi 3 site-specific normal power heat sink, which consists of one NDCT. The applicant states that the NDCT will be located at least a distance equal to its height away from Seismic Category 1 and 2 structures. Therefore, there is no potential for the cooling tower to fall and damage safety-related structures or components. Furthermore, the NDCT is made from noncombustible materials.

The staff reviewed the applicant's information and could not find additional details on the location of the NDCT. The staff also could not find any design features to prevent flooding or control the effects from a flood in case a cooling tower failed on nearby safety-related areas or near the safety-related SSCs, as they relate to the requirements of GDC 4. In addition, there was no information in the FSAR with respect to Subsection 10.4.5.6, "Flood Protection," of the ESBWR DCD, Revision 9. In accordance with SRP Section 10.4.5, "Circulating Water System," 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, in RAI 10.04.05-1, the staff requested the applicant to provide additional information about (1) the cooling tower failure analysis; (2) provisions incorporated into the Fermi 3 CWS design to prevent the unacceptable flooding of areas containing safety-related equipment; or (3) provisions incorporated into the Fermi 3 CWS design to mitigate the consequences of flooding.

The applicant's response to RAI 10.04.05-1, dated January 29, 2010 (ADAMS Accession No. ML100331450), refers to a response that was included as part of the response to RAI 02.04.02-3, dated November 20, 2009 (ADAMS Accession No. ML093280179). In that response, the applicant states that the failure of a pipe or component in the NDCT or elsewhere in the CWS would not have an adverse impact on the design functions of safety-related SSCs. The applicant also states that the largest components in the NDCT are the CWS discharge piping. The four CWS pumps are arranged in parallel, and the discharge lines combine into two parallel main circulating water supply lines to the main condenser. A pipe break in the combined line would be a limiting pipe break scenario. For the most part, the CWS pipes are routed below grade. A postulated rupture of one of the CWS pipes above grade would result in water flowing into the area of the yard near the NDCT. However, the NDCT is located at an elevation lower than the power block area where Category I structures are located. Also, in Revision 2 of the FSAR, the applicant provided supplemental information in Subsection 10.4.5.6 to reflect the above response, in which the applicant states that the grade elevation where Category I structures are located will be more than 2.1 meters (7 feet) above the current elevation. The NDCT is not located in the area that is being elevated. Therefore, the applicant states that the water discharged from the postulated break in the CWS line above grade will flow away from the power block. Furthermore, FSAR Figures 2.1-204 and 2.4-215 provide the relative location of the NDCT with respect to the power block structure and the extent of the area that will be elevated.

In addition, the applicant states in the RAI response that the pipe failures above ground bound other piping and component failures in the CWS because the underground and smaller-diameter components will have lower flow rates than in a postulated failure of the above-ground, large-bore CWS pipe. The discharge water from such a failure will flow away from any safety-related structures and will not cause any flooding to these structures. Also, the applicant considers a failure of the NDCT basin and states that such a failure will have no effect on safety-related structures because the NDCT is lower than the grade elevation of the power block, and the basin water level elevation is lower than the levels in the surrounding areas.

Based on the above discussions, the staff found that the applicant's response to RAI 10.04.05-1 is acceptable because it provides design provisions to accommodate the effects of discharging water that may result from a failure of a component or piping in the CWS. Therefore, this RAI 10.04.05-1 is closed. In addition, the staff found that the conclusions in NUREG–1966 regarding the requirements of GDC 4, with respect to the effects of discharging water that may result from the failure of a component or piping in the CWS, remain valid.

10.4.5.5 *Post Combined Operating License Activities*

There are no post COL activities related to this section.

10.4.5.6 *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 confirms that the applicant has addressed the required information relating to the CWS, 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 CWS that were incorporated by reference are resolved.

In addition, the staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 10.4.5 of NUREG–0800, and other NRC RGs. The staff's review concludes that the site-specific CDI for the CWS in this section of the Fermi 3 COL FSAR is acceptable and does not change the conclusions of NUREG–1966. The staff found that the EF3 CDI for the CWS meets the relevant NRC regulations and acceptance criteria defined in NUREG–0800, Section 10.4.5. The staff also concludes that the information presented for the EF3 CDI is acceptable and meets the requirements of GDC 4.

10.4.6 Condensate Purification System

10.4.6.1 *Introduction*

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

10.4.6.2 *Summary of Application*

Section 10.4.6 of the Fermi 3 COL FSAR, Revision 7, 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:

<u>*COL Item*</u>

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

In FSAR Subsection 10.4.6.3, the applicant adds information about the chemistry parameters in the CPS to address COL Item STD COL 10.4-1-A. The applicant provides FSAR Table 10.4-201, which summarizes the manufacturer's recommended threshold values of the chemistry parameters and the associated operator actions.

<u>*Supplemental Information*</u>

- EF3 SUP 10.4-1

In FSAR Subsection 10.4.6.2, the applicant provides plant-specific supplemental information that adds a sentence stating that the CPS condensate filters and demineralizers are capable of accommodating 100 percent of the feedwater flow.

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 the Commission regulations for the CPS, and the associated acceptance criteria, are in Section 10.4.6 of NUREG–0800.

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, NRC staff reviewed and approved Section 10.4.6 of the certified ESBWR DCD. The staff reviewed Section 10.4.6 of the Fermi 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 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 CPS.

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

COL Item:

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

The applicant provides FSAR Table 10.4-201, which 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) hydrogen water chemistry guidelines. The staff found 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, the EPRI BWR water chemistry guidelines, and the requirements of GDC 14.

Supplemental Information

- EF3 SUP 10.4-1

The applicant adds a sentence stating that the CPS condensate filters and demineralizers are capable of accommodating 100 percent of the feedwater flow. The staff found this statement acceptable because this design feature gives the system the capabilities to operate in a cascading configuration, while accommodating 100 percent of the feedwater flow.

10.4.6.5 *Post Combined License Activities*

There are no post COL activities related to this section.

10.4.6.6 *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 relating to the CPS, 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 CPS that were incorporated by reference are resolved.

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[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.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 10.4.6 of NUREG–0800, and other NRC RGs and industry standards. The staff's review concludes that the information in this section of the Fermi 3 COLA FSAR is acceptable and meets the requirements of GDC 14 and the NRC-endorsed EPRI guidelines for BWR hydrogen water chemistry. The staff evaluated COL Item STD COL 10.4-1-A and Supplemental Information EF3 SUP 10.4-1 in this section and finds that the applicant has satisfactorily addressed these items.

10.4.7 Condensate and Feedwater System

10.4.7.1 *Introduction*

This FSAR section addresses the C&FS, which receives condensate from the condenser hotwell; supplies condensate to the CPS; and delivers high-purity feedwater to the reactor at the required flow rate, pressure, and temperature. The C&FS does not serve or support any safety function and has no safety design basis. A failure of this system will not compromise any safety-related system or prevent a safe shutdown.

10.4.7.2 *Summary of Application*

Section 10.4.7 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 10.4.7 of the certified ESBWR DCD, Revision 10, referenced in 10 CFR Part 52, Appendix E. In addition, in FSAR Section 10.4.7, the applicant provides the following:

Supplemental Information

- EF3 SUP 10.4-2

The applicant provides supplemental information stating that the C&FS components can accommodate 100 percent feedwater flow to support a cascading feedwater configuration.

10.4.7.3 *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 C&FS, and the associated acceptance criteria, are in Section 10.4.7 of NUREG–0800.

10.4.7.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 10.4.7 of the certified ESBWR DCD. The staff reviewed Section 10.4.7 of the Fermi 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the 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 C&FS.

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

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[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.

Supplemental Information

- EF3 SUP 10.4-2

The Fermi 3 COL FSAR, Revision 3, Section 10.4.7 did not include any departures, COL items, supplemental information, or standard content. However, in the response to RAI 12.02-7, dated August 5, 2011 (ADAMS Accession No. ML11221A075), the applicant proposed to add new supplemental information in FSAR Subsection 10.4.7.2.1 by adding the following sentence: "The C&FS components can accommodate 100 percent feedwater flow to support a cascading feedwater configuration."

The staff reviewed the proposed change to FSAR Subsection 10.4.7.2.1. The staff found that in the ESBWR DCD, the steam and power conversion system design and the balance of plant (BOP) heat balance were based on the C&FS operating in a pumped-forward configuration. While the staff's review of the DCD information did indicate that the C&FS is capable of being configured to operate in a cascading configuration, the staff found that the DCD does not discuss the operation of the system in the cascading mode, nor does the DCD directly identify a system configuration for routing 100 percent of the feedwater flow through the CPS, as stated in the proposed supplemental information to be added to the Fermi 3 COL FSAR. Therefore, the staff issued RAI 10.04.07-1 requesting the applicant to clarify whether the proposed change to the COL FSAR constitutes a departure. The RAI also asked the applicant to provide appropriate justification for the applicant's determination on the classification of the added information, along with supporting information to specify how operating in the cascading mode is bounded by the relevant evaluation included in the ESBWR DCD.

The applicant's response to RAI 10.04.07-1, in a letter dated December 14, 2011 (ADAMS Accession No. ML11350A200), indicates that the information added to the COL FSAR pertaining to the operation of the C&FS in a cascading configuration does not represent a deviation from the design information in the DCD; it is therefore not considered a departure. In support of that determination, the applicant provides the following:

- The supplemental information added to Chapter 10 of the FSAR ensures sufficient capacity in the C&FS and CPS to allow full feedwater flow to pass through the CPS.
- The ESBWR feedwater heater drain systems are normally operated in a pumped forward configuration. The Fermi 3 FSAR does not modify the ESBWR DCD description of normal plant operation; i.e., Detroit Edison intends to operate Fermi 3, as described in the DCD, in a pumped forward configuration.
- The ESBWR DCD safety analyses and anticipated operational occurrences analyses are not impacted by operation in the cascade configuration because feedwater temperature must be maintained within the feedwater temperature operating domain. If necessary, Feedwater Heater No. 7 can be placed into service to ensure that feedwater system temperature is maintained within the operating domain.
- When operating in a cascade configuration, feedwater heaters will remain in service. Feedwater flow will continue to be controlled and regulated by ESBWR control systems. ESBWR setpoints and controls maintain feedwater within the feedwater temperature operating domain throughout evolutions of balance of plant (BOP) system configurations. Thus, reactor safety is unaffected by operation in a cascade configuration. Cascade configuration does not impact safety-related functions or components.

- The FSAR and DCD describe the design bases, design features, and system functional requirements that are implemented during detailed design and procurement for the construction of the plant. The BOP system capacity identified in the Fermi 3 FSAR supplements will be applied during detailed design activities by implementing the design requirements of the ESBWR DCD. For example, codes and standards referenced by the ESBWR DCD will be implemented as described by the DCD. DCD Chapter 3, "Design of Structures, Components, Equipment, and Systems," describes the ESBWR design criteria, including classification, flood protection, protection against dynamic effects associated with the postulated rupture of piping, and seismic design requirements, among others.
- As described in the DCD, C&FS and CPS will have sufficient capacity and control stability to accommodate normally anticipated step and ramp changes in reactor power.

The staff reviewed the information provided in the applicant's response to RAI 10.04.07-1 relevant to the supplemental information proposed to be added to FSAR Subsection 10.4.7. The RAI response indicates that the C&FS will normally be operated in the pumped forward configuration but may at times be run in a cascade configuration, based on operational conditions and reactor water iodine concentrations, if necessary to control reactor water iodine concentrations.

The staff reviewed the applicant's response as to why the ESBWR safety analyses and anticipated operational occurrence analyses are not impacted by operation of the C&FS in a cascade configuration. The applicant clarifies that when operating in the cascade configuration, the feedwater temperature can be maintained within the feedwater temperature operating domain by placing Feedwater Heater No. 7 into service, if necessary. The staff agreed that the C&FS in the ESBWR DCD bounds the Fermi 3 C&FS operation in the cascade configuration. In addition, the design features and system functional requirements that are in operation during detailed design and procurement will provide for equipment selection that supports the 100 percent feedwater flow through the entire C&FS.

Based on the above review, the staff found the addition of the Supplemental Information EF3 SUP 10.4-2 acceptable because the evaluation of the C&FS in the ESBWR DCD bounds the C&FS cascade configuration operation that the applicant proposed to add to Subsection 10.4.7.2.1 of the Fermi 3 COL FSAR. In addition, the staff verified that this information is in Revision 4 of the FSAR. Therefore, this RAI 10.04.07-1 is closed.

10.4.7.5 *Post Combined License Activities*

There are no post COL activities related to this section.

10.4.7.6 *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 relating to the C&FS, 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 C&FS that were incorporated by reference are resolved.

In addition, the staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 10.4.7 of NUREG–0800, and other NRC

RGs. The staff's review concludes that the applicant has satisfactorily addressed Supplemental Information EF3 10.4-2. Furthermore, because the ESBWR DCD bounds C&FS system operation in the cascade configuration, the proposed operation of the C&FS is acceptable since it does not change the conclusions arrived at in NUREG–1966.

10.4.8 Steam Generator Blowdown System (PWR)

As stated in the ESBWR DCD, this section is not applicable to the ESBWR design.

10.4.9 Auxiliary Feedwater System (PWR)

As stated in the ESBWR DCD, this section is not applicable to the ESBWR design.