Advanced Safety Evaluation Report With No Open Items for the U.S. EPR

Chapter 10, “Steam and Power Conversion System”

CONTENTS

LIST OF FIGURES

No figures were included in this chapter.

LIST OF TABLES

10 STEAM AND POWER CONVERSION SYSTEM

10.1 Summary Description

This section of the applicant's Final Safety Analysis Report (FSAR) contains an introductory description of the steam and power conversion systems and is summarized below in this report. A more detailed description of the content of the application, and the staff's evaluation of that information, is provided in Sections 10.2, 10.3, and 10.4 of this report.

Thermal energy from the reactor is transferred to the main turbine generator (TG) for conversion into electric energy by the steam and power conversion system. The main elements of the steam and power conversion system include the main steam supply, TG, main condensers, circulating water, condensate and feedwater, and emergency feedwater systems.

10.2 Turbine Generator

This section of the report describes the TG for the U.S. EPR. The TG converts the thermal energy supplied by the main steam supply system (MSSS) into electrical energy.

10.2.1 Introduction

The TG is a non-safety-related system that converts the energy of the steam produced in the steam generators (SGs) into mechanical shaft power and then into electrical energy. The flow of steam is directed from the SGs to the turbine through the MSSS, turbine stop valves, and turbine control valves. After expanding through a series of turbines, which drives the main generator, exhaust steam is transported to the main condenser.

10.2.2 Summary of Application

FSAR Tier 1: FSAR Tier 1 sections associated with the TG include Section 2.8.1, "Turbine-Generator System Instrumentation and Control I&C," and Section 2.8, "Steam and Power Conversion Systems." The basic configuration of the TG is shown in FSAR Tier 1, Figure 2.8.1-1, "Turbine Generator System Basic Configuration," and the location of equipment is listed in FSAR Tier 1, Tables 2.8.1-1, "Turbine-Generator System Equipment Mechanical Design," and FSAR Tier 1, 2.8.1-2, "Turbine-Generator System Equipment I&C and Electrical Design," that is all equipment is located in the Turbine Building. FSAR Tier 1, Section 2.8.1, "Turbine-Generator System," makes the following additional statements regarding the TG:

- Turbine overspeed control is provided by a separate turbine overspeed protection system, in addition to the normal speed control function, and is included to minimize the possibility of turbine rotor failure and turbine missile generation.
- Turbine rotor integrity is provided through the combined use of selected materials with suitable toughness, analyses, testing, and inspections.
- The probability of turbine missiles (material failure with overspeed-related failure) is $<1 \times 10^{-4}$ per turbine year.
- This orientation of the TG is favorable with respect to protection from turbine missiles.

FSAR Tier 2: FSAR Tier 2, Section 10.2, "Turbine-Generator," and FSAR Tier 2, Section 3.5.1.3, "Turbine Missiles," provide the following information. The TG performs no safety-related functions and, therefore, has no nuclear safety-related design bases. Selected TG principal design features include:

- The TG is designed for base load operation. The design of the TG has provisions for load following for future consideration.

- The TG is capable of a load step of 10 percent of rated load below 50 percent power or a ramp rate of 5 percent per minute of actual load in the range of 50 to 100 percent, without causing a turbine trip (TT).

- The TG is designed to trip automatically under abnormal conditions and to accept a sudden loss of full load without exceeding design overspeed.

ITAAC: Inspections, tests, analyses, and acceptance criteria (ITAAC) for the turbine-generator are shown in FSAR Tier 1, Table 2.8.1-3, "Turbine-Generator System Inspections, Tests, Analyses, and Acceptance Criteria."

Technical Specifications: There are no Technical Specification (TS) requirements associated with the TG.

10.2.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are listed in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (hereafter referred to as the SRP), Section 10.2, "Turbine Generator," and are summarized below. Review interfaces with other sections can also be found in SRP Section 10.2, Item I, "Areas of Review."

1. Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion (GDC) 4, "Environmental and dynamic effects design bases," as it relates to the TG for the protection of structures, systems, and components (SSCs) important to safety from the effects of turbine missiles.

2. 10 CFR Part 52, 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and U.S. Nuclear Regulatory Commission (NRC) regulations.

Acceptance criteria adequate to meet NRC regulations and SRP guidance include:

1. A turbine control and overspeed protection system should control turbine action under all normal or abnormal operating conditions and should meet the single failure criterion.

2. The TG main steam stop and control valves and reheat steam stop and intercept valves should protect the turbine from exceeding set speeds and should protect the reactor system from abnormal surges.

3. The TG should have the capability to permit periodic testing of components important to safety while the unit is operating at rated load.

4. The turbine forged or welded rotor should be made from a material and by a process that tends to minimize flaw occurrence and maximize fracture toughness properties.

10.2.4 Technical Evaluation

Reviews of the application and supporting FSAR Tier 2 information were performed in accordance with SRP Sections 10.2 and 10.2.3, Subsection III, Review Procedures. The results and conclusions reached are as follows:

10.2.4.1 *Turbine Generator*

The steam and power conversion (SPC) system is designed to remove heat energy from the reactor and to generate electric power in the TG. Steam generated in the four SGs is supplied via the MSSS to the main turbine. The turbine exhaust steam is then condensed and deaerated in the main condenser where rejected heat is transferred to the circulating water system. Feedwater pumps return the condensate to the SGs through regenerative feedwater heaters that heat the condensate using extraction steam from the turbines. A turbine bypass system (TBS) is provided in the design to discharge at least 50 percent of the reactor's design steam flow, with one bypass valve out-of-service directly to the condenser for startup, hot shutdown, cooldown, and certain plant transients. FSAR Tier 2, Section 10.1, "Summary Description" of the Steam and Power Conversion (SPC) system, and FSAR Tier 2, Table 10.1-1,"Major Steam System Parameters and Turbine-Generator Design Data," provide a description of the SPC system, as well as the design data and protective features.

This report addresses the design of the main turbine-generator system as described in FSAR Tier 2, Sections 10.1 and 10.2. An alternative turbine design originally described in FSAR Tier 2, Sections 10.1.A and 10.2A has been withdrawn from the design certification application in response to RAI 106, Question 10.02-5 (applicant's March 31, 2009, response). Since it is no longer part of the design, it is not discussed further in this report. The staff's evaluation of the condensate and feedwater system is discussed in Section 10.4.7 of this report. Other steam and power conversion systems such as the main steam supply system, main condensers, condenser evacuation system, gland sealing system, turbine bypass system, circulating water, condensate cleanup, steam generator blowdown, and emergency feedwater systems are evaluated in later sections of Chapter 10 of this report.

Main Turbine System

The TG is a non-safety-related system that converts the energy of the steam produced in the SGs into mechanical shaft power and then into electrical energy. Main steam is provided to the single-flow high pressure (HP) turbine through a pair of four stop and control valves that regulate steam flow. The HP turbine exhaust steam is reheated in two moisture separators which then supply the single-flow intermediate pressure (IP) turbine through stop and intercept valves. After expanding across the IP turbine blading, steam flows to the three double-flow low pressure (LP) turbines. The HP and IP turbines are contained in a common casing. The main condenser condenses the LP turbine exhaust steam and transfers cycle heat to the circulating water system. The turbines are connected in tandem and operate at 188.5 radians/second (1800 rpm). A three-phase synchronous electric generator is coupled directly to the turbine shaft. The generator has a hydrogen-cooled rotor and water-cooled stator and is provided with a static excitation system coupled to its shaft. According to FSAR Tier 2, Table 10.2-1, “Performance Characteristics,” of the TG, the generator is nominally rated at 1710 MWe. Descriptions of major components and valves are provided in FSAR Tier 2, Section 10.2.2.1.1, “TG Package Equipment.”

The staff reviewed the TG system in accordance with SRP Section 10.2. The design of a TG system is acceptable if the integrated design meets the requirement of GDC 4 as it relates to the protection of the SSCs important to safety from the effects of turbine missiles. Also, to satisfy GDC 4, the SRP recommends a turbine overspeed protection system (with suitable redundancy and diversity) to minimize the probability of turbine missiles. Further, the SRP describes the specific criteria acceptable to meet the requirements of GDC 4. The staff’s review of the TG system includes FSAR Tier 2, Section 10.2, including the general arrangements, design descriptions and principal design features, valve descriptions, turbine supervisory instrumentation, and performance characteristics as depicted in FSAR Tier 2, Table 10.2-1. The heat balance information, design features, and performance characteristics conform to the U.S. EPR’s TG megawatt rating; thus, the staff finds that the steam and power conversion system is designed for the maximum expected energy from the nuclear supply system.

The TG system performs no safety-related functions and is appropriately designed as non-safety-related. Nonetheless, the failure of the TG could affect the functioning of safety-related SSCs. The staff reviewed the TG system in accordance with the guidance provided in SRP Section 10.2, focusing on those portions of the TG system, its subsystems and components that are considered essential for the safe integrated operation of the reactor facility. According to FSAR Tier 1, Tables 2.8.1-1 and 2.8.1-2, all TG equipment is located in the Turbine Building. Based on the staff’s review of FSAR Tier 2, Table 3.2.2-1, “Classification Summary,” there are no safety-related systems or components that have been identified as being located in the Turbine Building; thus, a failure in the TG package does not directly affect any SSCs important to safety. (Turbine missiles are evaluated in Section 10.2.3 of this report). Verification of the location of TG equipment will be performed via ITAAC 2.2 contained in FSAR Tier 1, Table 2.8.1-3.

TG Arrangement and Orientation

Regarding the general arrangement of the TG system, SRP Section 10.2, Subsection III, Item 1 describes the staff review of the system, the piping and instrumentation diagrams (P&IDs), and the general arrangement of the TG system. This review is intended to ensure that the TG system and associated equipment are safe for an integrated operation of the reactor facility. The staff reviewed the orientation of the TG in Section 3.5.1.3 of this report.

Turbine Steam Admission and Non-Return Extraction Steam Valves

The electrohydraulic governor and the primary and emergency backup systems actuate to close the turbine stop, control, intermediate stop, intercept, and spring-assisted extraction steam non-return isolation valves to prevent the turbine rotor from exceeding its design overspeed limit of 120 percent of rated speed. The four turbine stop and four intermediate stop valves are redundant from their respective four control and four intercept valves. The valve arrangements are typical of designs previously approved by the staff. The details of these valves are provided in FSAR Tier 2, Section 10.2.2.1.1. The valve closure times for the turbine stop and control valves and the reheat stop and intercept valves are approximately 0.3 seconds, and are based on preventing turbine overspeed following a loss-of-full load.

In an April 26, 2012, response to RAI 430, Questions 10.02-9 and 10.02-10, the applicant provided additional information and a markup to FSAR Tier 2, Section 10.2.2.1.1. The markup provided further details, such as the location, number, and type of these non-return valves in various extraction lines to the feedwater heaters (FWH). Air-assisted swing check valves with piston actuator, air-to-open, spring-to-close type are used on the high pressure extraction lines to FWHs 6 and 7, as well as, to intermediate FWHs 3 and 4 to prevent turbine overspeed; whereas, swing check valves without an actuator are used on the extraction to deaerating FWH to prevent water induction into the turbine. The applicant further stated that this extraction line to the deaerator does not need air-assisted valves since the reheat stop and control valves are installed in the steam line downstream of the moisture separator reheater (MSR), which prevent an uncontrolled overspeed from occurring in case of steam backflow to the turbine. FSAR Tier 2, Figure 10.2-5, "Non-Return Valve Air Schematic," is a representative diagram of the air line.

Based on a review of the information in FSAR Tier 2, Section 10.2.2.1.1 and responses to RAI 430, Questions10.02-9 and 10.02-10, the staff concluded that the U.S. EPR steam admission and NRVs are designed with adequate provisions to prevent turbine overspeed and water induction into the turbine. Further, based on the above discussions on TG position and orientation, the staff finds that the applicant adequately addressed the considerations referred to in SRP Subsection III Item 3, and that the design ensures that no single valve failure can disable, due to the valve redundancy, or otherwise compromise the overspeed control function of the TG system. Therefore, the staff finds the design acceptable in this regard. Accordingly, the staff considers RAI 430, Questions 10.02-09 and 10.02-10 resolved.

10.2.4.2 *Turbine Generator System Overspeed Protection Instrumentation and Controls*

This section of the report discusses the TG normal control and overspeed protection devices (e.g., digital, software, and hardware) and associated subsystems and components. The staff used the guidance of SRP Section 10.2 to determine that the requirements of GDC 4 criteria, as it relates to the TG system for the protection of the SSCs important to safety from the effects of turbine missiles by providing a turbine overspeed protection system (with suitable redundancy) to minimize the probability of generation of turbine missiles, are satisfied. The intent of this review of the TG in this section is to verify:

- The capability of the TG control and overspeed protection systems to:
  - Detect a turbine overspeed condition
  - Actuate appropriate system valves or other protective devices
  - Preclude an overspeed condition that exceeds the design overspeed
- The overspeed protection instrumentation and controls with respect to:
  - Redundancy, diversity, and independency
  - Testability
  - Reliability

FSAR Tier 2, Section 10.2.2.9, "Overspeed Protection," states that the overspeed protection for the turbine is provided by:

- Electrohydraulic governor system
- A primary overspeed electrical trip system
- A backup overspeed electrical trip system
- Manual TT button located in the main control room (MCR) and manual TT button local to the turbine

The staff also issued RAIs and follow-up RAIs that are listed below, to obtain sufficient information regarding the redundancy, independency, and diversity of the TH control and protection systems. The applicant provided additional information in response to the staff's RAIs to address these considerations. The applicant also provided FSAR Tier 1 and Tier 2 markups to include corresponding changes in the next revision of the FSAR. The staff's evaluation of these responses and FSAR markups are reflected appropriately in the following subsections of this report.

The staff reviewed the U.S. EPR T&G Instrumentation and Controls (I&C) in FSAR, Revision 3. Based on its review of the letter dated July 27, 2010, in RAI 430, Questions 10.02-8, 10.02-9, and 10.02-10, the staff requested that the applicant ensure that the FSAR markup language is included in the next FSAR revision. In several final responses to RAI 430, Questions 10.02-8, 10.02-9, and 10.02-10, dated June 9, 2011, and April 26, 2012, the applicant modified FSAR, Revision 3 turbine generator system (TGS) I&C design descriptions and submitted FSAR markup responses labeled, "Interim Revision 4." Therefore, the staff considered all FSAR Interim Revision 4 markups in the responses to RAI 430 as confirmatory items to ensure that the FSAR markup language is included in the next docketed FSAR revision. The staff reviewed FSAR Revision 4 and considers these confirmatory items closed.

10.2.4.2.1 TGS I&C Control System Normal Conditions

The guidance of SRP Section 10.2, Section II, "Acceptance Criteria," Item 1.A, provides that the TG control system should control turbine action under all normal operating conditions. FSAR Tier 2, Sections 10.2.2.5 through 10.2.2.8 provide design descriptions for the TG control system. The staff reviewed and evaluated these design descriptions for compliance with the requirements of the above SRP guidance.

FSAR Tier 2, Section 10.2.2.5, "TG Control System," provides that two redundant, digital speed governors give main steam control valves and reheat control valve position commands. Also, FSAR Tier 2, Section 10.2.2.1.1, "TG Package Equipment," states that the primary function of the control valves is to control steam flow to the turbine in response to the turbine trip system system.

As described in FSAR Tier 2, Sections 10.2.2.5 and 10.2.2.8, the normal speed digital governor control process works as follows:

1. Three normal speed sensors produce three separate analog signals that are sent to both of the redundant speed governors.

2. The two speed governors process the analog signals, provide position commands to the main steam valves and reheat control valves flow control units.

3. The flow control units send positioning signals to their respective control valve's electrohydraulic actuator, which positions the control valves for speed control through the normal turbine operating range.

Further, FSAR Tier 2, Section 10.2.2.6 requires that the speed control is used during startup and has a minimum adjustable set point range of zero to 100 percent of rated speed and that the speed governors for normal speed-load control fully closes the control and intercept valves at 103 percent of rated turbine speed. The maximum rotational speed attainable upon loss of a single normal governing device does not exceed 103 percent of rated turbine speed. Load control is used during normal operation and has a set point range of zero to 100 percent of maximum capacity.

The staff finds that for normal speed-load control, the speed governor action of the electrohydraulic control system cuts off steam at approximately 103 percent of rated turbine speed by closing the control and intercept valves, which conforms to the guidance in SRP Section 10.2, Subsection III, Item 2.C.

10.2.4.2.2 TG Protection and Overspeed Control Systems for Abnormal Conditions

SRP Section 10.2, Section II, provides that the turbine control and overspeed protection systems should control turbine actions under all abnormal operating conditions and should ensure that a full-load TT will not cause an overspeed beyond acceptable limits. Further, the staff reviewed the U.S. EPR TG protection and overspeed design descriptions for the abnormal operating conditions and its evaluation is provided below.

Turbine overspeed protection – design overview

FSAR Tier 2, Section 10.2.2.9, "Overspeed Protection," provides that there are three independent electronic channels that energize three solenoid valves. Each solenoid valve acts on two hydraulic relays of the trip block in order to perform a hydraulic two-out-of-three (2 out of 3) trip voting. The solenoid valves are kept energized by separate electronic relays that are part of the three electronic protection channels of the turbine triple redundant protection system. The turbine triple redundant protection system schematic is shown in FSAR Tier 2, Figure 10.2-2, "Overspeed Protection System Schematic." Upon de-energizing at least 2 out of 3 electronic relays of the triple redundant protection system electronic protection channels, this will de-energize the trip block solenoid valves that will act on hydraulic relays of the trip block which will discharge the pressurized fluid supplied by the trip block and will allow the high pressure and intermediate pressure valves to close by spring action initiating a TT by closing the control valves, thereby shutting off main steam flow to the turbine. The trip block is the interface between the electronic and hydraulic turbine steam flow control systems. The trip block schematic is shown in FSAR Tier 2, Figure 10.2-3.

Electronic TT signals received from the TGS overspeed control and protection systems and/or other associated plant I&C systems, as well as manual TT actuation signals, are sent to the electronic turbine triple redundant protection system. As noted, after receipt of a trip signal, the hydraulic controllers for the main stop, control, reheat stop, and intercept valves, shut the respective valves. In addition, the air supply solenoid valve of each extraction non-return valve will move to the exhaust position to close the check valves.

Primary and Backup Overspeed Protection Systems (Mechanical versus Electrical)

The guidance of SRP Section 10.2, Subsection III, "Review Procedures," Item 2.C states that the reviewer verifies and determines that a mechanical (primary) overspeed trip device (system) will actuate the control, stop, and intercept valves at approximately 111 percent of rated speed. Further, the criteria in SRP Section 10.2, Subsection III, Item 2.D, describes how an independent and redundant backup electrical trip circuit senses the turbine speed by magnetic pickup and closes all valves associated with speed control at approximately 112 percent of the rated speed.

FSAR Tier 2, Section 2.8.1, "Turbine Generator System," provides that turbine overspeed control is provided by two separate turbine overspeed protection systems, in addition to the normal speed control function. FSAR Tier 2, Section 10.2.2.9, states that the TGS overspeed trip system consists of a primary electrical overspeed trip system and a backup electrical overspeed trip system. These primary and backup overspeed protection systems are provided to minimize the possibility of the turbine rotor failure and missile generation.

Since the U.S. EPR replaced the mechanical trip device with another electrical system, which may not provide the same level of diversity as that called for by SRP Subsection III, Item 2.C, in RAI 430, Question 10.02-9, the staff requested that the applicant provide appropriate justification for this exception to the SRP guidance and reflect its justification in the FSAR. In addition, the staff requested that the applicant revise Technical Report ANP-10292, "U.S. EPR Conformance with SRP Acceptance Criteria," to indicate that a mechanical trip device is not used to provide overspeed protection for the U.S, EPR turbine overspeed trip protection. In an April 26, 2012, response to RAI 430, Question 10.2-9, Item 1, the applicant agreed to revise Technical Report ANP-10292 and stated that they are taking an exception to the SRP Section 10.2 guidance to incorporate a mechanical overspeed protection system and will utilize two diverse, digital, electrical overspeed protection systems to satisfy the SRP Section 10.2 guidance.

In addition, the guidance of SRP Section 10.2 provides that an applicant is required to evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with NRC regulations. To address this guidance, in RAI 430, Question 10.02-9, Item (2), the staff requested that the applicant provide a summary description and establish a basis for concluding that the reliability of the proposed design (i.e., two electrical, digital, software, overspeed trip systems) is at least equivalent to those that include a diverse mechanical overspeed trip system. In an April 26, 2012, response the applicant stated that in Electric Power Research Institute (EPRI) Technical Report 1013461, "Turbine Overspeed Trip Modernization," the following features are listed as the disadvantages when utilizing a mechanical overspeed trip system: (1) Limited accuracy and reliability; (2) no on-line diagnostics or surveillance available; (3) difficult to set, maintain and calibrate; and (4) requires high risk test procedures. Whereas, for an electrical overspeed trip system, the applicant listed the following features as advantages: (1) improved accuracy, safety and reliability; (2) automated calibration, diagnostics and alarms; and (3) eliminates the need for high risk tests. The applicant further stated that the electrical system can be tested during operation without overspeeding the turbine, the trip point can be set within one percent of the desired trip speed, and provides continuous status feedback on failure of system components and monitors speed sensor accuracy. Furthermore, the electrical overspeed system also allows redundancy in the components and two-out-of-three trip logic, which will minimize the number of false trips of the turbine.

The applicant’s response also stated that the turbine overspeed system design requires that the electrical overspeed protection systems will have a minimum Safety Integrity Level (SIL) rating of 3, which, in accordance with International Electrotechnical Commission (IEC) 61508-1, “Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems,” would give a probability of a failure per hour of .≥ 10E-8 < 10E-7.

Based on the above discussions of the turbine overspeed protection system and the staff’s review of the additional information of the turbine overspeed protection and justifications provided in the applicant’s response and FSAR markups for the turbine overspeed protection system, the staff concluded that an electrical overspeed trip system will provide a safer and more reliable overspeed protection system than the mechanical system. The electrical overspeed trip system can be tested during operation, it can provide continuous status feedback on failure of system components and monitors speed sensor accuracy, and it can be tested without stressing the turbine in an overspeed event. Also, the staff finds that the electrical overspeed protection systems of the U.S. EPR turbine are as diverse as the mechanical and electrical protection systems listed in SRP Section 10.2, Paragraph III.2.(c), and thereby conform to NRC regulations.

Primary and Backup Overspeed Protection System Independence and Separation

SRP Section 10.2, Subsection III.2.D provides that the backup electrical overspeed trip system may use the same sensing techniques as the electrohydraulic (EHC) control system. However, the circuitry was reviewed to confirm that the control signals from the two systems are isolated from and independent of each other. The staff uses this guidance for the EHC for normal control as well as the primary and backup electrical overspeed systems.

FSAR Tier 2, Section 10.2.2.9 provides that each overspeed protection system will be installed in a separate cabinet and will be powered by separate power sources. There are no components, process inputs, or process outputs shared between the two overspeed protection systems. Each overspeed protection system has a set of three independent speed sensors (speed probes). Part of the applicant’s response to RAI 430, Question 10.02-10, Item (4) states that the two sets of overspeed protection sensors are connected to two separate electronic overspeed protection systems, with no common or shared components, and are powered by two separate power sources. In addition, FSAR Tier 2, Section 10.2.2.5, states that the three normal control speed governor speed sensors are independent of the overspeed protection system’s speed sensors. Each electronic overspeed protection system consists of three separate electronic boards for analog speed sensor input signal conversion, overspeed trip threshold processing, and generation of digital trip output signals for activation of an overspeed trip. In its response to RAI 430, Question 10.02-9, Item (2), the applicant added in the FSAR Revision 4 markups, that the output signals from the overspeed protection systems are hardwired to the relays in each of the triple redundant protection channels, which are hardwired to the solenoid valves of the trip block and that the digital trip signals from the output of the two electrical overspeed protection systems are isolated from and independent of each other.

FSAR Tier 2, Revision 4, Figure 10.2-2, “Overspeed Projection System Schematic,” markups provided in the response to RAI 430, Question 10.02-10, shows the primary and backup overspeed protection systems (shown as Overspeed Protection 1 and Overspeed Protection 2, respectively) will be physically located in separate I&C cabinets. Based on the above discussion of separation details, the staff finds that the control signals for the EHC and overspeed protection systems are isolated from and independent of each other and, therefore, is consistent with the review guidance in SRP Section 10.2, Subsection III, Item 2.D.

Primary and Backup Overspeed Protection System Redundancy

FSAR Tier 2, Section 10.2.2.9 states that the primary electrical overspeed trip system fully closes the valves at about 110 percent of rated speed. The backup electrical overspeed protection system is provided to close the valves at about 111 percent of rated speed. The two overspeed protection systems are redundant from the speed probes to the turbine trip relays. Each overspeed protection system is electrically independent and the speed probes are independent of each other. Based on its review of the information in FSAR Tier 2, the applicant's RAI responses, and the staff's earlier discussions in this report, the staff finds that the primary and backup overspeed systems are independent and perform redundant overspeed protective actions at different overspeed thresholds.

Primary and Backup Overspeed Protection System Diversity

The applicant's exception to the SRP Section 10.2 guidance to implement an independent mechanical and electrical overspeed trip systems must demonstrate that the alternative design, (two electrical, digital, software controlled overspeed trip systems), provides acceptable diversity with respect to SRP Section 10.2 design guidance. To defend against potential common-cause failures (CCF), the staff considers high quality system designs, including the use of defensive design measures to avoid or mitigate faults and to cope with unanticipated conditions, and diversity and defense-in-depth (D3) design strategies to be key elements in digital software system design. High quality software and hardware reduce failure probability. However, despite high quality of design and use of defensive design measures, software errors may still defeat protective functions in redundant system channels. Therefore, an alternative design should demonstrate adequate, sufficient, and acceptable design diversity to defend against potential CCFs. In order to make a finding of adequate and acceptable design diversity for the applicant's alternative design, the staff used, in part, the guidance of NUREG/CR-6303, "Method for Performing Diversity and Defense-in-Depth Analysis of Reactor Protection Systems." The guidance separates design diversity into six diversity categories, which include: Design diversity; equipment diversity; functional diversity; human diversity; signal diversity; and software diversity. The staff applied an augmented NUREG/CR-6303 diversity assessment to the turbine overspeed protection system due to the fact that the TGS is a non-safety-related system.

FSAR Tier 2, Section 10.2.2.9 states that each overspeed trip system will be designed and manufactured by a different vendor and that each vendor will directly manufacture its own systems components (e.g., motherboards, sensors). Each vendor will also develop diverse software to transform the analog speed sensor signal into a digital signal. Also, the software between the two overspeed protection systems will differ in parameters, dynamics, or logics. In addition, FSAR Tier 1, Table 2.8.1-3, "Turbine-Generator System Inspection, Test, Analysis, and Acceptance Criteria (ITAAC)," Item 3.2, "Acceptance Criteria," will verify that each electrical overspeed system is designed and manufactured by a different vendor and that the software used to transform the analog speed signal into a digital signal is diverse between the two overspeed protection systems.

Each NUREG/CR-6303 diversity category has several attributes and associated levels of effectiveness. The staff reviewed these diversity categories and the levels of effectiveness and finds the following categories applicable to the U.S. EPR turbine overspeed protection systems and provides its evaluation below:

1. Equipment Diversity: Factors increasing equipment diversity between two groups or items of equipment in decreasing order of effect are: (a) different manufacturers with

different designs; (b) same manufacturer with different design; (c) different manufacturers making the same design; (d) different versions of the same design

2. Functional Diversity: Factors increasing functional diversity between two independent subsystems in decreasing order are: (a) different underlying mechanism; (b) different purpose, function, control logic, or actuation means; and (c) different response time scale.

   Due to the design requirement that the primary overspeed protection system closes the valves at 110 percent of rated speed and the backup overspeed protection system closes that the valves at a later time (111 percent of rated speed) functional diversity is increased.

3. Human Diversity: Due to the design commitment to have different vendors design and manufacture the overspeed trip systems, the staff approves the human diversity attributes of "different design organizations" and "different designers, engineers, or programmers."

4. Signal Diversity: Signal Diversity between two sources applies in the U.S. EPR design. Since the U.S. EPR design commitment that the overspeed protections systems will have separate, independent, and redundant speed sensors to detect and monitor turbine speed, the staff approves the signal diversity attribute of "…the same reactor or process parameter sensed by a different redundant set of similar sensors."

5. Software Diversity: One of the factors increasing diversity among software designs meeting the same requirements is the use of different algorithms, logic, and program architecture. Due to the design commitment (with corresponding ITAAC Acceptance Criteria verifying the as-built diversity design) that the software between the two overspeed protections systems will be different in parameters, dynamics, or logic, the staff approves the software diversity attribute of "…different algorithms, logic, and program architecture."

6. Design Diversity: The applicant did not require the two overspeed protection systems to be designed using different technologies and/or connection of components. The staff finds the U.S. EPR design did not incorporate this design diversity attribute that would address the NUREG/CR-6306 design attribute. Based on the above discussions that the primary and backup overspeed protection systems of U.S. EPR address five of the six diversity categories design attributes of NUREG/CR-6303, (e.g., equipment diversity, functional diversity, human diversity, signal diversity, and software diversity), the staff finds that the primary and backup overspeed trip systems demonstrate adequate and acceptable diversity with respect to the guidance in SRP Section 10.2, Subsection III.2.

Findings for Turbine Overspeed Protection Evaluation

Based on earlier discussions in this section with respect to turbine control and overspeed protection systems, the staff finds that the turbine primary and backup overspeed systems speed detecting sensors are independent of each other and the normal control system's speed control sensors. Each set of turbine rotor overspeed sensors are able to detect turbine rotor speed with no reliance or dependence from information from other speed sensors or information from other speed control systems. Also, the staff's review of the overspeed primary and backup protection systems confirmed that the control signal circuitry from the two overspeed protection systems are isolated from and independent of each other and the normal speed control digital governor system. Based on the staff's NUREG/CR-6303 design diversity assessment between the primary and backup electric digital software trip systems, the in-depth defense provided by the U.S. EPR TG systems include adequate design diversity and diverse overspeed protection means. The overspeed protection system will actuate the control, stop and intercept valves upon the appropriate overspeed threshold being met. The staff also finds that the primary and backup electrical TG trip systems are independent and physically separated from one another. The staff finds the noted overspeed trip design threshold requirements of 110 percent of rated speed for the primary electrical overspeed trip system and 111 percent of rated speed for the backup electrical overspeed protection system are within the bounds of SRP Section 10.2, Subsection III., Items 2.C and 2.D guidance, respectively; and therefore acceptable.

Further, based on the staff's review of the applicant's responses to RAI 430, Questions 10.02-8, 10.02-9, and 10.02-10 and the applicant's FSAR Revision 4 markups, the staff identified the following relative to the two electrical digital software overspeed protective systems:

1. the applicant's methodology for justifying the acceptability of using an electrical digital software backup overspeed trip system versus a mechanical system

2. adequate design diversity between the primary and backup electrical systems in an ITAAC verification of the as-built design diversity

3. separate and independent primary and backup electronic overspeed system's circuit design

4. minimum design requirement for Safety Integrity Level (SIL) rating

5. suitable overspeed control system redundancy from the overspeed speed sensors to the triple redundant protective system trip relays

Based on the above discussion and those delineated in earlier sections of this report, the staff concluded that there is adequate design diversity, redundancy, and independency among the U.S. EPR TG primary and backup electrical digital software trip overspeed protection systems. The staff further confirms that the applicant's proposed alternative to use digital software controlled primary overspeed trip system as an alternative to mechanical, which is recommended in SRP Section 10.2, Subsection III. Item 2.C is acceptable.

10.2.4.2.3 Turbine Overspeed Control Single Failure

The guidance of SRP Section 10.2, Subsection II, Item 1.A, states that the overspeed protection system should meet the single failure criterion. The guidance of SRP Appendix 7.1-C, "Acceptance Criteria and Guidelines for Instrumentation and Control Systems Important to Safety," Section 5.1, "Single-Failure Criterion," states that Institute of Electrical and Electronics Engineers (IEEE)-603 requires that any single failure within the safety system shall not prevent proper protective action at the system level when required and that the applicant's analysis should confirm that the requirements of the single-failure criterion are satisfied. The U.S. EPR turbine I&C speed control system is classified as a non-safety-related system, however, the guidance of SRP Appendix 7.1-C, Section 2, states that although IEEE-603 is intended only for safety systems, the criteria for IEEE-603 are applicable to any I&C system with applicable considerations including design bases, redundancy, independence, single failures, qualification, bypasses, status indication, and testing. The staff used the guidance of SRP Appendix 7.1-C to determine whether the turbine overspeed protection system design addresses the single failure criterion.

Furthermore, for the staff to perform an evaluation adequately, in RAI 430, Question 10.02-10, the staff requested that the applicant provide additional design details associated with the U.S. EPR TG overspeed protection systems. In an April 26, 2012, response, the applicant provided its final responses and markups of FSAR sections, in particular, Sections 10.2.2.5 and 10.2.2.9. Based on its review of the responses and FSAR markups for FSAR Interim Revision 4, the staff provides below an evaluation for the single failure for the two electrical overspeed protection systems.

Normal Speed Control (Single Failure)

FSAR Tier 2, Section 10.2.2.5 states that the normal control digital speed governors operate in a redundant hot standby configuration such that if one speed governor fails, the second speed governor still measures speed and controls the valve position. If both speed governors fail, the triple redundant protection system will order a TT. In an April 26, 2012, response to RAI 430, Question 10.02-10, the applicant stated that the loss of one or two of the governor speed signals will cause an alarm and that the loss of all three governor speed signals will cause the turbine to trip. Also, FSAR Tier 2, Section 10.2.2.6 states that the maximum rotation speed attainable upon loss of a single normal governing device does not exceed 103 percent of rated turbine speed. Further, FSAR Tier 2, Section 10.2.2.9 states that TT initiation devices are not used for normal control of the TG unit. Based on the single failure design descriptions in the updated FSAR sections, the staff finds that a postulated single failure of the components in the normal speed control digital governor system will not prevent the proper overspeed protective action at the system level when required.

Primary and Backup Overspeed Systems – Single Failure

In an April 26, 2012, response to RAI 430, Question 10.02-10, Item 11, the applicant stated that each (primary and backup) overspeed protection system will be installed in separate cabinets with separate power sources. Therefore, single power source failures will not fail both overspeed protection systems. Additionally, each electrical overspeed protection systems has three independent speed probes and signal conversion modules located on three separate electronic motherboards. Furthermore, the FSAR Tier 2, Section 10.2.2.5 updates state that the loss of one of the overspeed protection system speed signals will cause an alarm and that the loss of two overspeed protection system speed signals will cause the turbine to trip. Also, the applicant’s April 26, 2012, response to RAI 430, Question 10.02-9, Item 2, states that the digital trip output signals from the overspeed protection systems are hardwired to the relays in each of the triple redundant protection system channels and that these output signals from the motherboards of each overspeed protection system are isolated from and independent of each other. In addition, FSAR Tier 2, Section 10.2.2.9 describes that the actuation of the turbine protection system does not rely on components in the normal speed control digital governor electro-hydraulic control system.

Based on the fault tolerant design descriptions in the FSAR for the primary and backup overspeed control system response to single failures, the staff finds that a postulated single failure of I&C components in the primary and backup overspeed protection system will not prevent the proper overspeed protective action at the system level when required.

Turbine Triple Redundant Protection System (Trip Channels Single Failure)

FSAR Tier 2, Section 10.2.2.9 describes how the triple redundant protection system electronic trip channels are independent in the U.S. EPR TG design. The loss of one of the turbine protection electronic trip channels will cause an alarm. The loss of two-out-of-three trip channels will cause the turbine to trip. The three electronic trip channels energize three solenoid valves. The three solenoid valves are designed to trip on a loss of power. The overspeed trip block system is a two-out-of-three trip system such that if at least two solenoid valves are de-energized, the turbine will be tripped (i.e., an interruption and discharge of the fluid supply by the trip block will cause the high pressure and intermediate pressure valves to close by spring action, thus cutting off steam supply to the turbine).

Therefore, based on the single failure fault tolerant design descriptions of the triple redundant protection system trip channels, the staff finds that a postulated single failure of I&C components in the triple redundant protection system trip channels will not prevent the proper overspeed protective action at the system level when required.

Findings for Turbine I&C Overspeed Control Single Failure

Based on the evaluated I&C component single failure design descriptions evaluated above, the staff finds that because of design redundancy the I&C normal control digital governor system, the electronic overspeed protection systems, and the triple redundant protection system, will function for a single I&C component failure and will not prevent the proper overspeed protective action at the system level when required. Accordingly, the staff finds that the overspeed I&C electrical digital protection system's design meets the single failure criterion.

10.2.4.2.4 Turbine Full-load Turbine Trip Controls Evaluation

The guidance of SRP Section 10.2, Subsection II, "Acceptance Criteria," Item 1.1.A states that a turbine control and overspeed protection system should ensure that a full-load TT will not cause the turbine to overspeed beyond acceptable limits and that, under these conditions, the control and protection system should permit an orderly reactor shutdown by use of either the turbine bypass system and main steam relief system or other engineered safety systems. FSAR Tier 2, Section 10.2.1, "Design Basis," states that the TGS is designed to accept a sudden loss of full-load without exceeding design overspeed. The staff informed the applicant in RAI 430, Question 10.02-2, Item (1), that for the turbine steam admission valves, the bases for the closure times were not explained and that this information needed to be included in the FSAR. In an April 26, 2012, response to RAI 430, Question 10.02-2, Item (1), the applicant stated:

> The closing times for the main steam stop and control valves and the reheat stop and intercept valves are based on preventing turbine overspeed following loss of full load. The closing time of the valves is defined as the time from the signal received by the actuator trigger to the valve closed position indication. Based on fast closing test results, this time is less than 300 milliseconds, and it includes a 100 millisecond stable period resulting from hydro-mechanical reaction time, before the closing slope is performed in less than 200 milliseconds. Full load rejection simulation, based on conservative assumptions, including a maximum of 300-millisecond closing time for the valves, show that the turbine remains less than 108 percent rated speed.

The applicant also stated in their response to RAI 430, Question 10.02-2, Item (1):

> Following a loss of load event, the governor system is designed to limit the turbine speed to 108 percent of nominal speed, while the maximum expected overspeed following a full load rejection at valves wide open and assuming governor system failure and an overspeed protection system trip is approximately 117 percent. The TG rotor is designed to withstand 120 percent overspeed

condition. Therefore, the design of the overspeed protection system is consistent with the manufacturer's turbine missile analysis.

FSAR Tier 2, Section 10.2.2.7 states that automatic load control is used to permit subsequent operation at house load (i.e., load required to run station auxiliaries) in the event of a load rejection from 100 percent load. FSAR Tier 2, Section 7.7.2.3.4, "Reactor Power Limitation with respect to Generator Power," states that in the case of a TT or generator load rejection to house load, in order to limit the energy level of the primary system to avoid reaching a full reactor scram threshold, the non-safety-related reactor control, surveillance and limitation (RCSL) system will initiate a partial trip (an insertion of a sub-bank of control rods into the core). The plant will reach a new partial trip target power. Main steam over-pressure control and reactor coolant primary heat removal will be performed by automatically modulating the turbine bypass valves that are controlled by the non-safety-related PAS. Both the RCSL and the PAS I&C control systems are evaluated in Section 7.7 of this report. As summarized in FSAR Tier 2, Section 15.2.1, "Loss of External Load" (LOEL), a TT generates a non-safety-related partial trip that inserts a limited number of control rods to avoid an unnecessary full scram reactor trip. The non-safety-related turbine bypass system operates to control steam generator pressure and the non-safety-related pressurizer spray operates to control reactor coolant steam pressure (both controlled by the PAS). The staff notes that, in the LOEL event analysis, the severity of the LOEL event is determined by the closure time of the turbine control valves, with a shorter closure time corresponding to more severe conditions. Therefore, assuming a small (100 milliseconds) value for the closure of the turbine stop valve for the LOEL TT event bounds the closure time for the turbine control valve (listed as 300 milliseconds in FSAR Tier 2, Section 10.2).

FSAR Tier 2, Section 7.2.1.2.4, "Partial Cooldown Actuation," states that the partial cooldown actuation function is preferably performed by utilizing the non-safety-related turbine bypass system valves (PAS controlled). However, the safety-related main steam relief trains, controlled by the safety-related safety automation system (SAS), are provided to cope with turbine bypass control system failure.

Findings for Turbine Full-load Turbine Trip

Based on the above noted turbine governor system overspeed limit noted in the response to RAI 430, Question 10.02-2, Item (1), the LOEL mitigation design descriptions, the basis for the main steam valve closure times, the credited steam pressure control operation of the turbine control bypass system, and the RCSL and PAS non-safety-related systems, and LOEL mitigation during a full-load rejection event, the staff finds that the turbine I&C controls will not cause the turbine to overspeed beyond acceptable limits and will permit an orderly reactor shutdown by use of the turbine bypass system and other evaluated systems.

10.2.4.2.5 Other Turbine System Abnormal Conditions Evaluation

FSAR Tier 2, Revision 4, Section 10.2.2.5 markup provides a listing of 10 abnormal conditions that will automatically initiate a TT (also discussed in FSAR Tier 2, Section 10.2.2.5).

In RAI 430, Question 10.02-2, Item (10), the staff requested that the applicant provide additional design descriptions in the FSAR of indication and annunciation that are provided to monitor the status of the TG and to alert operators of abnormal conditions. FSAR Tier 2, Revision 4, Section 10.2.2.10 states that the turbine supervisory instrumentation (TSI) system acquires data for the turbine control system, provides monitoring and diagnostics, and interfaces with the plant DSC to furnish information on operating parameters in the MCR. The architecture of the control system is shown in Figure 10.02-10-2, which was submitted in the applicant's response to RAI 430, Question 10.02-2, Item (4). The figure graphically displays the TSI ethernet board connections to other EGS I&C systems as well as the ethernet TCP/IP interface between the TG I&C control system and the plant DCS. The TSI processes and monitors sensor measurements for the protection and proper operation of the TG. Alarm and TT thresholds associated with these measurements will be displayed in the MCR. An alarm sheet is located in the MCR that informs the operator of any TGS anomaly.

Two levels of monitoring thresholds are established; an alarm threshold and a trip threshold. If monitored conditions pass through the first protective threshold (i.e., such as "high" level), the condition will be displayed as an alarm. If the second threshold is passed over (such as "high-high" level) the condition will lead to a TT through the triple redundant turbine protection system. Any measurement single failure (1oo3 failed monitored disturbance or drifting exceeding the first threshold) is communicated to the operator through an alarm sheet. If 2oo3 measurements fail (second threshold reached), it leads to a turbine trip. The operator is informed of any anomaly and has access to the corresponding alarm sheet in order to identify the failure location. Thus, the staff finds that for the listed abnormal operating conditions, monitoring and alarm designs of the TGS is capable of detecting an abnormal condition and will inform the operator of the abnormal condition. If the abnormal conditions persist, the staff finds that the TGS I&C will trip the turbine.

Based on the staff's review of the turbine I&C overspeed fault tolerant design, single failure mitigation, and the in-depth defense provided by the overspeed diverse protection design, the staff concludes that turbine I&C normal and overspeed protection systems controls the turbine actions under all listed and evaluated abnormal operating conditions.

10.2.4.3 *Turbine Manual Turbine Trip*

FSAR Tier 2, Section 10.2.2.9, "Overspeed Protection," states that the overspeed protection for the turbine is also provided by manual TT buttons located in the MCR and local to the turbine. FSAR Tier 2, Section 7.3.1.2.17, "Turbine Trip on Reactor Trip Initiation," states that the capability for component level control for the TT function is available to the operator on both the non-safety-related process information control system (PICS) panel and the safety-related safety information control system (SICS) panel that are both located in the MCR. The capability for manual system-level initiation of TT is provided on the SICS in the MCR. Four manual system-level initiation controls are provided where the activation of any two of the four controls results in a TT. This is a hardwired activation signal. There is also a hardwired manual trip button located close to the turbine front end bearing. FSAR Tier 2, Revision 3, Figure 10.2-2 shows that the manual trip actuation signal inputs bypass the normal and overspeed control systems and goes directly to the TT redundant protection system for both the MCR (remote) and the local manual trip signals.

Based on listed manual TT connections locally and from the MCR to the turbine triple redundant protection system, the staff finds that the manual trip is a hardwired diverse TT protection means and that a manual trip will function for abnormal conditions, including a single I&C component failure.

10.2.4.4 *Turbine Control and Overspeed Protection Systems Testing*

The guidance of SRP Section 10.2, Subsection II, "Acceptance Criteria," Item 1.1.A, states that the overspeed protection system should be testable when the turbine is in operation. The SRP guidance also states that the reviewer verifies the capability to test essential components during TGS operation. As stated in FSAR Tier 2, Section 10.2.2.9, and in the applicant's April 26, 2012, response to RAI 430, Question 10.02-9, Item (4b), the three triple redundant protection system overspeed protection channels are tested individually on a daily basis, during normal operation, which allows the system to be online and monitoring turbine overspeed conditions while testing an individual protection channel. The test is performed by artificially increasing an individual channel turbine speed by simulating a speed increase at the protection channel's overspeed card. Once the appropriate overspeed protection thresholds have been exceeded, an alarm is displayed and the trip block's solenoid valve is de-energized, which in turn opens two trip block plate valves. The 2oo3 logic keeps the turbine from tripping and the two remaining channels are operational for turbine overspeed protection if an actual overspeed condition is present during an online test of one turbine overspeed protection channel. This online testing tests the triple redundant protection channels overspeed trip system, including individual trip devices.

The test indicates whether there has been a failure of an electronic card, interposing relay, trip block solenoid valve, or trip block plate valve. If the solenoid valve or plate valves do not function correctly, an alarm is generated. The procedure is then repeated for the remaining two channels.

Table 10.02-10-1 of the applicant's response to RAI 430, Question 10.02-10, Item (9), lists several typical tests that are performed on the turbine overspeed protection and governing systems. Table 10.2-3 below lists the TGS I&C speed control-specific tests.

Table 10.2-3 I&C Turbine Test Performed on Turbine Protection and Turbine Governing System*

Test	Purpose	Criteria	Periodicity
Real Speed	To check that the turbine and the three turbine protection channels trip when the turbine speed is 110%	The turbine and the three turbine protection channels have tripped at 110% nominal speed.	Fuel Cycle
Overspeed Test	To check that the turbine protection channel 1 trips when the channel 1 overspeed card artificially increases the channel 1 turbine speed. The same test is carried out on the turbine protection channels 2 and 3 in turn.	Each channel test has to be "successful."	Daily
Turbine Protection Channels	To check the turbine protection channel 1 trips when the channel 1 turbine generator control trip logic is activated. The same test is carried out on the turbine protection channels 2 and 3 in turn.	Each channel test has to be "successful."	Weekly
Safety-Related Protection	This test is carried out during turbine operation. The frequency is specified in FSAR Tier 2, Chapter 16 Technical Specifications. It allows transmission	Each channel test has to be "successful."	24 months

System Trip	of the TT signals between the reactor protection system and the turbine control system. Each of the four channels of the reactor protection system is tested.		
Non-Safety Control System Trip	To check that the turbine protection signals from the non-safety plant control system (Train A and Train B) to the turbine control system. This test is carried out once a week during turbine operation.	Each test has to be "successful."	Weekly
Manual Trip	To check that the turbine protection channels 1, 2, and 3 trip when the local or backup emergency control panel trip push button has been triggered manually.	The turbine and the three turbine protection channels have tripped when the local or remote trip push button has been triggered manually.	Fuel Cycle

The staff finds that the turbine overspeed control system is designed to permit periodic testing of its overspeed protective TT functioning when the reactor is in operation, including the capability to test turbine overspeed protection channels independently to determine whether failures and losses of system designed redundancy have occurred. Based on noted turbine I&C testing and surveillance design descriptions, the staff finds that the overspeed I&C protection system is testable when the turbine is in operation and that this testing of the I&C overspeed components is capable while the unit is operating at rated load.

10.2.4.5 *Conclusions for TSG Overspeed Systems*

Based on the staff's review of the turbine I&C fault tolerant single failure design, credited turbine I&C speed controls normal and overspeed control systems' design independence, separation of overspeed system and ethernet data communication network, and in-depth design I&C overspeed system diversity commitments, the staff finds that the redundancy and in-depth design I&C overspeed system diversity commitments is sufficient to assure that no single I&C component failure results in loss of the overspeed protection function and that the removal from service of a single turbine overspeed I&C component or channel does not result in loss of the required minimum redundancy to perform the overspeed control protective actions. Because of the in-service testability of the turbine overspeed I&C system, the staff finds that the turbine overspeed protection system has been designed for high functional reliability.

Since the turbine overspeed system consists of a redundant train portion and a failsafe single train portion, the design ensures high functional reliability for tripping the turbine before overspeeding. The staff concludes that the turbine I&C overspeed design is acceptable because it meets the requirements of GDC 4 with respect to the protection of structures, systems, and components important to safety from the effects of turbine missiles. The staff finds that the applicant has met this part of the GDC 4 requirement by providing a turbine I&C overspeed protection system to control turbine action under all operating conditions, which ensures that a full-load turbine trip will not cause the turbine to overspeed beyond acceptable limits.

10.2.4.6 *Turbine Trip Block*

FSAR Tier 2, Section 10.2.2. provides the details, and FSAR Tier 2, Figure 10.2-3 depicts a schematic of the TT block. The trip block provides an interface between the electrical and hydraulic systems. The trip block is a single unit and is redundant by design. There are three separate flow channels between the solenoid valves and six plate valves, and a common inlet and outlet header. There are two separate fluid drain lines back to the hydraulic tank, one from the solenoid valves, and one from the plate valves. The only single failure cause would be the supply orifice, which could leak or plug. Plugging or leakage of the supply orifice would result in an interruption of the control fluid supply and closing of the main steam and reheat stop and control valves. The three independent electronic channels energize three fail safe solenoid valves (trip by loss of power). Each solenoid valve acts on two hydraulic relays of the trip block in order to perform the hydraulic two-out-of-three voting. The turbine will be tripped when at least two solenoid valves are de-energized. An interruption and discharge of the fluid supply by the high pressure and IP valves causes these valves to close by spring action.

Failure of the hydraulic piping between the trip block and the valve actuator, or between the hydraulic fluid tank and the valve actuator will cause a loss of fluid pressure, which closes the valves. Thus, the trip block is designed fail safe, due to the fact that any failure (e.g., loss of power, loss of safety fluid pressure, fluid leak) will cause a turbine trip. Further, the drain piping from the trip block is independent of the drain headers from the main steam and reheat stop and control valves. The operational details of the trip block and associates subsystems and components are provided in FSAR Tier 2, Sections 10.2.2.9, 10.2.2.10, and in the applicant's April 26, 2012, responses to RAI 430, Questions 10.02-9 and 10.02-10. In addition, the trip block is automatically tested daily as part of the safety channel tests, as described in FSAR Tier 2, Section 10.2.2.12. Failure of the 2oo3 trip signals will cause the control fluid to drain from the trip block directly to the tank through two drain lines.

Based on the staff's review of the TT block and associated trip channel arrangement and solenoid valve fail safe operation, the staff finds that the trip block is designed as a fail safe unit, and, therefore is acceptable. Further, the staff finds that the hydraulic piping between the trip-block, the valve actuators, and the fluid tank has built-in redundancy in its design. Therefore, the staff finds that the trip-block meets the SRP guidance, and thereby conforms to the NRC regulation with respect to redundancy and independency.

Daily testing of the primary and backup overspeed protection systems, including the trip block, confirms that the valves of the trip block are functional. Testing and inspections of turbine components are described in FSAR Tier 2, Section 10.2.2.12.

10.2.4.7 *Turbine Overspeed and Control Fluid Hydraulic and Air Systems*

To address operating experience insights, and because the U.S. EPR design provides an alternate approach to demonstrate diversity from that called for in SRP Section 10.2 (i.e., one mechanical and one electrical overspeed trip system), in RAI 430, Questions 10.02-9 and 10.02-10, the staff requested that the applicant address the details of the air/hydraulic systems as they relate to turbine overspeed systems. Specifically, the staff requested that the applicant address the flow paths, shared components, failure modes, and common cause failure (CCF) vulnerabilities. In an April 26, 2012, response to RAI 430, 10.02-9 and 10.02-10, the applicant provided additional information including proposed markups to future revisions of the FSAR to reflect these responses. Based on these applicant responses and FSAR markups, the staff's evaluation of the U.S. EPR design for the air/hydraulic systems is summarized below.

The control fluid system provides HP hydraulic fluid to open the steam admission valves and TT solenoid valves. Failure of this hydraulic fluid closes the valves to safe conditions, specifically under trip conditions. The control fluid system consists of one fluid reservoir tank with two 100 percent capacity pumps, two 100 percent capacity 25 micron filters, associated valves and instrumentation, and a regeneration system and control fluid cooling system. Stainless steel piping is used to supply hydraulic fluid to the valve actuators. Connections at the actuator are made with a flexible hose to protect the pipe from vibration. Control fluid from the valve actuators is collected in two stainless steel drain headers, one on each side of the turbine. These drain headers combine into one common drain header, which is sloped back to the control fluid reservoir. The drain headers are sized to handle the maximum control fluid flow requirements maintaining the required valve stroke times. FSAR Tier 2, Figure 10.2-4, "Control Fluid Drain Headers," provides a schematic representation of these drain lines/headers.

The staff determined that when a trip signal is caused by the overspeed protection system or by any other trip signals, the control fluid is rapidly discharged to the drain manifold. The fluid pressure quickly reduces to atmospheric pressure enabling the spring to close the valves. The fluid returns to the control fluid tank by gravity through the drain headers. Also, the fluid reservoir is provided with inlet breather and an electric heater to control the moisture content in the fluid.

The sizing of the return lines, the materials of construction of the system and the continuous filtration of the control fluid minimize the potential for blockage of the return lines. Periodic testing of the turbine valves confirms that the return lines are not plugged. Daily testing of the primary and backup overspeed protection systems, including the trip block, confirms that the valves of the trip block are functional. Testing and inspection of turbine components are described in FSAR Tier 2, Section 10.2.2.12.

The air-assisted check valves in the extraction steam lines to the feedwater heaters are held open with instrument air and the valve can operate as a non-actuated swing check valve. The valve can operate as a non-actuated swing check valve. The actuator will return to the closed position when a trip signal is received by the solenoid valve used to supply air to the actuator. The solenoid valve shifts to the exhaust position causing a loss of inlet pressure on the quick exhaust valve. Loss of inlet pressure causes the quick exhaust valve to rapidly vent the actuator piston chamber allowing the actuator spring to rotate the valve shaft and push the valve disc into the flow stream to ensure closure of the valve upon the start of flow reversal. Closure time of the non-return valve is within one second after the solenoid valve receives a trip signal. A test switch on the solenoid valve allows both the check valve and the solenoid valve to be periodically exercised. Loss of air supply or power to the extraction non-return valve actuator will cause the actuator to move to the close position under spring force.

In an April 26, 2012, response to RAI 430, Questions 10.02-9 and 10.02-10 and associated FSAR Tier 2, Revision 4 markup, the applicant provided the details as related to the diversity and redundancy features of the turbine overspeed protection systems and associated TT block, and the control fluid drain systems. Also, the applicant added figures depicting the redundant features of these control and fluid systems. Both primary and emergency electrical overspeed systems are redundant; independent; and diverse to/from each other.

Based on the above discussions and its review of the applicant's responses to RAI 430, Questions 10.02-9 and 10.02-10, the staff finds that the FSAR adequately addressed the design and the operational aspects of its control fluid systems and their shared components to eliminate the CCF as recommended in NUREG-1275, "Evaluation of Air-Operated Valves at

U.S. Light-Water Reactors." The FSAR design consists of provisions with multiple headers and adequate flow paths and drain lines in the hydraulic part of the overspeed control system. Multiple hydraulic oil return paths are provided to drain the fluid from the solenoid trip valves and steam admission valves (main steam valves (MSVs), check valves (CVs,) ISVs, and IVs) to the central hydraulic fluid reservoir. In addition, these drain lines are designed with large diameter pipes to and appropriate slopes toward the central reservoir. Periodic testing will reduce the probability of blockages and of plugging the drain lines with corrosion products. Further, periodic surveillance testing of the valves and trip devices will ensure that the drain lines are not plugged. Also, the staff identified that the applicant addressed the concerns identified in NUREG-1275 in its design, construction, materials, and testing requirements to minimize or eliminate the CCF in the hydraulic and air systems associated with the TG control and hydraulic/air systems, including the TG steam admission and extraction non-return valves. Therefore, the staff concluded that the applicant adequately designed and made adequate provisions to the air/hydraulic systems and their flow paths to support the turbine overspeed protection functions and, therefore, finds the U.S. EPR design acceptable. RAI 430, Questions 10.02-9 and 10.02-10 were being tracked as confirmatory items. The staff reviewed FSAR Revision 4 and considers these confirmatory items resolved.

10.2.4.8 *Inspections, Tests, Analyses, and Acceptance Criteria*

FSAR Tier 1, Table 2.8.1-3, "Turbine – Generator System ITAAC," provides the ITAAC information. In accordance with 10 CFR 52.47(b)(1) requirements as discussed in the regulatory criteria section of this report, the applicant identified these ITAAC for the U.S. EPR TG system. Section 14.3.7 of this report evaluates FSAR Tier 1 information for balance-of-plant SSCs, and the evaluation of FSAR Tier 1 information in this section is an extension of the evaluation provided in Section 14.3.7 of this report. This evaluation pertains to plant systems of the FSAR Tier 1 information for the main turbine.

The staff in FSAR Tier 1, Revision 0 through Revision 3 confirmed that it included appropriate Tier 1 requirements for the TG system to comply with 10 CFR 52.47(b)(1) requirements. Based on its review of these sections, the staff determined that additional information was needed, as it relates to testing of the as-built TG, specifically, the turbine control and overspeed trip systems and associated controls. Therefore, in RAI 430, Question 10.02-8, the staff requested that the applicant provide additional information to complete its evaluation of the U.S. EPR ITAAC. In a June 9, 2011, response, the applicant provided additional information and an FSAR markup reflecting its response. ITAAC Item 3.1 states that the applicant is committed to provide controls in the MCR to trip the turbine generator (by the operator) as required. ITAAC Item 3.2 states that the applicant is committed to perform tests and inspections and confirm that the TG is designed with diverse and independent overspeed protection systems. The details are provided above in Table 2.8.3-1, and associated details are described in various sections of FSAR Tier 2. The staff concluded that the above specified ITAAC with the design commitments and information discussed in the application would verify the installation of the U.S. EPR TG set in accordance with the SRP guidance, and thereby conforms to NRC regulations. Therefore, the staff finds that the information contained in FSAR Tier 1, Table 2.8.1-3 is complete and considers the applicant's response to RAI 91, Question 10.02-7 acceptable. RAI 91, Question 10.02-7 was being tracked as a confirmatory item. The staff reviewed FSAR Revision 4 and considers this confirmatory item closed.

10.2.4.9 *Inservice Inspection and Testing*

FSAR Tier 2, Section 10.2.2.12, "Turbine Inservice Inspection and Testing," describes the turbine inservice inspection and test program to identify flaws or component failures that are detected in the overspeed sensing and tripping subsystems, associated valves, or any other condition that could lead to an overspeed condition. As discussed in FSAR Tier 2, Section 10.2.2.12, TG valves and one of each type of steam extraction non-return valve are physically disassembled and inspected on a 3-1/3 year basis in accordance with American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel (B&PV) Code, Section XI, and are exercised monthly and observed for valve motion. This section also states that the primary and backup overspeed trips are automatically tested when in operation on a daily basis. The staff finds this in accordance with SRP Section 10.2 guidance for an inspection program. However, the application did not state whether or not valve design is such that monthly exercising can be performed at full load in accordance with SRP Section 10.2. Therefore, in RAI 91, Question 10.02-3 and 10.02-4, and RAI 430, Question 10.02-9, the staff requested that the applicant provide additional information in this regard.

In an April 26, 2012, response to RAI 430, Question 10.02-9, the applicant provided the following testing details and a markup of FSAR Tier 2, Section 10.2.2.12 to that effect:

- The TG steam admission valves and extraction non-return valves are exercised weekly at a minimum of 97 percent load and the valve motions are observed.
- The components of electro-hydraulic governor (normal operation) and each channel of the primary and backup overspeed protection and trip-block are automatically tested on a daily basis during TG operation.
- Rate of seat leakage and valve closure time and thrust of the steam admission valves is tested at each refueling, including a functional test of the hydraulic protection circuit.
- Conditions of the valve seat of the extraction non-return valves will be inspected in accordance with the manufacturer's recommendations.

In addition, the applicant stated in its FSAR markup that the Combined License (COL) applicant that references the U.S. EPR design will provide a site-specific program, including inspection and testing intervals consistent with the TG manufacturer recommendations.

Based on its review of the applicant's responses and FSAR Tier 2, Section 10.2.2.12 markups, the staff concluded that the applicant adequately addressed the inservice inspection program details for its steam admission and non-return valves, as well as the TT block component details for the U.S. EPR design, which the staff finds acceptable because they conform to the industry codes and the SRP guidance. The staff considers RAI 91, Questions 10.02-3 and 10.02-4 and RAI 430, Question 10.2-9 resolved.

10.2.4.10 *Initial Plant Testing*

The staff reviewed preoperational and startup testing associated with the TG system described in FSAR Tier 2, Section 14.2, "Initial Plant Test Program," which includes control system and valve failure position testing prior to operation (FSAR Tier 2, Section 14.2.12.7.10, Test No. 068), load swing tests upon synchronization at 30 percent power (FSAR Tier 2, Section 14.2.12.18.2), and greater than 98 percent power tests (e.g., trip of the main generator output breaker, load following, and loss of offsite load). Turbine overspeed testing is conducted during the Pre-Core Turbine Over-Speed Test No. 174, prior to TG system operation. The test acceptance criteria will verify that both overspeed device trips occur within design limits. In summary, the staff finds the FSAR addressed adequately the testing requirements for the TG system, including testing of the overspeed trip devices.

10.2.4.11 *Technical Specifications*

There are no Technical Specification requirements associated with the Turbine Generator.

No Technical Specifications are identified as being directly associated with the TG system, with the exception of the Turbine Trip on Reactor Trip Confirmation instrumentation which is required to be operable per FSAR Tier 2, Chapter 16, "Technical Specifications," Table 3.3.1-2.B.1. This feature generates a TT at one second after a reactor trip. This occurs in order to avoid a mismatch between primary and secondary power which would result in excessive reactor coolant system (RCS) cooldown with a potential return to critical conditions and power excursion. This feature is evaluated by the staff in Section 7.3 of this report.

10.2.4.12 *Turbine Rotor Integrity*

10.2.4.12.1 Turbine Rotor Integrity for Standard Turbine

Turbine rotors have large masses and rotate at high speeds during normal operation and, therefore, failure of a turbine rotor may result in the generation of high-energy missiles that may affect safety-related equipment and components. Therefore, the staff has reviewed the turbine rotor using the guidelines in SRP Section 10.2.3 to ensure that the turbine rotor materials have acceptable fracture toughness and mechanical properties to maintain the integrity of the turbine rotor and that the turbine rotor has a low probability of failure.

Material Specifications

FSAR Tier 2, Section 10.2.3.1 specifies that the turbine rotors are made from vacuum melted or vacuum degassed Ni-Cr-Mo alloy steel, and tramp elements are controlled to the lowest practical concentrations. In addition, FSAR Tier 2, Table 10.2-2 specifies that the low pressure turbine rotors are fabricated from material that has the "nearest American Society for Testing and Materials (ASTM) designation" of ASTM A471, Class 2, and that the high pressure turbine rotor is 22CrNiMo 12-7 (which has no equivalent ASTM specification). The staff determined that FSAR Tier 2, Table 10.2-2 did not provide sufficient information concerning the material used for the low pressure (LP) and high pressure (HP) turbine rotors in accordance with SRP Section 10.2.3 to assess its acceptability for turbine rotor integrity and, therefore, issued RAI 100, Question 10.02.03-1. In a January 30, 2009, response to RAI 100, Question 10.02.03-1, the applicant indicated that the combined operating license (COL) applicant will procure a turbine that meets or exceeds the FSAR bounding specifications, or provide suitable justification for the departure. The staff noted that the FSAR does not provide applicable material specifications for procuring the turbine rotors and, therefore, in a follow-up RAI 294, Question 10.02.03-17, the staff requested that the applicant include the applicable material specifications in the FSAR in order to determine if the chemical composition (i.e., limiting trace elements, etc.) will improve fracture toughness, along with any operating experience of these materials, as the applicant claims. In addition, the description of the procedures used to minimize flaws, improve toughness, and minimize chemical segregation should be discussed as requested in the above RAI. RAI 294, Question 10.02.03-17 was being tracked as an open item.

In a March 26, 2012, response to RAI 294, Question 10.02.03-17, the applicant proposed to include the specific chemical compositions and material properties for the HP, inspection procedure (IP) and LP rotor materials in FSAR Tier 2, Section 10.2.3.1 and in FSAR Tier 2, Tables 10.2-2 through 10.2-5. The staff reviewed the specific chemical compositions and material properties and agrees that trace elements are minimized to improve the fracture toughness. In addition, the March 26, 2012, response also discussed the procedures that are used to minimize flaws, improve toughness and minimize chemical segregation, along with current operating experience of this material. The staff notes that deoxidation and degassing practices are performed on this material to minimize flaws and chemical segregation. The operating experience provided includes 32 rotors using the HP and IP material with 925,000 cumulative operating hours, and 84 rotors using the LP material with 4,622,000 cumulative operating hours with no defects detected. Therefore, based on the acceptable chemical composition, the use of degassing practices and satisfactory operating experience of these materials, the staff finds that the materials used for the HP and LP rotors will improve the fracture toughness, and minimize chemical segregation to ensure the integrity of the rotors. The staff confirmed that FSAR Tier 2, Revision 4 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers the open item in RAI 294, Question 10.02.03-17 resolved.

In addition, in a January 30, 2009, response to RAI 100, Questions 10.02.03-1 and 10.02.03-3, the applicant stated in Revision 1 of the FSAR that the applicable chemical analysis tests and mechanical tests will be performed on the procured turbine rotor. Therefore, the as-built rotors will have a chemical analysis test, Charpy V-notch impact tests, and tensile test performed in accordance with ASTM A370 on each turbine rotor forging element. The mechanical testing will be performed in accordance with ASTM A370 with a minimum of three test specimens, which follows the guidance of SRP Section 10.2.3. Therefore, since the applicable tests to be performed on the as-built turbine rotors are specified in the FSAR and will be performed in accordance with ASTM A370, the staff finds that the necessary tests to determine the material properties and integrity of the turbine rotor will be performed on the as-built turbine rotor.

FSAR Tier 2, Section 10.2.3.1 also states that the turbine rotor materials have the lowest fracture appearance transition temperatures (FATT) and highest Charpy V-notch energies obtainable. The material will be processed to maintain 50 percent FATT at -18 ºC (0 ºF) maximum for the LP turbine rotors, and a minimum Charpy V-notch energy of 8.3 kg m (60 ft-lbs) at the minimum operating temperature of each LP rotor in the tangential direction. In a January 30, 2009, response to RAI 100, Question 10.02.03-2, FSAR Tier 2, Revision 1, Section 10.2.3.1, was revised to state that the FATT tests will be in accordance with ASTM A370 using a minimum of 10 test specimens. The FATT is determined to be the temperature corresponding to 50 percent crystallinity based on plotted curves from the Charpy V-notch impact energy and the percentage of crystallinity. The staff finds this acceptable, since the impact energy and FATT will be determined for the as-built turbine rotor using the standardized testing methodology of ASTM A370, and the FATT and Charpy V-notch impact energy values will be determined in accordance with the guidance in SRP Section 10.2.3.

For the reasons described above, the staff finds that the material specification and the associated processing procedures will provide a suitable material for the turbine rotor that will maintain its toughness to resist brittle fracture.

Fracture Toughness

FSAR Tier 2, Section 10.2.3.2 states that turbine rotors are made from material that have adequate material strength and toughness, while providing high reliability and efficiency during operation. The LP turbine rotor will have a ratio of the fracture toughness K_{IC} (as calculated from the material tests performed on the rotor) to the maximum tangential stress at speeds from normal to 120 percent of the rated speed of at least 10 sq rt mm (2 sq rt in.) at minimum operating temperature. Fracture toughness adequate to prevent brittle fracture during startup is verified by calculating startup curves specifying the appropriate startup temperature and warm-up time. The fracture toughness properties will be calculated from material tests that follow the guidance in SRP Section 10.2.3. However, the staff notes that FSAR Tier 2, Section 10.2.3.2 lists all four acceptable methods in SRP Section 10.2.3 for obtaining the fracture toughness properties of the turbine rotor. In addition, in a January 30, 2009, response to RAI 100, Question 10.02.03-4, the applicant stated that the specific method to calculating fracture toughness properties of the turbine rotor from material properties tests will be identified by the COL applicant upon selection of the specific rotor design. The staff finds this acceptable, since the COL applicant will provide the specific method of calculating the fracture toughness properties depending upon the specific rotor design. However, FSAR Tier 2, Table 1.8-2, COL information item 10.2-5 in the FSAR should be revised to specify that the method of calculating the fracture toughness properties of the turbine rotor material should be provided. Therefore, the staff issued a follow-up RAI 294, Question 10.02.03-18, and requested that the applicant revise COL information item 10.2-5 in the FSAR to provide the method of calculating the fracture toughness properties of the turbine rotor material. RAI 294, Question 10.02.03-18, was being tracked as an open item.

In a May 19, 2011, response to RAI 294, Question 10.02.03-18, the applicant proposed to revise COL information item 10.2-2 in the FSAR to specify that the method of calculating the fracture toughness properties of the turbine rotor material will be provided. The staff finds this acceptable since the COL applicant will provide the method of calculating the fracture toughness along with the material properties that includes the fracture toughness values. The staff confirmed that FSAR Tier 2, Revision 2 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers the open item in RAI 294, Question 10.02.03-18 resolved.

FSAR Tier 2, Section 10.2.3.2 also states that stress calculations of the turbine rotor assembly take into account loads and thermal gradients. In addition, the fracture mechanics calculations are performed on the rotors taking into account the maximum acceptable size defect for U.S. standards, and the calculations verify that the initial defect, after increasing due to fatigue during the equipment lifetime, does not propagate and remains non-critical by a large margin in regard to brittle fracture. FSAR Tier 2, Section 10.2.3.4 only states the acceptance criteria from SRP Section 10.2.3, paragraph II.4, but does not provide assurance that these calculations conform to the guidelines in the SRP. In a January 30, 2009, response to RAI 100, Question 10.02.03-5, the applicant stated that the COL applicant will provide these calculations in its specific turbine missile analysis. This turbine missile analysis is provided to the staff by the COL applicant to address, in part, the COL information item 3.5-2 in FSAR Tier 2, Table 1.8-2. The staff finds this acceptable, since the COL applicant will provide the necessary information concerning these calculations in the bounding turbine missile analysis as required by the COL information item 3.5-2, and the as-built turbine rotor analysis will be provided to the staff 1 year prior to loading the fuel in accordance with ITAAC 1.0a in FSAR Tier 1, Table 2.8.1-3.

In response to the staff's RAIs, the applicant included in Revision 1 of FSAR Tier 2, Section 10.2.3, the fracture mechanics evaluation in the turbine missile analysis taking into account the maximum acceptable defect size, which is 3 mm (0.12 in.) for the rotor and 5 mm (0.20 in.) for the shaft. In addition, the analysis and turbine design will take into consideration stress corrosion cracking. The stresses from interference fits do not apply, because shrunk-on disc with interference fits are not used. Instead, rotors are welded as described in FSAR Tier 2, Revision 1, Section 10.2.3.4. The staff finds that the criteria that will be used for the analysis contains the applicable design stresses and the maximum defect size used in the analysis and can be detected by current ultrasonic inspection methods, thereby providing reasonable assurance of the integrity of the rotor.

For the reasons set forth above, the staff finds that the fracture toughness of the rotor material will be determined in accordance with an acceptable method in accordance with SRP Section 10.2.3.

Turbine Rotor Design

FSAR Tier 2, Section 10.2.3.4 states that the turbine assembly is designed to withstand normal operating conditions, anticipated transients, and accidents resulting in a turbine trip without loss of structural integrity. The staff concluded that the design overspeed of the turbine (120 percent) was determined to be at least 5 percent above the highest anticipated speed resulting from a loss of load, since the primary overspeed trip device will fully close the main steam stop valves at 110 percent of rated speed, and an independent and redundant backup electrical overspeed trip circuit will close the valves at 111 percent of rated speed. The staff finds this conforms to the guidance provided in SRP Section 10.2.3.II.4, and therefore is acceptable.

However, FSAR Tier 2, Section 10.2.3.1 specifies a forged turbine rotor, while FSAR Tier 2, Section 10.2.3.4 states that the rotors are a welded design. In a January 30, 2009, response to RAI 100, Question 10.02.03-6, the applicant stated that the HP part of the high/intermediate pressure (HIP) rotor assembly is one forged section. The IP part of the HIP rotor assembly consists of three forged sections. The HIP rotor assembly is a welded rotor consisting of the four forgings. The rotors of the low pressure turbine are a welded rotor design. Based on this information, the HIP rotor assembly consists of four forged pieces welded together. However, it is unclear to the staff whether the LP rotor consists of forged pieces or how many pieces. Therefore, in follow-up RAI 294, Question 10.02.03-19, the staff requested that the applicant provide clarification of the LP rotor, including a sketch. The HIP should also be included in the sketch to understand the arrangement of the turbine rotors, including all weld locations for HIP and LP, and their accessibility for inspection. RAI 294, Question 10.02.03-19 was being tracked as an open item.

In a December 15, 2011, response to RAI 294, Question 10.02.03-19, the applicant provided the information requested, including a sketch which showed that the LP rotor consists of ten forgings that are welded together. The response also provided information that these forgings are ultrasonically inspected after machining and heat treatment. After the forgings are welded together the welds are ultrasonically inspected in the radial, longitudinal and tangential directions (before and after the stress relieving heat treatment). Further evaluation of the preservice inspection is provided below under the heading of "PreService Inspection." The staff finds this response acceptable since it clarifies that the LP rotor consists of small forgings welded together that receive volumetric inspections to verify the integrity of the material and of the welds. Accordingly, the staff considers the open item in RAI 294, Question 10.02.03-19 resolved.

In addition, the applicant's response to RAI 100, Question 10.02.03-6, provided that, since these are welded rotors, keyways are not used as in shrunk-on turbine rotor discs. However, in a January 30, 2009, response to RAI 100, Question 10.02.03-8, the applicant stated that holes are drilled for the pins used to fix the moving blades to the turbine rotors. These holes are drilled once the blades are attached to the turbine rotor and, therefore, a surface examination is not performed. However, to account for not performing a magnetic-particle or liquid penetrant examination of the holes, the turbine missile analysis will account for this by considering a potential initial defect in the turbine rotor at the zero point. In addition, ultrasonic examination is performed on the forged pieces. Also, there are no finished bores in this turbine design. Based on this information, in follow-up RAI 294, Question 10.02.03-20, the staff requested that the applicant provide the following information to determine whether the integrity of the turbine rotor can be determined prior to service:

1. Confirm this is a solid-core rotor (non-bored). If this is the case, provide the following:

    - Discuss how the non-bored rotor will be 100 percent ultrasonically inspected in accordance with FSAR Tier 2, Sections 10.2.3.5 and 10.2.3.6, since there is no bore to gain access to perform the ultrasonic inspection.

    - Typically, each fabricated rotor has destructive testing performed at various locations to ensure homogeneity and acceptable material properties. Justify that the material properties for each rotor fabricated will have the specified material properties and homogeneity throughout the forged rotor, including the interior, which is normally bored out. Also, provide any supporting evaluations or tests.

2. Confirm that ultrasonic testing is performed on the forged parts after the holes are drilled, and that this inspection can detect defects at the hole region.

3. Define the term "zero point" in your response to RAI 100, Question 10.02.03-8.

RAI 294, Question 10.02.03-20 was being tracked as an open item.

In a March 26, 2012, response to RAI 294, Question 10.02.03-20, the applicant confirmed that the turbine generator has a solid-core rotor (non-bored) as shown in a December 15, 2011, response to RAI 294, Question 10.02.03-19. Although it is a non-bored rotor, the rotor consists of several small forgings that are welded together. These small forgings are accessible for performing 100 percent volumetric inspection (ultrasonic) before and after welding. The root pass of each weld is radiographically inspected to ensure the interior of the weld is acceptable before the weld is completed. The completed welds are also volumetric inspected (ultrasonic). Inservice inspection of the welds is evaluated in the "Inservice Inspection" section below.

The March 26, 2012, response to RAI 294, Question 10.02.03-20, also provided information on the destructive testing to justify the homogeneity of the material properties throughout the forged rotor. The applicant stated that there are several series of mechanical tests that are performed on the HIP and LP rotors. For the LP rotors, the mechanical tests are performed on the forging material before and after heat treatment. This is to verify that the mechanical properties of the material starts out within the acceptable range, and continues to be within the acceptable range after heat treatment. Even though this is a non-bored rotor, the material properties are consistent throughout each of the smaller forgings. For example, the LP rotors consist of ten small forgings, in lieu of one large mono-block forging; large mono-block forgings require additional requirements and specific locations for taking mechanical test specimens to ensure homogeneity of the material. However, this is not the case for this welded rotor consisting of ten small forgings; although test specimens are removed from areas that are near the interior of the forging which further assures the material properties are consistent throughout the forgings. The staff agrees that these welded rotors provide a homogenous material with consistent mechanical properties throughout the forgings.

In addition, the March 26, 2012, response to RAI 294, Question 10.02.03-20, provided information on the pin holes used to attach the blades to the turbine rotor. The applicant stated that these pin holes that are drilled in the rotors will receive a visual examination. A surface examination cannot be performed since these holes are inaccessible for a surface examination.

In addition, the area of the rotor where these holes are drilled receive a volumetric examination to ensure that only sound material is drilled. The staff finds this acceptable, since the holes are inaccessible for a surface examination, which is consistent with the requirements of Section III of the ASME Code. Even though the area is volumetrically examined before drilling, and visually inspected after drilling to verify that no defect is present, the turbine missile analysis assumes a theoretical flaw in this area for conservatism. This is the zero point area which consists of an initial defect in the axial radial plane, which includes the disc fingers that lies between the disc outer diameter to the bottom of the pin hole. The staff agrees that assuming a defect in this whole area is a conservative assumption. The staff finds this response acceptable since it verified that the inspections performed on the turbine rotors are consistent with the ASME Code, Section III. Furthermore, the mechanical testing performed on the material ensures the integrity of the rotor. Accordingly, the staff considers the open item in RAI 294, Question 10.02.03-20 resolved.

Preservice Inspection

The turbine rotor forgings are rough machined prior to heat treatment and a visual, surface, and 100 percent volumetric (ultrasonic) examination will be performed in accordance with the ASME Code, Sections III and V. The acceptance criteria that will be used are those specified for Class 1 components in the ASME Code, Sections III and V. Welds joining each forged section of the turbine rotors are ultrasonically examined in accordance with the ASME Code, Section V. However, the staff determined that FSAR Tier 2, Section 10.2.3.5 did not specify that the welds in the turbine rotor assembly are ultrasonically examined in the radial and radial-tangential sound beam directions, as stated in SRP Section 10.2.3 and, therefore, issued RAI 100, Question 10.02.03-7. In a January 30, 2009, response to RAI 100, Question 10.02.03-7, the applicant revised FSAR Tier 2, Revision 1, Section 10.2.3.5 to state that each weld for the turbine rotor assembly will be ultrasonically examined in the radial, longitudinal, and tangential directions, and the acceptance criteria shall be the most stringent between the manufacturer’s standards and the ASME Code, Section III, NB-5300. The preservice inspection description is acceptable to the staff because it includes a 100 percent volumetric inspection performed in accordance with the ASME Code, Sections III and V. The acceptance criteria for the forgings (ASME Code, Section III, NB-2540) and the welds (ASME Code, Section III, NB-5300) are considered appropriate to ensure the initial integrity of the turbine rotor and conform to the guidance in SRP Section 10.2.3.

In addition, the staff determined that FSAR Tier 2, Section 10.2.3.5 did not specify that the preservice inspection includes magnetic particle or liquid penetrant examinations of finished bores, keyways, and drilled holes, and that no flaws are allowed in the keyway and hole regions as specified in SRP Section 10.2.3 guidance and, therefore, issued RAI 100, Question 10.02.03-8. In a January 30, 2009, response to RAI 100, Question 10.02.03-8, the applicant stated that keyways and bores are not used in the turbine rotor design. However, holes are drilled for pins used to attach the moving blades to the rotors. These holes are drilled after the blades are attached to the rotor and, therefore, magnetic-particle or liquid penetrant examinations are not performed. However, to account for not performing a magnetic-particle or liquid penetrant examination of the holes, the turbine missile analysis will account for this by considering a potential initial defect in the turbine rotor at the zero point. In addition, ultrasonic examination is performed on the forged pieces. The staff's concern with regard to this approach is set forth above and the applicant's responses were found acceptable by the staff. Accordingly, the staff considers the open item in RAI 294, Question 10.02.03-20 resolved.

The turbine rotor assembly will be spin tested at the design overspeed of 2160 revolutions per minute (rpm) (120 percent of normal rated speed) prior to service the Section 10.2.3 specify a spin test be performed at five percent above the highest anticipated speed. For the turbine design, the highest anticipated speed (1998 rpm) is 111 percent of normal speed (1800 rpm). Since five percent above 1998 rpm is 2098 rpm, the spin test will be performed at the design overspeed of 2160 rpm, which exceeds the 2098 minimum rpm that would conform to the guidance of SRP Section 10.2.3. Therefore, the staff finds that a spin test of the turbine rotor assembly performed prior to service at the design overspeed of 2160 rpm is acceptable, and the test will demonstrate that the turbine rotor assembly will maintain its structural integrity during an overspeed event. This conforms to the guidelines specified in SRP Section 10.2.3. For the reasons set forth above, the initial turbine rotor condition provides a baseline for future inservice inspections to ensure that flaws will not propagate resulting in the fracture of the turbine rotor and generation of potential missiles.

Inservice Inspection

FSAR Tier 2, Section 10.2.3.6 states that the turbine rotor inservice inspection program uses visual, surface, and volumetric examination to inspect the turbine rotor assembly. It then lists the specific inservice inspection activities for the HP and LP turbine rotor assemblies, which are to be performed every 10 years, and include visual and surface examinations. However, there is no volumetric inspection (i.e., ultrasonic examination) listed.

In response to RAI 18, Question 03.05.01.03-1; RAI 100, Question 10.02.03-9; and RAI 109, Question 03.05.01.03-3, the applicant stated that FSAR Tier 2, Section 10.2.3.6 will be changed to perform inservice inspections in conformance to the inspection intervals from the turbine manufacturer's turbine missile analysis provided by the COL applicant. A COL applicant that references the FSAR will provide a site-specific turbine rotor inservice inspection interval in conformance to the turbine manufacturer's turbine missile analysis.

The staff determined that this approach did not conform to SRP Section 3.5.1.3 in that the FSAR did not provide for a volumetric inspection to be performed nor require that the COL applicant submit the turbine missile analysis. The wording proposed in the applicant's response to the staff's RAIs only provided that the COL applicant submits to the NRC the inspection interval, and not the complete inservice inspection plan, which provides the extent of inspections, types of inspections, acceptance criteria, and inspection intervals. Accordingly, the staff issued RAI 100, Question 10.02.03-9 to address these concerns. In a January 30, 2009, response to this RAI 100, Question 10.02.03-9, the applicant stated that each specific turbine missile analysis is a function of the selected turbine and, therefore, is a COL applicant-provided analysis. Once a specific turbine design has been selected, the COL applicant provides a design-specific turbine missile analysis as required by the ITAAC item Nos. 1a and 1b in FSAR Tier 1, Table 2.8.1-3. Therefore, the applicant considers that the turbine rotor inservice inspection program is correctly described in FSAR Tier 2, Sections 10.2.3.6, and associated ITAAC. The staff notes that FSAR Tier 2, Section 10.2A.3.6 did specify that the COL applicant will provide the inspection program. However, FSAR Tier 2, Section 10.2A has been deleted, since an alternate turbine design will not be used. FSAR Tier 2, Section 10.2.3.6 for the standard turbine design only provides that the COL applicant submit the inspection interval, not the inspection program (which includes the types of inspections, extent of inspections, acceptance criteria, and inspection intervals). Therefore, in follow-up RAI 294, Question 10.02.03-21, the staff requested that the applicant revise COL information item 10.2-5 for the standard turbine design in FSAR Tier 2, Table 1.8-2 of the FSAR Tier 2, to state the inspection “program” and “interval” to ensure the COL applicant submits this information for the staff to review during the COL review. RAI 294, Question 10.02.03-21 was being tracked as an open item.

In a May 19, 2011, response to RAI 294, Question 10.02.03-21, the applicant proposed to revise COL information item 10.2-5 to state that the COL applicant submits the inspection program and interval consistent with the manufacturer’s turbine missile analysis. The staff finds this acceptable since this ensures the COL applicant will submit the information necessary for the staff to review during the COL review. Accordingly, the staff considers the open item in RAI 294, Question 10.02.03-21 resolved.

Contrary to the applicant’s response, the staff also notes that the ITAAC, as currently written, does not require the COL applicant to submit a turbine missile analysis. The ITAAC is used after issuance of the COL license to ensure that the material properties of the as-built rotor conform to the turbine missile analysis, since the material properties of the as-built rotor are not known until after procurement (which may be after the issuance of the COL license). However, in FSAR Tier 2, Table 1.8-2, COL information item 3.5-2 calls for the COL applicant to provide a bounding turbine missile analysis to confirm that the probability of turbine missile generation, P1, is less than 1×10^{-4}. The staff notes that in a January 31, 2013, response to RAI 439, Question 14.03.07-36, and a February 4, 2013, response to RAI 109, Question 03.05.01.03-2, the applicant changed the value of P1 to be 10^{-5} and is reviewed below in regards to the ITAAC. Therefore, the inspection program will be based on the turbine missile probability analysis and should be submitted to the NRC, which conforms to SRP Section 10.2.3.

In addition, in a January 30, 2009, response to RAI 100, Question 10.02.03-9, the applicant stated that volumetric examination is not a standard inservice inspection, but is performed if any indications are identified during visual and surface examination. The staff notes that visual and surface examination do not provide 100 percent volumetric inspection of the turbine rotors to ensure that defects such as cracks are discovered prior to reaching critical crack size (which is determined from the turbine missile analysis). Such conditions have the potential for compromising the integrity of the turbine rotor and ultimately resulting in turbine missile generation. The staff also notes that ultrasonic inspection of turbine rotors is a standard inservice inspection and is referenced in the guidelines of SRP Sections 3.5.1.3 and 10.2.3. Therefore, in RAI 294, Question 10.02.03-22, the staff requested that the applicant include ultrasonic inspection of the turbine rotors in the inservice inspection program described in FSAR Tier 2, Section 10.2.3.6. RAI 294, Question 10.02.03-22 was being tracked as an open item.

In a December 15, 2011, response to RAI 294, Question 10.02.03-22, the applicant stated that the 100 percent volumetric inservice inspection for the welded rotor is not necessary because the turbine missile analysis accounts for not performing inservice volumetric inspections and that the 100 percent volumetric preservice inspection ensures that unacceptable defects are not present. The rotor is 100 percent volumetrically inspected during manufacturing using the acceptance criteria specified for Class 1 components in the ASME Code, Sections III and V. This is the same acceptance criteria used for the reactor coolant pressure boundary. Then, a turbine missile analysis is performed assuming defects are present in the rotor, and demonstrate that the propagation of defects under cyclic loading will not lead to rotor failure. For stress corrosion cracking (SCC), the crack will initiate in the area in contact with the steam since the interior of the rotor was purged with an inert gas during welding of the rotor forgings. A surface examination will be able to detect these SCC cracks. The turbine missile analysis also assumes a crack in the pin-root blade attachments on the rotor that demonstrates the assumed crack does not propagate to the critical crack size between the inspection periods. The crack in this pin-root blade attachment area can be detected by a surface examination.

The staff agrees that the turbine design of this weld rotor is different than previous shrunk on disc rotors or mono-block rotor designs. The advantages of this welded rotor design provides a more homogenous material and minimizes defects due to the smaller forging sizes, and allows for complete pre-service inspections. This welded rotor design also moves the loading and stresses to the outer surface of the rotor in lieu of keyways or bores on conventional rotors. This makes surface examination of the rotor the preferred method of detecting these outer surface cracks. The staff also agrees that SCC defects will initiate at the outer surface of the rotor and therefore can be detected by a surface examination.

However, the welded rotor design has welds that need to be accounted for and, therefore, should either be evaluated to ensure their integrity or a volumetric examination should be performed during inservice inspection intervals. In the December 15, 2011, response to RAI 294, Question 10.02.03-22, the applicant proposed to include a new COL information item 10.2-6, which states that a COL applicant will include ultrasonic examination of the turbine welds or provide an analysis that demonstrates any defects in the rotor welds will not grow to critical size for the life of the rotor. The staff agrees with the proposed COL information item since the COL applicant will either evaluate the welds or perform volumetric examination should during the inservice inspection intervals. Accordingly, the staff considers the open item in RAI 294, Question 10.02.03-22 resolved.

The staff finds the inservice inspection of the turbine rotor is acceptable, since it meets the guidelines of SRP Section 10.2.3 to ensure that the turbine rotor integrity is maintained to preclude the generation of missiles, as required by GDC 4 of 10 CFR Part 50, Appendix A.

ITAAC: The staff also reviewed FSAR Tier 1, Table 2.8.1-3, which provides the inspections, tests, analysis, and acceptance criteria regarding the turbine rotor. There are two commitments numbered 1.0 in FSAR Tier 1, Revision 0, Table 2.8.1-3. In a December 1, 2008, response to RAI 100, Question 10.02.03-10, FSAR Tier 1 was revised in Revision 1 to clarify Table 2.8.1-3 by having ITAAC Commitment Nos 1.0a and 1.0b. In a December 1, 2008, response to RAI 100, Question 10.02.03-11, the FSAR Tier 1 was revised in Revision 1 to clarify ITAAC Commitment 1.0a to include that the acceptance criteria for the as-built turbine material property data, rotor and blade design, and preservice testing and inspection meet the requirements of the turbine missile probability analysis. However, the staff notes that ITAAC Commitment Np. 1.0a should apply to the as-built turbine rotor. Therefore, the staff issued follow-up RAI 294, Question 10.02.03-23, and requested that the applicant confirm that the analysis of the turbine rotor material properties and the turbine disk integrity applies to the as-built turbine rotor, and that the ITAAC is revised accordingly. RAI 294, Question 10.02.03-23 was being tracked as an open item.

In a March 26, 2012, response to RAI 294, Question 10.02.03-23, the applicant stated the term "plant specific" would be applied in describing the analysis. However, the staff's concern was that the analysis should use the "as-built" rotor material properties. Several iterations of this ITAAC cumulated in the new renumbered ITAAC commitment number 2.4 in Revision 5 of FSAR Tier 1, Table 2.8.1-3, which stated that the "plant-specific analysis will be conducted of the as-built turbine material property data" and that a "report exists and concludes that the as-built turbine rotor meets the requirements of the manufacturer's turbine missile probability analysis." The staff finds ITAAC Commitment No. 2.4 in Revision 5 of FSAR Tier 1, Table 2.8.1-3 (previously ITAAC Commitment No. 1.0a) acceptable since the ITAAC will be based on the as-built turbine material properties. Therefore, the staff considers the open item in RAI 294, Question 10.02.03-23 resolved.

The staff finds that ITAAC Commitment No. 2.4 will ensure that the as-built turbine rotors, with respect to the turbine material property data, rotor and blade design, and preservice and inservice inspection and testing, will conform to the manufacturer's turbine missile probability analysis.

The ITAAC Commitment 1.0b states that "an analysis exists and concludes that the probability of turbine material and overspeed related failures resulting in external turbine missiles are [less than 10^{-4}] per turbine year." However, in FSAR Tier 1, Revision 5, Table 2.8.1-3, the ITAAC were renumbered and ITAAC Commitment 1.0b is now ITAAC Commitment 2.5. In addition, a January 31, 2013, response to RAI 439, Question 14.03.07-36, and a February 4, 2013, response to RAI 109. Question 03.05.01.03-2, provided the applicant's revised ITAAC Commitment 2.5 in FSAR Tier 1, Revision 5, Table 2.8.1-3, which stated that an analysis concludes that the probability of turbine material and overspeed related failures, resulting in external turbine missiles is less than 10^{-5} per turbine year. This is based on the conclusion that not all essential structures, systems and components are located outside of the low-trajectory hazard zone. The staff finds ITAAC Commitment 2.5 acceptable, since the orientation of the turbine generator is now considered unfavorably oriented using the guidelines of RG 1.115, and that a turbine missile probability analysis will be performed by the COL applicant to conclude that the probability of turbine missiles is less than 10^{-5} per turbine year. The staff also notes that COL information item 3.5-2 calls for the COL applicant to submit the analysis for NRC approval.

10.2.5 Combined License Information Items

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.2.5-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
10.2-2	A COL applicant that references the U.S. EPR design certification will provide applicable material properties of the site-specific turbine rotor, including the method of calculating the fracture toughness properties.	10.2.3.1
10.2-3	A COL applicant that references the U.S. EPR design certification will provide applicable site-specific turbine disk rotor specimen test data, load-displacement data from the compact tension specimens and the fracture	10.2.3.2

Item No.	Description	FSAR Tier 2 Section
	toughness properties.	
10.2-5	A COL applicant that references the U.S. EPR design certification will provide the site-specific turbine rotor inservice inspection program and inspection interval consistent with the manufacturer's turbine missile analysis.	10.2.3.6
10.2-6	A COL applicant that references the U.S. EPR design certification will include ultrasonic examination of the turbine rotor welds or provide an analysis which demonstrates defects in the root of the rotor welds will not grow to critical size for the life of the rotor.	10.2.3.6
10.2-7	A COL applicant that references the U.S. EPR design certification will provide the site-specific inservice inspection program, inspection intervals, and exercise intervals consistent with the turbine manufacturer's recommendations for the main steam stop and control valves, the reheat stop and intercept valves, and the extraction non-return valves.	10.2.2.12
10.2-8	A COL applicant that references the U.S. EPR design certification will provide a reliability evaluation of the overspeed protection system, which includes the inspection, testing, and maintenance requirements needed to demonstrate reliable performance of the system.	10.2.2.9

10.2.6 Conclusions

Based on its review, the staff concludes that the information provided by the applicant in FSAR Tier 1, Section 2.8.1 and FSAR Tier 2, Section 10.2 related to the TG system, in particular turbine control and overspeed protections is sufficient to perform and meet the design-basis functions and meet regulatory criteria discussed and identified earlier in this report. The staff finds that the applicant meets these requirements based on the following considerations:

1. The design of the TG will control the speed of the turbine under all operating conditions and will ensure that the turbine speed will not exceed 120 percent of rated speed following a load rejection while operating at full power. The turbine overspeed protection systems consists of (a) a turbine control system for normal operation and, (b) a primary electrical, as well as a backup electrical and independent emergency overspeed trip systems for abnormal operations, with built-in redundancy and diversity features.

2. The turbine is provided with fail-safe components and subsystems, and will not have adverse affects on safety-related SSCs in the plant under abnormal operating conditions of the TG system and its subsystems and components.

The staff also concludes that the applicant has established ITAAC to perform proper testing and inspections of the turbine control systems to ensure turbine trips on receiving overspeed trip signals. Further, the staff concludes that the TG system is designed to allow periodic tests, which are to be performed while the plant is in operation.

With regard to turbine rotor integrity, the staff further concludes that, the integrity of the turbine rotor will be acceptable and will meet the requirements of 10 CFR Part 50, Appendix A, GDC 4, since the turbine rotor assemblies are conservatively designed and will use suitable materials with acceptable fracture toughness that will be inspected before and during service as provided in Revision 5 of the FSAR. This provides reasonable assurance that the probability of generating a turbine missile from a turbine rotor failure is low during normal operation, including transients up to design overspeed.

In addition, the staff concludes that the open item associated with RAI 91, Question 10.2-7 is closed. The staff finds the applicant's responses to RAI 430, Questions 10.02-8, 10.02-9, and 10.02-10 acceptable. The staff reviewed FSAR Revision 4, and confirms that the applicant has incorporated the proposed markup changes into the FSAR. Accordingly, the staff considers all the confirmatory items discussed above resolved.

10.3 Main Steam Supply System

10.3.1 Introduction

The MSSS transfers steam produced in the SGs to the HP turbine of the main turbine-generator. The MSSS also provides steam to the second stage steam reheaters, deaerator pegging steam (for startup), and backup auxiliary steam. Portions of the MSSS are safety-related. Under accident conditions, the MSSS isolates the steam generators and the safety-related portion of the system from the non-safety-related downstream piping and components, such as the non-safety-related main turbine.

10.3.2 Summary of Application

FSAR Tier 1: The MSSS is described in FSAR Tier 1, Section 2.8.2. The basic configuration of the system is shown in Figure 2.8.2-1, and equipment data are listed in Tables 2.8.2-1 and 2.8.2-2.

FSAR Tier 2: FSAR Tier 2, Section 10.3 provides supplemental system information. FSAR Tier 2, Section 10.3.1 provides the following safety-related functions of the MSSS:

- To isolate the main steam lines in the event of excessive steam flow that could result in reactor over-cooling
- To provide initial residual heat removal under accident conditions by venting steam to the atmosphere
- To isolate the SG steam side in the event of a tube rupture

ITAAC: ITAAC criteria for the main steam supply system are given in FSAR Tier 1, Table 2.8.2-3, "MSS Inspections, Tests, Analyses, and Acceptance Criteria [5 sheets]."

Technical Specifications: The following FSAR Tier 2, Chapter 16, "Technical Specifications," (TS) cover components within the MSSS:

- TS 3.7.1 Main Steam Safety Valves (MSSVs)
- TS 3.7.2 Main Steam Isolation Valves (MSIVs)
- TS 3.7.4 Main Steam Relief Trains (MSRTs)

10.3.3 Regulatory Basis

NRC regulations for this area of review and the associated acceptance criteria are listed in NUREG-0800, Section 10.3, “Main Steam Supply System,” and are summarized below. Review interfaces with other SRP sections are also provided in SRP Section 10.3, Item I, “Review Interfaces.”

1. GDC 1, “Quality standards and records” as it relates to quality standards commensurate with the importance of the safety function to be performed.
2. GDC 2, “Design bases for protection against natural phenomena,” as it relates to safety-related portions of the system being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods.
3. GDC 4,”Environmental and dynamic effects design bases,” with respect to safety-related portions of the system to withstand the effects of external missiles, internal missiles, pipe whip and jet impingement forces associated with pipe break.
4. GDC 5, “Sharing of structures, systems and components,” as it relates to sharing of SSCs of the steam and power conversion systems of different nuclear power units.
5. GDC 34, “Residual heat removal,” as it relates to the system function of transferring residual and sensible heat from the reactor system in indirect-cycle plants.
6. 10 CFR 50.63, “Loss of All Alternating Current,” as it relates to the ability of a plant to withstand for a specified duration and then recover from a station blackout (SBO).
7. 10 CFR 52.47(b)(1), which requires that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and NRC regulations.

Acceptance criteria adequate to meet the above requirements include the following:

1. RG 1.29, “Seismic Design Classification”
2. RG 1.115, “Protection Against Low-Trajectory Turbine Missiles”
3. Branch Technical Position (BTP) 5-4, “Design Requirements of the Residual Heat Removal System”
4. NUREG-0138, Issue No. 1, "Staff Decision of Fifteen Technical Issues Listed in Attachment to November 3, 1976, Memorandum from Director, NRR to NRR Staff," U.S. Nuclear Regulatory Commission, November 1976”

10.3.4 Technical Evaluation

10.3.4.1 *Main Steam Supply System*

The staff reviewed the MSSS design, described in FSAR Tier 1 and Tier 2 sections, in accordance with SRP Section 10.3. The acceptability of the system is based on meeting the requirements of GDC and the SRP acceptance guidance as described above in the regulatory basis of this report.

The FSAR provides a brief description of the MSSS in FSAR Tier 2, Section 10.3.2.1, "General Description." The primary function of the MSSS is to transport high pressure steam from the SGs to the high pressure turbine. The secondary function of the system is to supply steam to the second stage steam reheaters of the moisture separators, deaerator pegging steam (during startup), and auxiliary steam system. This secondary steam supply comes off of the main steam lines upstream of the turbine stop valves. The MSSS consists of safety-related, as well as non-safety-related portions. The safety-related portions of the MSSS include piping and valves between each SG outlet nozzle and its respective MSIV. The remainder of the system and equipment including main turbine are non-safety-related. Under accident conditions, the MSSS isolates the SGs and the safety-related portion of the system from the non-safety-related portions.

The MSSS consists of four SGs, main turbine-generator (including moisture separator reheaters), and associated piping, valves, and instrumentation. Each of the four steam lines connects to the SG outlet nozzle and terminates in the Turbine Building at each of four turbine stop valves. Each steam line exits the Reactor Building, passes into a divisional valve room, and is routed across a pipe bridge into the Turbine Building. Branch lines within the Turbine Building connect to second stage reheaters, deaerator pegging (for startup only), auxiliary steam, and turbine bypass to the main condenser. A flow diagram of the system is provided in FSAR Tier 2, Figure 10.3-1, "Main Steam Supply System." Also, FSAR Tier 2, Table 10.3-1 provides design data for the MSSS.

The MSSS safety functions are (1) to isolate the main steam lines in the event of excessive steam flow, (2) to provide initial residual heat removal under accident conditions by controlled venting of steam to the outside atmosphere, and (3) to isolate the SG steam side in the event of a tube rupture.

In FSAR Tier 2, Section 10.3.2.2, "Component Description," the FSAR describes the major components of the MSSS, the main steam piping, and instrumentation and controls.

Major system components include, but are not limited to, the MSSVs, MSRIVs, main steam relief control valves (MSRCVs), and MSIVs. Two MSSVs are supplied per steam line. These valves provide overpressure protection for the steam generators and main steam piping, and discharge directly to the outside atmosphere. The MSSVs are designed to ASME B&PV Code, Section III, Class 2, Seismic Category I requirements. The MSSVs are set to lift at a nominal main steam pressure of 10,170 kPa (1460 psig) for the first valve and a nominal 10,370 kPa (1490 psig) for the second valve. The main turbine stop and control valves and the valves associated with the reheaters are described in FSAR Tier 2, Section 10.2, "Turbine Generator."

With respect to design standards for MSSS piping and components, SRP Section 10.3, Subsection III, "Review Procedure," Item 3 describes that the essential portions of the MSSS are designed to Quality Group B and/or Seismic Category I requirements. The U.S. EPR main steam lines from the SGs up to and including the fixed restraint downstream of the MSIVs, are designed and constructed in accordance with Quality Group B and Seismic Category I, which the staff finds acceptable as the U.S. EPR proposed design is in accordance with the SRP guidelines. Further, the FSAR states that the remaining piping of the MSSS piping up to the turbine stop valve and second stage reheaters will be designed in accordance with ASME Code B31.1, "Power Piping Code," which the staff finds acceptable, because this complies with power piping codes and standards (see Section 3.2.2, "System Quality Group Classification," of this report). Furthermore, FSAR Tier 2, Table 3.2.2-1 provides the quality group and seismic design classification details of components and equipment of the MSSS.

MSIVs are located just outside containment in valve rooms. These valves isolate the steam generators in the event of excessive steam flow to prevent reactor over-cooling. Each MSIV is capable of closure in 4.5 seconds or less against full steam-generator steam flow and a differential pressure (in either direction) of 118 percent of normal operating pressure. This satisfies SRP Subsection III, 5.E, which states the MSIVs should close against maximum steam flow. During normal operation, the MSIVs are held open by hydraulic oil pressure. MSIV pilot solenoid valves are normally closed and energized to open the MSIV. Therefore, on loss of either hydraulic pressure or electric power, the MSIVs will fail shut.

The main steam safety valves and main steam relief isolation valves are closed during normal operation. Auxiliary steam from the MSSS has the non-safety function of supplying turbine gland steam during startup and heating steam for feedwater storage. Backup sources of auxiliary steam are used during startup and during low-power operation. Also, FSAR Tier 2, Section 10.3.2 provides details on MSSS sampling, condensate drains, and instrumentation of the MSSS.

The MSSS operational aspects are provided in FSAR Tier 2, Section 10.3.2.3, "System Operation," which includes brief descriptions during plant startup, normal operation, and shutdown operations. Further, an evaluation of the MSSS abnormal and anticipated operational occurrences is described in FSAR Tier 2, Chapter 15, "Transient and Accident Analyses," of the application. Also, FSAR Chapter 15 provides description of accident analyses, specifically an evaluation of a main steam line break and SG tube rupture (SGTR) and, therefore, this section of the report does not cover these analyses.

In FSAR Tier 2, Section 10.3.3, "Safety Evaluation," the applicant provided its evaluation of the safety-related portions of the MSSS and its compliance with the requirements of the GDC identified in the "Regulatory Basis" for this section. The staff compared the FSAR information against these GDC and regulatory requirements in 10 CFR 50.63 regarding SBO and 10 CFR 52.47(b)(1) on ITAAC, and the staff presents its discussions as follows:

Regarding GDC 2, compliance of the MSSS is based on meeting the requirements, as related to withstanding the effects of natural phenomena. FSAR Tier 2, Section 10.3.3 states that safety-related portions of the MSSS are located in the Reactor Building and valve rooms, which are part of the Safeguard Buildings. Also, the safety-related portions of the MSSS outside the containment are located at higher elevations in order to be protected from internal flooding. The containment and the Safeguard Buildings are designed to withstand the effects of natural phenomena, such as hurricanes, floods, tsunamis, earthquakes, and tornadoes, and will protect the MSSS from these phenomena. The staff reviewed FSAR Tier 2, Figure 10.3-1, and confirmed the locations of the safety-related MSSS as stated by the applicant. Also, the location of the safety-related portions of the MSSS will be confirmed by ITAAC as shown in FSAR Tier 1, Table 2.8.2-3, Item 2.2. Further, safety-related portions of the MSSS are designed to remain functional during and after a safe-shutdown earthquake (SSE) (see Section 3.2.1, "Seismic Classification," of this report). Based on the above, the staff finds the U.S. EPR MSSS design acceptable as related to withstanding the effects of natural phenomena and, therefore, the staff concludes that the MSSS design meets the requirements of GDC 2.

With respect to meeting the GDC 4 requirements, the FSAR states as follows: The safety-related portions of the MSSS are designed to withstand the effects of external missiles, as well as internally generated missiles, pipe whip, and jet impingement forces from postulated pipe breaks. Also, the safety-related portions of the MSSS outside containment are protected from internal missiles and other dynamic piping effects by separated trains in the valve rooms, so that, at most, one valve room is affected. The TG is oriented to direct potential turbine missiles away from the MSSS such that the MSSS is protected against turbine missiles. Further, the FSAR describes that the safety-related and non-safety-related portions of the system is separated by a fixed anchor-point to assure that non-seismic piping does not impact the safety system, as shown in FSAR Tier 2, Figure 10.3-1. From the valve rooms to the fixed point, each main steam line is protected from the others by anti-whip pipe restraints which are designed to prevent the ruptured main stream line from whipping into safety-related structures, systems and components. The staff reviewed the FSAR and determined that the separated trains in separate valve rooms, together with appropriately selected fixed anchor points between the non-safety and safety-related piping, and appropriate turbine orientation will protect the system against dynamic affects. Accordingly, the MSSS design is acceptable and meets the requirements of GDC 4.

Further, regarding the GDC 4 requirements, the applicant addressed consideration of steam and water hammer and relief valve discharge load effects on the MSSS. GDC 4 requires the MSSS design to accommodate dynamic affects, which includes the capability to withstand the effects of steam and water hammer and relief valve discharge loading. FSAR Tier 2, Section 10.3.3 states the MSSS design considers relief valve thrust loads and steam and water hammer loads due to rapid valve closure. Furthermore, the MSSS design includes protection against water entrainment by sloping the MSSS piping to drain low points. However, the FSAR lacks a description of the application of these loads to the MSSS design. Also, the FSAR states procedures should be implemented to preclude steam hammer loads; the FSAR does not include any COL information item for the COL applicants to develop and implement these procedures. Therefore, in RAI 106, Question 10.03-1-I, the staff requested that the applicant provide additional details for the accommodation of these hammer and thrust loads in the MSSS design. Also, the staff requested a COL information item to ensure procedures are established to preclude steam hammer or an alternative.

In a November 26, 2008, response to RAI 106, Question 10.03-1-I, the applicant stated that piping and piping support design, including design considerations for steam and water hammer and thrust loads, are described in FSAR Tier 2, Section 3.12, "ASME Code Class 1, 2, and 3 Piping Systems, Piping Components, and their Associated Supports." In its response, the applicant also proposed and later revised FSAR Tier 2, Section 10.3.3, in Revision 1 of the FSAR, to call for plant operating and maintenance procedures to include precautions to prevent steam hammer and relief valve discharge loads. The revision to FSAR Tier 2, Section 10.3.3, also included the need to make sure that MSSS piping is properly warmed and drained of condensate during plant startup. Further, the system maintenance and operating procedures will include guidance and precautions to be exercised during system and component testing and changing valve alignments to confirm that valves in the MSSS operate properly. Since FSAR Tier 2, Table 1.8-2, COL Information Item 13.5-1 already calls for COL applicants to provide site-specific procedures, the applicant asserted that the changes to FSAR Tier 2, Section 10.3.3

has the same affect as a separate COL information item to assure procedures are established to preclude these loads. Therefore, the applicant stated the above revisions to FSAR Tier 2, Section 10.3.3 and the inclusion of the current FSAR Tier 2, Table 1.8-2, COL Information Item 13.5-1 eliminates the need to add a new COL information item to address the steam hammer and relief valve loads on the MSSS. Since a COL applicant will address the COL information item, the staff finds the applicant's response acceptable.

The staff reviewed the applicant's November 26, 2008, response to RAI 106, Question 10.03-1-I, along with the revisions to FSAR Tier 2, Section 10.3.3 that have been incorporated into FSAR Revision 1. The staff also reviewed the information in FSAR Tier 2, Section 3.12 and the COL Information Item 13.5-1 with respect to the steam and water hammer and the relief valve load issues for the MSSS. Based on these reviews, the staff determined that the FSAR as modified call for COL applicants to include precautions in the plant operating and maintenance procedures to prevent steam and water hammer and relief valve discharge load effects on the safety-related portions of the MSSS piping. Accordingly, the FSAR revisions to Section 10.3.3, the information in FSAR Tier 2, Section 3.12, and the COL Information Item 13.5-1, satisfies the GDC 4 requirements, as it relates to withstanding the effects of steam and water hammer and the relief valve discharge loads on the MSSS, and also eliminates the need for an additional COL information item in this regard. Consequently, the staff considers RAI 106, Question 10.03-1-I resolved.

Based on its review of the information provided in FSAR Tier 2, Section 10.3.3 and the above discussion, the staff finds that the design of the MSSS is acceptable as related to GDC 4, regarding steam and water hammer and relief valve discharge loads.

Further, the staff's evaluation of the effects of postulated high-energy line breaks is discussed in Sections 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside of Containment," and 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," of this report.

The MSSS of the U.S. EPR Design Open Item is not shared between or among other nuclear units. Therefore, the requirements of GDC 5 are not applicable to the MSSS.

Regarding GDC 34, the FSAR states that the safety-related portions of the MSSS satisfy GDC 34 regarding residual heat removal (RHR) from the reactor coolant system. The MSSS provides RHR function by venting SG steam to the outside atmosphere by MSRTs and cooling down the RCS to the point of placing the RHR system in operation. Each main steam line has one MSRT located upstream of its MSIV. Each MSRT consists of a normally closed, fast opening MSRIV and a downstream, normally open MSRCV. With two of the four trains available, the FSAR states that the MSRT can cool the reactor to initiate the RHR within 36 hours following plant shutdown. Also, the MSSS design should conform to NUREG-0138, Issue No. 1, regarding credit being taken for non-safety-related valves downstream of the MSIVs to limit blowdown of a second SG in the event of main steam line break upstream of the MSIV. FSAR Tier 2, Table 10.3-3, "Main Steam Branch Piping (2.5 Inches and Larger), Downstream of MSIV," is credited to limit blow-down of the second SG. The only non-safety valves that are credited for this purpose in FSAR Tier 2, Table 10.3-3 are the HP turbine stop valves, which address NUREG-0138, Issue No. 1. If credit is taken for the turbine stop valves under the circumstances, the MSRTs in the intact SGs can still perform their function.

Additionally, FSAR Tier 1, Section 2.8.2 shows the rated capacity of each MSRT to be 1.293×10^6 kg/hr (2.844×10^6 lbm/hr) at an inlet static pressure of 9550 kPa (1370 psig). Under these conditions, one MSRT can relieve approximately 975 MWt, or the rough equivalent of 21 percent rated reactor thermal power. Even with the MSRCV positioned at 40 percent open (with reactor power at zero), one MSRT can remove over 8 percent rated reactor thermal power. Accordingly, two MSRTs have more than enough capacity to cool the plant until RHR system initiation within 36 hours of a plant shutdown. However, it is not clear whether a single-failure analysis has been performed on the controls for the MSRCVs. Also, FSAR Tier 2, Table 10.3-4, "Main Steam Supply System Single Active Failure Analysis," discusses power failures associated with MSRCVs. Further, FSAR Tier 2, Table 7.3-2, "FMEA Summary for ESF Actuations," evaluates emergency safety features (ESF) control failures. However, it is not clear whether single control failures will impact more than one MSRCV at a time. Therefore, in RAI 106, Question 10.03-1-II, the staff requested that the applicant provide clarification in this regard to ensure that a single control failure will not impact more than one MSRCV.

In a November 26, 2008, response to RAI 106, Question 10.03-1-II, the applicant stated that a single control failure will not impact more than one MSRCV. Referring to FSAR Tier 2, Figure 7.3-12, "MSRCV Control," the applicant stated that control processing is performed and control orders are generated for each MSRCV in a different division of instrumentation and controls. The applicant further stated that independence between the divisions is implemented so that a single-failure in one division does not affect the ability of the remaining divisions to perform their function by using dedicated sensors and signal selection to prevent erroneous control actions. The applicant proposed changes to the I&C portion of FSAR Tier 2, Section 10.3.2.2, to clarify that a single control failure will not impact more than one MSRCV.

The staff reviewed the applicant's information including the changes in FSAR Tier 2, Revision 1, Section 10.3.2.2, and concluded that the equipment is separated such that potential control failures have been adequately evaluated and, therefore, considers RAI 106, Question 10.03-1-II resolved. Based on the above discussions, the staff finds that the FSAR adequately addressed the MSSS as it relates to single control failure of the MSRCVs, and also its compliance with GDC 34 requirements of transferring residual and sensible heat from the reactor system in indirect-cycle plants. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 106, Question 10.03-1-II resolved.

In the event of an upstream steam line break, the MSIVs are automatically signaled to close by various isolation signals, including a signal on a rapid decrease of SG pressure. Isolation is ordered when two out of four pressure detectors on any one SG indicate a pressure decrease faster than a specified allowable rate. The staff evaluation of the controls regarding the MSIV isolation is included in Section 7.3, "Engineered Safety Features Systems," of this report.

Regarding compliance with 10 CFR 50.63 (the SBO rule), the FSAR states that the MSSS does not supply steam to power safety-related auxiliaries and, therefore, steam supply is not a factor in a postulated SBO event. However, safety-related portions of the system have been designed to remove decay heat for core cooling and for safe-shutdown during SBO conditions. The MSRTs are relied upon to remove decay heat during an SBO. Uninterruptible power supplies are provided to assure MSRT availability in the absence of vital alternating current (ac) power to permit MSRT operation during the SBO coping period. As discussed previously, a single MSRT has the capacity to remove as much as eight percent rated reactor thermal power through steam discharge to atmosphere. The MSRTs have sufficient capacity to mitigate an SBO event. Consequently, the portion of SBO mitigation provided by the MSSS is adequate, and the staff concludes the requirements of 10 CFR 50.63 as related to the MSSS are met.

In RAI 106, Question 10.03-1-III, the staff stated the ITAAC for the MSSS is provided in FSAR Tier 1, Table 2.8.2-3, "MSS Inspections, Tests, Analyses, and Acceptance Criteria." The staff reviewed these ITAAC requirements and finds them adequate, except that the staff determined that inspection and testing associated with the MSRCVs did not conform to the throttling and control capabilities of these valves. For example, in FSAR Tier 1, Table 2.8.2-3, Item 7.3 provides testing for full-flow capacity of the MSRTs (i.e., with the MSRCV fully open). Similarly, Item 7.1 in the table will test that MSRCVs conforms to positions as shown in FSAR Tier 1, Table 2.8.2-2 (i.e., one of which is throttled). However, the FSAR did not clearly specify which throttle positions are tested, and ensure that post-accident partial cooldown can be accomplished. Similarly, FSAR Tier 2, Section 14.2, "Initial Plant Test Program," Test No. 148 provides some testing of valve signals and position indicators, but did not fully test the accident mitigation features. Therefore, in RAI 106, Question 10.03-III, the staff requested that the applicant provide additional information and/or clarification in this regard.

In a November 26, 2008, response to RAI 106, Question 10.03-III, the applicant stated that additional information will be added to FSAR Tier 1, Table 2.8.2-1 to specify the throttle positions of the MSRCV being tested in ITAAC 2.8.3-7.1. The applicant indicated that MSRCV testing will consist of being positioned 40 percent open and also capable of a linear variation between 40 percent and 100 percent open. The applicant further stated that testing information being added to FSAR Tier 1, Table 2.8.2-1 will conform to the information in FSAR Tier 2, Section 10.3.2.2.

The applicant further stated that FSAR Tier 2, Section 14.2.12, Test No.148 verifies proper operation of the MSRT valves prior to testing with steam during hot functional testing (HFT). In Test No.148, these valves are verified to be operating correctly to prevent over-cooling during operation, which is described in FSAR Tier 2, Section 10.3.2.2. The applicant proposed to revise the Test No.148 in FSAR Tier 2, Section 14.2.12 to include more details on test methods, and also conform to FSAR Tier 2, Section 10.3.2.2, to simulate the throttle positions of the MSRCVs, based on levels of thermal power.

The applicant noted that after the MSRT valves are demonstrated to be functional in Test No. 148, they will be tested during HFT using Test No. 152, which is described in FSAR Tier 2, Section 14.2.12. Test No. 152 is a dynamic test performed to verify the flow paths of the MSRT during partial cooldown. According to the applicant, operating experience from current plants indicates that dynamic testing is necessary to prevent over-cooling. FSAR Tier 2, Section 14.2.12, Test No. 152 will also be revised to specify the throttle position being tested. Furthermore, MSRCV throttling addressed in FSAR Tier 2, Section 15.1.4.1 will be revised in conformance to the information in FSAR Tier 2, Section 10.3.2.2.

In Revision 1 of the FSAR, the applicant incorporated the proposed changes as discussed above, into FSAR Tier 1, Table 2.8.2-1 and FSAR Tier 2, Sections 14.2.12 (for Test No. 148 and Test No. 152) and 15.1.4.1. The staff reviewed these changes to the FSAR in Revision 1, and since the applicant specified the throttle positions and this is now reflected in the Hot Functional Testing (HFT), the staff concluded that sufficient information is provided to assure adequate testing of the throttle positions of the MSRT valves and simulated thermal levels. Also, the proposed additions to the testing included safety-related functions, such as, verification of flow paths of MSRT during partial cooldown, electrical independence and redundancy of safety-related power supplies. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response, and adequately addressed the ITAAC for the MSSS and meets the requirements of 10 CFR 52.47(b)(1). Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 106, Question 10.03-III resolved.

Additionally, in RAI 106, Question 10.03-1-IV, the staff requested that the applicant provide additional information related to the safety-related functions of the MSRCVs and MSIVs as follows:

1. FSAR Tier 2, Section 10.3.2.2 indicates that the MSRCVs perform the safety-related function of controlling the MSRT steam flow to prevent over cooling of the RCS. Describe the design and operation of the MSRCVs that would achieve the above stated safety-related function.

2. FSAR Tier 2, Section 10.3.2.2 also states that the MSSS piping is designed with capability to periodically test the operability of the MSIVs and determine if valve leakage is within acceptable limits.

   - Provide the acceptable limits of leakage through each MSIV.

   - Assure these MSIV leakage limits conform to the assumptions described in main steam line break analyses documented in FSAR Tier 2, Section 15.1.5.

3. With respect to safety-related MSIV actuators, describe the methods to protect the actuators from environmental and dynamic (pipe whip and jet impingement) effects from a main steam line break upstream of the MSIV that is associated with the broken line.

In a November 26, 2008, response to RAI 106, Question 10.03-1-IV, the applicant stated as follows:

1. FSAR Tier 2, Section 10.3.2.2 describes that each MSRCV is designed for a maximum capacity sufficient to pass the rated relieving capacity of the MSRT. During partial cooldown, if the turbine bypass system is not available, these MSRCVs control MSRT steam flow, which is described in FSAR Tier 2, Sections 7.3.1.2.4, "Partial Cooldown Actuation," and 7.3.1.2.5, "Main Steam Relief Isolation Valve Opening." Further, FSAR Tier 2, Section 7.3.1.2.6, "Main Steam Relief Train Isolation," describes that in the event of low SG pressure, MSRT isolation is accomplished by closing both the MSRIV and MSRCV. Also, each MSRT can be isolated by manual controls. Should the MSRIV fail to close in a MSRT, the MSRT can be isolated by closing its MSRCV. The staff has determined that the MSRCVs as described provide a safety-related function of controlling MSRT steam flow to prevent over cooling of the RCS. The applicant stated that FSAR Tier 2, Section 10.3.2.2 will be revised to provide a reference to FSAR Tier 2, Sections 7.3.12.4, 7.3.12.5, and 7.3.12.6 to reflect the above response, which the staff finds acceptable. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers Part 1 of RAI 106, Question 10.03-1-IV resolved.

2. a) Allowable leakage of MSIVs is based on the capability of metal seated gate valves. Each MSIV is tested for seat leakage in forward and reverse flow directions by the valve supplier. FSAR Tier 2, Table 6.2.4-1, "Containment Isolation Valve and Actuator Data," contains the data related to these valves. The applicant further stated that inservice leak testing of each MSIV is performed by pressurizing the valve cavity between disks; the associated requirements of these valves are provided in Tier 2, Table 3.9.6-2, "Inservice

Valve Testing program Requirements." The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed to in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers Part 2(a) of RAI 106, Question 10.03-1-IV resolved.

b) The MSIV seat leakages are negligible compared to the effects of the large steam flow through a line break; therefore, no MSIV leakages are assumed in the analyses. The staff finds this response acceptable and, therefore, considers Part 2(b) of RAI 106, Question 10.03-1-IV resolved.

3. In its response, the applicant stated that the main steam line between the SG outlet nozzle and the MSIV outside the containment is designed using leak before break approach, which precluded a pipe break in this part of main steam. The staff finds that main steamline breaks (MSLBs) inside and outside containment up stream of MSIV are analyzed and presented in FSAR Tier 2, Section 15.1.5. The staff needed the applicant to assure that the system and components (e.g., MSIVs) required for accident mitigation are designed to safety grade requirements and qualified for operation under the accident environment conditions. Therefore, in follow-up RAI 224, Question 10.03-2, the staff requested that the applicant address this issue since it is important to support safety analyses documented in FSAR Tier 2, Chapter 15.

In a July 13, 2009, response to RAI 224, Question 10.03-2, the applicant stated that the U.S. EPR uses leak-before-break (LBB) methodology to eliminate consideration of breaks in the main steam piping inside the containment (from SG to the first anchor at the containment penetration). Therefore, unlike the safety analysis described in FSAR Tier 2, Section 15.0, no breaks are considered upstream of the containment penetration for the pipe stress analysis and support design. The description in Section 10.3.3 of this report is based on Tier 2 Section LBB analysis, not that in Chapter 15. The MSIVs are located in the main steam valve rooms. The applicant indicated that the piping through the containment penetrations up to the MSIVs meets the requirements of ASME Section III, Sub-article NE 1120 and the maximum stress criteria as required in BTP 3-4, Revision 2 for precluding breaks in the outside containment penetration area. The break exclusion for the outside penetration is described in FSAR Tier 2, Section 3.6.2.1.1.1.

The applicant indicated that the system is designed to prevent pipe whip and jet impingement (see Sections 3.6.1 and 3.6.2 of this report). With respect to a harsh environment, the applicant stated that the MSIVs are designed to safety grade requirements for operation under accident environmental conditions postulated for the main steam valve rooms. As described in FSAR Tier 2, Section 3.11.1.2, the environmental conditions for equipment qualifications for the main steam valve compartments (rooms) include harsh environment due to postulated MSLB in the valve room.

The applicant further noted in FSAR Tier 2, Section 10.3.2.3.5, that the MSSS is designed to meet the accident analyses in Section 15.0 including MSLB; pipe breaks upstream and downstream of the MSIV are considered. As noted in FSAR Tier 2, Section 10.3.2.2, the MSIVs are designed to close and isolate flow in either direction, which includes reverse flow from a MSLB upstream of an MSIV as described in FSAR Tier 2, Section 15.1.5. As stated in FSAR Tier 2, Section 10.3.3, safety-related portions of the MSSS outside of containment are located within the valve rooms inside the Safeguard Buildings and are protected from internal flooding as described in FSAR Tier 2, Section 3.4.3.4. The MSIVs are located within the valve rooms, which are protected from flooding.

The staff reviewed the applicant's responses to RAI 224, Question 10.03-2, along with FSAR Tier 2, Sections 10.3.2 and 10.3.3, and associated subsections and tables in Revision 1 of the FSAR, where safety classification for the MSIVs and seismic and environmental qualifications for the MSSS are described. Based on these reviews, the staff finds the applicant's responses acceptable since the main steam piping design conforms to the ASME Code, Section III and BTP 3-4 criteria with respect to the pipe break consideration. Therefore, the staff considers RAI 106, Question 10.03-1-IV, Part 3 and RAI 224, Question 10.03-2 resolved.

TS for the MSSS are specified in FSAR Tier 2, Section 3.7.1 (MSSVs), Section 3.7.2 (MSIVs), and Section 3.7.4 (MSRTs). Surveillance Requirements for TS 3.7.1 provide for a three percent pressure band around the nominal lift set-points of 10,170 kPa (1460 psig) and 10,370 Pa (1490 psig) for the main steam safety valves. Surveillance Requirements for TS 3.7.2 require timing checks for closure of the MSIVs in accordance with the inservice testing (IST) program. TS 3.7.4 requires periodic checks (24 months) of the repositioning features of the MSRCVs. These TS were reviewed and determined to conform to the design features and the design requirements of the MSSS.

10.3.4.2 *Inspection and Testing Requirements*

MSSS components are inspected and tested as part of the initial test program as discussed in FSAR Tier 2, Section 14.2. The staff's evaluation of the U.S. EPR initial test program is addressed in FSAR Tier 2, Section 14.2. In FSAR Tier 2, Section 10.3.4, the applicant states that safety-related active components in the MSSS are designed to be tested during plant operation as discussed in FSAR Tier 2, Section 3.9.6. The staff's evaluation of the inservice testing program is addressed in FSAR Tier 2, Section 3.9.6. The applicant further states that provisions are made to allow for inservice inspection of components in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section XI as discussed in FSAR Tier 2, Section 6.6. The staff's evaluation of the inservice inspection program is addressed in Section 6.6 of this report.

10.3.4.3 *Secondary-Side Water Chemistry*

The evaluation of the secondary-side water chemistry is discussed in Section 10.4.6, "Condensate TC Polishing System," of this report in conjunction with the condensate polishing system.

10.3.4.4 *Steam and Feedwater System Materials*

As set forth below, the staff reviewed and evaluated the information in FSAR Tier 2, Section 10.3.6, "Steam and Feedwater Materials," to ensure that the materials and fabrication of ASME Code Class 2 and 3 MSSS and feedwater (FW) system components comply with the guidelines detailed in SRP Section 10.3.6. The staff's finding is discussed below.

10.3.4.4.1 Material Selection and Fabrication of Class 2 and 3 Components

To meet the requirements of GDC 1, 10 CFR 50.55a, and 10 CFR Part 50, Appendix B, the materials used in the ASME Code Class 2 and 3 portions of the MSSS and main feedwater system must meet the requirements of the ASME Code, Section III and ASME Code Cases listed in RG 1.84 "Design Fabrication and Materials Code Case Acceptability, ASME Code, Section III, "which are incorporated by reference into 10 CFR 50.55a (d) and 10 CFR 50.55(e). Following the guidance provided in RG 1.50, "Control of Preheat Temperature for Welding of

Low-Alloy Steel"; RG 1.71, "Welder Qualification for Areas of Limited Accessibility"; RG 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants;" and ASME Code, Section III, Appendix D-1000, Article D-1000, "Non-mandatory Preheat Procedures" for low alloy steels and carbon steels may be used to implement the requirements of GDC 1, 10 CFR 50.55a, and 10 CFR Part 50, Appendix B.

FSAR Tier 2, Table 10.3-11 lists material specifications and grades for ASME Code, Section III MSSS and main FW system piping and piping not subject to the ASME Code; Section III. The staff reviewed the material specifications and grades in FSAR Tier 2, Table 10.3-11 and finds them acceptable because they are suitable for their intended application and meet ASME Code, Section III requirements. In addition, the staff notes that materials specified for use in non-code applications, identified in FSAR Tier 2, Table 10.3-11, are identical to those used for ASME Code, Section III applications. In RAI 165, Question 10.03.06-7, the staff requested that the applicant modify FSAR Tier 2, Table 10.3-11 to include weld filler material specifications and classifications used in ASME Code Class 2 and 3 steam and FW systems. In a February 27, 2009, response to RAI 165, Question 10.03.06-7, the applicant lists weld filler material specifications but does not list classifications. This information must be presented to the staff in order for the staff to determine whether the requirements of GDC 1 and 10 CFR 50.55a have been met. In RAI 272, Question 10.03.06-11, the staff requested that the applicant modify FSAR Tier 2, Table 10.3-11 to include weld filler material classifications. RAI 272, Question 10.03.06-11 was identified as an open item. In a September 9, 2010, response to the open item in RAI 272, Question 10.03.06-11, the applicant committed to modify FSAR Tier 2, Table 10.03-11 to include weld filler material classifications and provided a proposed revision to FSAR Tier 2, Table 10.03-11. The staff reviewed the response and finds it acceptable because the weld filler material specifications and classifications listed meet ASME Code Section III, thus complying with the requirements of GDC 1 and 10 CFR 50.55a. The staff confirmed that FSAR Tier 2, Revision 3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue; therefore, RAI 272, Question 10.03.06-11 is resolved.

The guidelines listed in RG 1.50 describes the staff-endorsed methods to control preheat temperatures before post-weld heat treatment when welding low-alloy steel in accordance with ASME Code, Section III. ASME Code, Section III, Appendix D, Article D-1000, provides recommended minimum preheat temperatures used to weld carbon steel and low-alloy steel components that are acceptable to the staff as noted in SRP 10.3.6. In FSAR Tier 2, Section 10.3.6.1, the applicant states that low-alloy steel is not used in the MSSS and main FW system. In addition, the preheat temperatures for carbon steel piping in the ASME Code, Section III, Division 1, Class 2 and 3 portions of the MSSS and main feedwater system will follow the guidance provided in ASME Code, Section III, Appendix D, Article D-1000. Accordingly, the staff finds the applicant's description of the preheating of ferritic materials during welding acceptable.

For nondestructive examination (NDE) of ferritic steel tubular products, compliance with applicable provisions of the ASME Code meets the requirements of GDC 1 and 10 CFR 50.55a regarding quality standards. The applicable provisions of ASME Code, Section III for the NDE of tubular product materials are provided in paragraphs NC-2550/ND-2550 through NC-2570/ND2570. In FSAR Tier 2, Section 10.3.6.1, the applicant stated that examination of tubular products in the ASME Code Class 2 and 3 portions of the MSSS and main FW system is in accordance with ASME Code, Section III, Division 1, Subarticles NC-2550/ND-2550 through NC-2560/NC-2560. The staff notes that NC-2570/ND2570 covers cast tubular products which are not identified in FSAR Tier 2, Section 10.3.6 for use in the MSSS or FW system. The staff finds this acceptable, because the U.S. EPR design meets the applicable ASME Code requirements for the NDE of tubular products.

ASME Code, Section III, requires adherence to the requirements of ASME Section IX for welder qualification for production welds. However, there is a need for supplementing this section of the ASME Code because the assurance of providing satisfactory welds in locations of restricted direct physical and visual accessibility can be increased significantly by qualifying the welder under conditions simulating the space limitations under which the actual welds will be made. RG 1.71 provides guidance to supplement ASME Code, Section IX, in this respect. FSAR Tier 2, Section 10.3.6.1 states that the guidance in RG 1.71 for additional welder qualification is applied for welds on ASME Class 2 and 3 components of the MSSS and FW system in locations of restricted direct physical and visual accessibility. The staff finds this acceptable, because the applicant will follow staff guidance regarding performance qualifications for welds that have limited accessibility.

RG 1.37 describes guidance for quality assurance for cleaning of fluid systems and associated components of water-cooled nuclear power plants that meets the requirement of 10 CFR Part B, Appendix B. In accordance with RG 1.37, the staff considers provisions and recommendations included in ASME NQA-1-1994 as generally acceptable for onsite cleaning of materials and components, cleanliness control, and preoperational cleaning and layup of water-cooled nuclear plant fluid systems. These provisions and recommendations provide an adequate basis for complying with the pertinent QA requirements of 10 Part 50, Appendix B subject to the regulatory positions listed in RG 1.37. FSAR Tier 2, Section 10.3.6.1 states that for the U.S. EPR design, cleaning and handling of ASME Code Class 2 and 3 components of the MSSS and FW system are in accordance with procedures described in RG 1.37. The staff finds this acceptable, because the applicant will follow staff recommendations regarding cleaning and handling of Class 2 and 3 components. Additional information regarding the applicant's compliance with ASME NQA-1-1994 is discussed in Section 17.5 of this report.

10.3.4.4.2 Fracture Toughness of Class 2 and 3 Components

FSAR Tier 2, Section 10.3.6.2, indicates that safety-related portions of MSSS and FW system Quality Group B (Class 2) and Quality Group C (Class 3) meet the fracture toughness requirements of ASME Code, Section III, Articles NC-2300 and ND-2300, respectively. The staff finds this acceptable, because the fracture toughness of materials selected for the U.S. EPR design for all ASME Code Class 2 and 3 components in the MSSS and main FW system meet ASME Code requirements.

10.3.4.4.3 Flow-Accelerated Corrosion

ASME Code, Section III, paragraphs NC-3121 and ND-3121, require that material subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provision made for these effects during the design or specified life of the component by a suitable increase in or addition to the thickness of the base metal over that determined by the design formulas.

The staff notes that historically, documents such as Generic Letter (GL) 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," have referred to flow-accelerated corrosion (FAC) as erosion/corrosion. Therefore, FAC and erosion/corrosion are used interchangeably throughout this safety evaluation report. In addition to design considerations to minimize erosion/corrosion, GL 89-08 stressed the importance of implementing formalized procedures or administrative controls to ensure continued long-term implementation of an FAC monitoring program for piping and components. Guidance provided by EPRI in NSAC-202L-R3, "Recommendations for an Effective Flow Accelerated Corrosion Program," includes procedures and administrative controls to ensure that the structural integrity of all carbon steel lines containing high-energy fluids is maintained by minimizing FAC effects. The guidance in EPRI Technical Report NSAC-202L-R3 is a refinement of the guidance developed by the industry that was endorsed by the NRC in NUREG-1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U.S. Nuclear Power Plants," April 1989. The EPRI guidance is applicable to new reactors and remains acceptable to the staff.

FSAR Tier 2, Section 10.3.6.3 states that the design of MSSS and main FW system incorporates considerations to prevent the occurrence of erosion and corrosion. A detailed design phase evaluation will be performed to identify portions of the main steam and main FW systems that are potentially susceptible to service-induced degradation mechanisms. The applicant further states that its detailed design phase evaluation provides reasonable assurance that piping material selections are appropriate for the operating conditions and that the systems are resistant to FAC, erosion, corrosion, and cavitation. The detailed design includes materials selection, limits on velocities, limits on water chemistry to reduce FAC, and erosion and corrosion of piping and components. Piping and components are fabricated from materials resistant to FAC unless the application is specifically evaluated and determined to be not susceptible to FAC degradation.

The applicant intends to use carbon steel material containing a minimum of 0.10 percent chromium in ASME Code Class 2 and 3 components that the applicant has determined are susceptible to FAC. Other systems that are non-safety-related and more prone to FAC degradation, such as FW heater drains or cold reheat, may use chrome-molybdenum or stainless steel materials. The guidance in EPRI Technical Report NSAC-202L-R3 indicates that the use of these types of materials effectively alleviates FAC damage in these systems. The applicant's determination that components containing a minimum of 0.10 percent chromium are resistant to FAC is based on recommendations in EPRI Technical Report NSAC-202L-R3. The staff notes that although materials with 0.10 percent chromium are considered resistant to FAC, NSAC-202L-R3 indicates that re-inspection is not necessary, only if the first inspection verifies that no significant wear is found.

The applicant's evaluation of the effects of FAC includes the MSSS, main FW system, condensate system, SG blowdown system, and the non-safety-related power conversion systems. In addition to main pipe lines in the aforementioned systems, the applicant's evaluation will include drains, vents, and bypass piping in these systems.

Based on the information provided by the applicant in FSAR Tier 2, Section 10.3.6 as discussed above, the staff finds that the applicant appropriately addresses FAC degradation by designing systems in a manner that mitigates the affects of FAC. However, the staff notes that while the U.S. EPR design life is considered to be 60 years, the applicant has stated in FSAR Tier 2, Section 10.3.6.3, that the minimum design wall thickness will be determined in the detailed design phase in order to allow for a minimum lifetime of the affected piping system of at least 40 years. The 40-year design life of the MSSS and main FW system appears to be inconsistent with the design life of the plant which is 60 years. Therefore, in RAI 272, Question 10.03.06-12, the staff requested that the applicant explain this discrepancy. In a September 8, 2010, response to RAI 272, Question 10.03.06-12, the applicant stated that the plant design objective is 60 years; however, the design objective allows for a design life of 40 years for components for which a 60 year design life is impractical, provided provisions are made in the plant design to allow replacement of the system or component. The applicant further stated that the number of design transients and stress cycles are based on a plant design life of 60 years. However, the applicant believes that current experience with FAC in nuclear plants only supports a design life of 40 years. The staff finds this acceptable because the applicant will ensure that piping and components will maintain their minimum design wall thickness for the initial 40 year licensing period of a plant. Therefore, the staff considers RAI 272, Question 10.03.06-12 resolved.

In addition to design considerations to minimize FAC as required by ASME Code, Section III and described in GL 89-08, an appropriate long-term monitoring program should be implemented to detect the potential wall thinning of high-energy ASME Code, Section III, and non-safety-related piping caused by FAC, following the guidance provided in GL 89-08. The applicant has addressed long-term monitoring for FAC in FSAR Table 1.8-2, COL Information Item 10.3-2 and described in FSAR Tier 2, Section 10.3.6.3. COL Information Item 10.3-2 states that a COL applicant that references the design certification will describe essential elements of a FAC condition monitoring program that is consistent with GL 89-08 and NSAC-202L-R3 for the carbon steel portions of the steam and power conversion systems that contain water or wet steam. The use of NSAC-202L-R3 as guidance for a long-term monitoring program to monitor FAC is acceptable to the staff, as indicated above and addresses the staff's concerns and the guidance described in GL 89-08.

10.3.5 Combined License Information Items

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.3.5-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
10.3-1	A COL applicant that references the U.S. EPR design certification will identify the authority responsible for implementation and management of the secondary-side water chemistry program.	10.3.5
10.3-2	A COL applicant that references the U.S. EPR design certification will describe essential elements of a FAC condition monitoring program that conforms to Generic Letter 89-08 and NSAC-202L-R3 for the carbon steel portions of the steam and power conversion systems that contain water or wet steam.	10.3.6.3

These above items are considered to be appropriate COL information items, and no more items are required.

10.3.6 Conclusions

For the reasons set forth above, the staff concludes that sufficient information has been provided by the applicant in FSAR Tier 2, Section 10.3, which supports that the MSSS can perform its safety and non-safety functions.

As stated above, the applicant has provided sufficient information to satisfy GDC 2, GDC 4, GDC 5, GDC 34, 10 CFR 50.63, and 10 CFR 52.47(b)(1) criteria, and SRP criteria, as described in the regulatory basis of this report.

The staff concludes that the main steam supply system and main FW system materials satisfy the relevant requirements of 10 CFR 50.55a; 10 CFR Part 50, Appendix A, GDC 1; and 10 CFR Part 50, Appendix B.

10.4 Other Features of Steam and Power Conversion System

10.4.1 Main Condensers

10.4.1.1 *Introduction*

The main condenser functions as the steam cycle heat sink, condensing steam from the main turbine or from the TBS. The main condenser uses a multi-pressure, three-shell condenser unit, with each shell located beneath its respective LP turbine. The tubes in each shell are oriented transversely to the TG longitudinal axis. Each shell contains two or more tube bundles and circulating water flows in series through the tubes inside the three single-pass shells. The hot-wells are partitioned and connected so that condensate cascades from the LP hot-well to the HP hot-well. The condensate pumps take suction from the HP hot-well.

10.4.1.2 *Summary of Application*

FSAR Tier 1: The only information provided in this section of the FSAR is limited to a statement in Section 2.8.1, "Turbine-Generator System," that exhaust steam is transported to the main condenser.

Figure 2.8.1-1 "Turbine Generator System Basic Configuration," shows the basic configuration of the turbine-generator system.

FSAR Tier 2: The applicant has provided a system description in FSAR Tier 2, Section 10.4.1, "Main Condenser," which is summarized here, in part. The main condenser performs no safety-related function and is designed to meet the following functional criteria:

- Condense steam from the three LP turbines. Provide a collection point for steam, demineralized water, drains, and vented air
- Accommodate up to 50 percent of the valves-wide-open (VWO) main steam flow directly from the TBS
- Receive steam from the turbine bypass system without exceeding the condenser high backpressure turbine trip
- Remove noncondensable gases through the main condenser evacuation system (MCES)

Main condenser design data is provided in FSAR Tier 2, Table 10.4.1-1, "Main Condenser Design Data."

As provided in FSAR Tier 2, Section 10.4.1.2.1, during normal plant operation, the main condenser is operated under a vacuum, and steam from the exhaust of the low pressure turbine is expanded down into the main condenser shells across the main condenser tubes and is condensed and collected in the hot-wells. The main condenser also serves as a collection point for steam and various other drains and extraction points. Main condenser vacuum is maintained by the MCES. During operation, continuous monitoring of condenser tube leak tightness is accomplished by leakage monitors.

During anticipated operational occurrences, the main condenser is capable of accepting steam from the TBS while maintaining condenser vacuum provided the circulating water system (CWS) remains in operation and spray water pressure is available.

Main condenser protection devices include low vacuum trips to initiate a TT or bypass trip for each condenser, condensate high and low water level alarms in the MCR, and conductivity meters installed to detect high conductivity. These meters and alarms are provided in the MCR. Periodic inspections of the main condenser are performed in conjunction with scheduled maintenance outages.

ITAAC: FSAR Tier 1 ITAAC for steam and power conversion systems are shown in Table 2.8.1-3, “Turbine-Generator System Inspections, Tests, Analyses, and Acceptance Criteria,” of the application. Item 2.1 and Item 2.2 require that the applicant conform to the basic configuration of Figure 2.8.1-1, and the verification that the equipment is located in the Turbine Building.

Technical Specifications: There are no TS requirements associated with the main condenser.

10.4.1.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.1, “Main Condenser,” and are summarized below. Review interfaces with other SRP sections also can be found in SRP Section 10.4.2, Item I.

1. GDC 60, “Control of releases of radioactive materials to the environment,” as it relates to provisions being included in the nuclear power unit design to suitably control the release of radioactive materials in gaseous and liquid effluents during normal operation, including anticipated operational occurrences. GDC 60 is applicable to the design of the main condenser system, because in pressurized water reactors (PWRs), radioactive materials may be deposited in the main condensers if there is a primary-to-secondary steam generator tube leak.

2. 10 CFR 52.47(b)(1), which requires that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

10.4.1.4 *Technical Evaluation*

The SRP states that the requirements of GDC 60 are met when the main condenser design includes provisions to prevent excessive releases of radioactivity to the environment which may result from a failure of a structure, system, or component in the main condenser. Acceptance is based on conforming to the criteria of SRP Section 11.3, Subsection II, Acceptance Criteria, Item 6, which provides guidance when there is a potential for explosive mixtures to exist.

The staff reviewed the design of the main condenser in accordance with SRP Section 10.4.1. The acceptability of the system design is based on its meeting the requirements of GDC 60 as it relates to ensuring that failures of the system do not result in excessive releases of radioactivity to the environment, do not cause unacceptable condensate quality, and do not flood areas housing safety-related equipment.

FSAR Tier 2, Section 10.4.1 describes the main condenser design; FSAR Tier 2, Figure 10.4.5-1 depicts this design. FSAR Tier 2, Sections 10.4.1.1 through 10.4.1.5 describe the system design bases, system description, system operation, safety evaluation, inspection and testing requirements, and instrumentation for the main condenser. Design parameters associated with the main condenser are provided in FSAR Tier 2, Table 10.4.1-1, "Main Condenser Design Data."

FSAR Tier 2, Section 10.4.1.1, "Design Basis," describes that the main condenser has no safety-related function and, therefore, has no safety-related design basis. The main condenser is designed to (1) condense steam exhausted from the main turbine, (2) accommodate up to 50 percent of the VWO main steam flow bypassed directly to the condenser by the TBS without exceeding condenser high backpressure TT pressure, and (3) remove noncondensable gases from the condensing steam through the MCES. The staff finds the design basis acceptable because it does not perform any safety-related functions. However, the staff's review identified that the applicant did not describe how the main condenser design precludes component or tube failures due to steam blowdown from the TBS. SRP Section 10.4.1, Subsection III, "Review Procedures," Item 3.D, states that design provisions should be incorporated into the main condenser that preclude component or tube failures due to steam blowdown from the turbine bypass system. Therefore, in order for the staff to complete its review of the main condenser design in accordance with the guidance provided in the above cited SRP review procedure, in RAI 83, Question 10.04.01-1, the staff requested that the applicant provide additional design details associated with these features and main condenser internals.

In a November 10, 2008, response to RAI 83, Question 10.04.01-1, the applicant indicated that design features such as baffles, flow distributors, and pressure breakdown devices are included in the main condenser design to preclude component or tube failures due to steam blowdown from the TBS. A description of these features has been added to FSAR Tier 2, Section 10.4.1. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.1 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.01-1 resolved. The staff finds this response acceptable, since it conforms to the above cited guidance in SRP review procedure.

In FSAR Tier 2, Section 10.4.1.2, "System Description," the applicant described that the main condenser uses a multi-pressure, three-shell condenser unit, with each shell located beneath its respective LP turbine. The three shells are designated as the LP shell, IP shell, and HP shell. Each shell contains two or more tube bundles and circulating water flows in series through the tubes inside the three single-pass shells. The hot-wells are partitioned and connected so that condensate cascades from the LP hot-well to the HP hot-well. The condensate pumps take suction from the HP hot-well. The condenser materials and design pressure of the circulating water system and condenser water boxes are site-specific. A COL applicant who references the design certification will describe the site-specific materials and design pressure and test pressure for its main condenser. These are COL Information Items 10.4-1 and 10.4-2, respectively, which are identified in Section 10.4.1.5 of this report. The condenser materials depend on the circulating water characteristics; titanium tubes and tube sheet overlay are used for sea water, while stainless steel tubes and overlays may be substituted for fresh water applications.

Also in FSAR Tier 2, Section 10.4.1.2, the applicant provided the methods used to reduce the corrosion and erosion of tubes and components. These methods are standard and based on operating experience; the staff finds these methods acceptable for controlling condenser cooling water leakage into the condensate. The review of compatibility of materials of construction with service conditions will be performed as part of the COL application review, since the FSAR states that such information will be provided by the COL applicant.

Further, in FSAR Tier 2, Section 10.4.1.2, the applicant described that during normal plant operation, the main condenser is operated under a vacuum and functions as the steam cycle heat sink. The main condenser also serves as a collection point for steam, equipment drains, extracted water, and vented air from other systems. The main condenser vacuum is maintained by the MCES. Continuous monitoring of condenser tube leak tightness is accomplished by leakage monitors. The hot-well of each condenser shell is compartmentalized to increase the accuracy of identifying the location of leakage. During anticipated operational occurrences, the main condenser is capable of accepting up to 50 percent of the VWO main steam flow from the TBS while maintaining condenser vacuum provided the CWS remains in operation and spray water pressure is available if operating conditions call for spray water. If the main condenser is unavailable to receive this flow, the steam is discharged to the atmosphere through the main steam relief trains or safety valves.

In FSAR Tier 2, Section 10.4.1.3, “Safety Evaluation,” the applicant provided its evaluation of the main condenser design. During normal operation and shutdown, the main condenser contains negligible quantity of radioactive contaminants. Should a primary-to-secondary leakage event occur, the MCES exhaust to the vent system for air removal, which is equipped with a monitor that will detect radiological activity (FSAR Tier 2, Section 10.4.2.2.1). In addition, as stated in FSAR Tier 2, Section 10.4.1.3, no hydrogen buildup is anticipated in the main condenser. While dissolved oxygen is present in the condensate and hot-well inventory, the amounts are very small compared to the amount of gas and vapor being evacuated by the MCES. The applicant further stated that there is no potential for explosive mixtures within the main condenser which would result in excessive releases of radioactivity and, therefore, the main condenser is not required to be designed to withstand the effects of an explosion because the staff determined that the main condenser need not be designed to withstand H2 explosions. Based on the above discussion and also because the main condenser effluent is continuously monitored to detect the radioactive leakage into and out of the condenser and the low probability of hydrogen buildup, the staff finds that the main condenser design conforms to the guidance provided in SRP Section 10.4.1, Item II.1, and therefore satisfies GDC 60.

In FSAR Tier 2, Section 10.4.1.3, the applicant further stated that the failure of the main condenser and the resultant flooding will not preclude operation of any essential system, because safety-related equipment is not located in the Turbine Building. Since there is no safety-related equipment located in the Turbine Building, the staff finds that the requirements of GDC 60 are met with respect to preventing flooding of areas housing safety-related SSCs due to main condenser failures. Furthermore, the staff verified that main condenser system degraded operation will have no adverse effect on the reactor primary or secondary systems; if the main condenser performance is sufficiently degraded, the backpressure increases to the main TT set-point and a TT is initiated, which is addressed in FSAR Tier 2, Section 15.2.2.

In FSAR Tier 2, Section 10.4.1.4, “Inspection and Testing Requirements,” the applicant stated that the main condenser components are inspected and tested as part of the initial plant startup program in accordance with SRP Section 14.2. The applicant further stated that periodic inspections of the main condenser are performed in conjunction with scheduled maintenance outages. The staff finds these inspections and tests acceptable, as they are normal practices for any design, and also the main condenser is a non-safety-related system and has no safety significance. With respect to inspection and testing, further details are provided below in ITAAC for the main condenser.

In FSAR Tier 2, Section 10.4.1.5, “Instrumentation Requirements,” the applicant provided the main condenser protection devices. The main condenser design has provisions to detect loss of condenser vacuum and to effect isolation of the steam source. The main condenser system is provided with low-vacuum trips resulting in a TT and bypass trip for each condenser. This is an effective means of isolating both sources of energy input to the condenser on a degrading vacuum condition. The staff finds these protection devices acceptable, as they conform to SRP Section 10.4.3, Item III.3 guidance.

Based on the above discussion, the staff finds the main condenser system and its components meet the requirements of GDC 60, as they relate to control of releases of radioactive effluents to the environment. For the same reasons, the staff finds that the MCS and its components do not cause unacceptable condensate quality and do not flood areas housing safety-related equipment.

Additionally, the staff reviewed the ITAAC requirements of FSAR Tier 1, Table 2.8.1-3, “Turbine Generator System Inspections, Tests, Analyses, and Acceptance Criteria,” and finds them sufficient to confirm the basic features of the main condensers. Inspections will be performed to ensure the proper location of the equipment in the Turbine Building and the general configuration of equipment. The initial plant test program will test the main condenser in Test No. 065, “Main Condenser and Main Condenser Evacuation System” (FSAR Tier 2, Section 14.2.12.7.7). This test includes dry hydrostatic testing, vacuum testing utilizing tracer gases, and verification of the proper functioning of protective devices, controls, and interlocks. A simulated loss of condenser vacuum is included in “Steam Turbine (Test No. 068)” for the steam turbine (FSAR Tier 2, Section 14.2.12.7.10) and condenser operating data, and the proper functioning of the gaseous waste processing system will be tested as part of Test No. 216. The staff concludes that sufficient testing of the main condenser system is described in FSAR Tier 2, Section 14.2. Based on the above details, the staff finds the main condenser ITAAC program acceptable.

10.4.1.5 *Combined License Information Items*

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.4.1-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section

10.4-1	A COL applicant that references the U.S. EPR design certification will describe the site-specific main condenser materials.	10.4.1.2
10.4-2	A COL applicant that references the U.S. EPR design certification will describe the site-specific design pressure and test pressure for the main condenser.	10.4.1.2

The staff finds the above listing to be complete. Also, the list adequately describes actions necessary for the COL applicant. No additional combined license information items need to be included in FSAR Tier 2, Table 1.8-2 for main condenser considerations.

10.4.1.6 *Conclusions*

The basis for acceptance of the main condenser system was conformance of the design, design criteria, and design bases to NRC regulations as set forth in GDC 60. For the same reasons set forth above, the staff concludes that the main condenser system design is acceptable and meets the requirements of GDC 60 with respect to failures not resulting in excessive releases of radioactivity to the environment. For the same reasons, the staff also concludes that the MCS will not cause unacceptable condensate quality, and will not flood areas housing safety-related equipment.

10.4.2 Main Condenser Evacuation System

10.4.2.1 *Introduction*

The main condenser evacuation system (MCES) is designed to remove air and noncondensable gases from the condenser and connected steam systems and to establish and maintain a vacuum during startup and normal operation. The system performs no safety-related functions and has no safety-related design basis.

10.4.2.2 *Summary of Application*

FSAR Tier 1: FSAR Tier 1, Section 2.8.10, ”Main Condenser Evacuation,” states that there are no entries for the MCES.

FSAR Tier 2: FSAR Tier 2, Section 10.4.2 provides information on the MCES. The system performs no safety-related functions and is designed to meet the following functional criteria:

- Remove air and noncondensable gases from the condenser and connected steam systems during startup, cooldown, and normal operations

- Establish and maintain vacuum in the condenser and connected systems during startup and normal operation by using mechanical vacuum pumps

ITAAC: FSAR Tier 1 ITAAC for steam and power conversion systems are shown in FSAR Tier 1, Table 2.8.1-3, of the application. Item 2.1 and Item 2.2 in the table require conformance to the basic configuration of FSAR Tier 1, Figure 2.8.1-1 and the verification that the equipment is located in the Turbine Building.

Technical Specifications: There are no TS requirements associated with the main condensers or the main condenser evacuation system.

Initial Plant Test Program: Inspection and testing of the MCES is performed prior to plant operation in accordance with Test No. 065 as described in FSAR Tier 2, Section 14.2, "Initial Plant Test Program."

10.4.2.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, SRP Section 10.4.2, "Main Condenser Evacuation System," and are summarized below. Review interfaces with other SRP sections also can be found in SRP Section 10.4.2, Item I.

1. GDC 60, "Control of Releases of Radioactive Materials to the Environment," as it relates to provisions being included in the nuclear power unit design to suitably control the release of radioactive materials in gaseous and liquid effluents during normal operation, including anticipated operational occurrences. GDC 60 is applicable to the design of the MCES, because in PWRs, radioactive materials may be deposited in the main condensers if there is a primary-to-secondary SG tube leak.

2. GDC 64, "Monitoring radioactivity releases," as it relates to the MCES design for monitoring of releases of radioactive materials to the environment during normal operation, including anticipated operational occurrences.

3. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and NRC regulations.

10.4.2.4 *Technical Evaluation*

The requirements of GDC 60 are met when the evacuation system design includes provisions to prevent excessive releases of radioactivity to the environment. Such releases may result from potential explosive mixtures. Accordingly, instrumentation should be provided to detect and annunciate the buildup of potentially explosive mixtures in the condenser. Such potential does not exist where systems are designed to maintain steam content above 58 percent by volume in hydrogen-air mixtures or nitrogen content above 92 percent by volume in hydrogen-air mixtures in all components of the MCES.

The staff reviewed the MCES in accordance with SRP Section 10.4.2. Also, the staff reviewed the MCES in accordance with the guidelines contained in RG 1.26, "Quality Group Classifications and Standards," and RG 1.33, "Quality Assurance Program Requirements (Operation)," as it relates to quality assurance (QA) programs for components that may contain radioactive materials. Acceptability of the MCES, described in the FSAR, is based on meeting the requirements of GDC 60 for controlling the releases of radioactive materials to the environment and the requirements of GDC 64 for monitoring the release of radioactive materials to the environment.

The MCES performs no safety-related function and has no safety-related design basis. The MCES is designed to remove air and noncondensable gases from the main condenser shells and connected steam systems and to establish and maintain a vacuum during startup, shutdown, and normal operation. The steam and air mixture extracted from each condenser shell is routed to one of two 100 percent capacity holding vacuum pumps. The vacuum pumps discharge the steam air mixture to moisture separators, where the steam condenses while the air is exhausted through the vent system for air removal into the nuclear auxiliary building ventilation system. The exhausted air is monitored for radiological activity.

In FSAR Tier 2, Section 10.4.2.1, "General Description," the applicant provided a detailed description of the MCES. FSAR Tier 2, Figure 10.4.2-1, "Main Condenser Evacuation System," depicts the MCES, whereas FSAR Tier 2, Figure 10.4.2-2, "Vent System for Air Removal," shows the air vent system. Further, in FSAR Tier 2, Section 10.4.2.2, "Component Description," the applicant described the major components of the system, which consist of mechanical vacuum pumps, seal water heat exchangers, and piping and valves. FSAR Tier 2, Table 3.2-1, "Classification of Structures, Systems, and Components," provides the quality group and seismic design classification of components and equipment of the MCES. The system is designed to Quality Group D standards, and the piping is designed in accordance with ASME B31.1, "Power Piping Code." Also, for the MCES, in FSAR Tier 2, Sections 10.4.2.3, 10.4.2.4, 10.4.2.5, and 10.4.2.6, the applicant described the system operation, safety evaluation, inspection and testing, and instrumentation, respectively.

The staff reviewed the applicant's design description, system flow diagrams, and design criteria for the components of the MCES. The staff finds that the MCES is appropriately classified as non-safety-related in accordance with the guidance in RG 1.26 and designed to Heat Exchange Institute (HEI) Standards for Steam Surface Condensers, 10th Edition, 2006. The MCES includes equipment and instruments to establish and maintain condenser vacuum and to prevent an uncontrolled release of radioactive material to the environment.

Mixtures of noncondensable gases and vapor that are discharged to the environment from the main condenser are not normally radioactive during normal plant operation. However, it is possible for the mixture to become contaminated in the event of primary-to-secondary system leakage resulting from SG tube leaks. Should this occur, radioactivity would be detected by a radiation monitor provided for in the vent system for air removal. FSAR Tier 2, Table 11.5-1, "Radiation Monitor Detector Parameters, Sheet 1 of 9," shows a continuous noble gas monitoring of the condenser exhaust and provides the range of detection for this monitor. Also, the system is provided with isolation valves to stop air removal from the condenser; in case of detection of high radioactive levels, the plant operator can secure any or all of the condenser flow paths closure of air intake isolation valves. Since the mixture of noncondensable gases and vapor discharged from the MCES is not normally radioactive during normal power operation and because the MCES effluent discharged to the nuclear auxiliary building ventilation system is continuously monitored for radioactivity and can be isolated if necessary, the staff finds that the GDC 60 and GDC 64 requirements are met with respect to control and monitoring of the radioactive materials to the environment.

While it is clear that monitoring is provided, in RAI 83, Question 10.04.02-1[1], the staff requested that the applicant provide additional clarification of the MCES discharge flow-path and locations of effluent radiation monitors, since FSAR Tier 2, Sections 10.4.2.1 and 10.4.2.4 describe the MCES effluent discharges as going into the nuclear auxiliary building ventilation system, whereas FSAR Tier 2, Figure 10.4.2-1, "Main Condenser Evacuation System," shows the system discharging into the turbine building air vent system. In a November 10, 2008, response to RAI 83, Question 10.04.02-1[1], the applicant clarified that the exhausts from the MCES vacuum pumps are combined into one header that is routed to the turbine building air vent system. The turbine building air vent system collects the exhaust from the MCES and the exhausters on the gland steam condenser, monitors the combined exhaust flows for radiation, and then conveys the exhaust flow to the nuclear auxiliary building ventilation system. FSAR Tier 2, Figure 10.4.2-2, “Vent System for Air Removal,” depicts this MCES effluent discharge from the turbine building vent system into the nuclear auxiliary building ventilation system, which the staff finds acceptable. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.02-1[1] resolved.

Additionally, in a November 10, 2008, response to RAI 83, Question 10.04.02-1[2], the applicant responded that during normal operation the main condenser has a negligible inventory of radioactive contaminants that could enter it through a SG tube leak. By referring to FSAR Tier 2, Section 11.5.4, “Process Monitoring and Sampling,” the applicant indicated that the main steam radiation monitoring system is used in conjunction with the MCES and SG blowdown radiation monitoring systems to identify SG tube leaks.

The staff reviewed the applicant’s response and FSAR Tier 2, Figures 10.4.2-1 and 10.4.2-2 and finds this configuration acceptable with respect to the requirements of GDC 60 and GDC 64, as they relate to controlling and monitoring of the radioactive effluents from the MCES. Therefore, the staff considers RAI 83, Question 10.04.02-1[2] resolved.

With respect to hydrogen buildup and explosive mixtures, in FSAR Tier 2, Section 10.4.2.4, the applicant stated that no hydrogen buildup is expected in the main condensers. The amounts of oxygen are negligible compared to the levels of gas and vapor being evacuated by the system. Therefore, there is no potential for explosive mixtures within the MCES, thus the MCES is not required to be designed to withstand the effects of an explosion. However, the FSAR does not provide any additional details in support of the conclusion that explosive mixtures cannot exist in the MCES. GDC 60 requires that the MCES design include provisions to prevent excessive release of radioactivity to the environment, and such releases may result from potential explosive mixtures. In PWRs, radioactive materials may be deposited in the main condensers if there is a primary-to-secondary SG tube leak. Also, the SRP acceptance criteria, SRP Section 10.4.2, Item 1.A describes that explosive mixture potential does not exist where systems are designed to maintain steam content above 58 percent by volume in hydrogen-air mixtures or nitrogen content above 92 percent by volume in hydrogen air mixtures in all components of the MCES. The staff did not determine such details in the application to justify that the system does not produce excessive explosive mixtures in the MCES. Therefore, in RAI 83, Question 10.04.2-1[2], the staff requested that the applicant provide the basis for its conclusion that explosive mixture potential does not exist in the MCES. Also, in RAI 83, Question 10.04.2-1[2], the staff requested that the applicant provide documentation including any hydrogen-air mixture calculations or other analyses that had been performed.

In a November 10, 2008, response to RAI 83, Question 10.04.02-1[2], the applicant clarified that hydrogen is the only explosive gas that can enter the main condenser. The applicant replied that sources of hydrogen include secondary-side systems through general corrosion, hydrogen generated by the thermal decomposition of hydrazine, and hydrogen from the primary coolant diffusing through the SG tubing material. The applicant further stated that the generation rate of hydrogen from these sources is small when compared to the amount of steam in the vapor space in the main condenser and the amount of water vapor in the MCES. Further, the design of the MCES and its vacuum pumps is such that the water vapor content will remain above 58 percent by volume of the total mixture, and there is no potential for any build up of explosive mixtures within the MCES. Furthermore, the vacuum pumps in the MCES are liquid ring type, and the mixture passing through the MCES is at low temperature and high humidity due to contact with the water ring. Additionally, the MCES operates continuously whenever the main condenser is in operation; therefore, there will be no buildup of noncondensable gases in the main condenser. The MCES operates at lower temperature and pressure than the back pressure in the condenser (the average design backpressure is 63.5 mm Hg (2.5 in. Hg)). The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.02-1[2] resolved.

Since the water vapor content in the MCES will remain above 58 percent by volume of the total mixture and there is no potential for explosive mixtures within the MCES in accordance with SRP Section 10.4.2, the staff concludes that the design of the MCES satisfies GDC 60 in this regard and considers RAI 83, Question 10.04.2-1[2] resolved.

The MCES has no direct impact on the reactor system. Should the MCES fail, condenser vacuum would gradually decrease as noncondensable gases build up. A decrease in turbine efficiency (due to failing vacuum) would result in an increase in reactor power, which is limited by the reactor control system as described in FSAR Tier 2, Section 7.7, “Control Systems not Required for Safety.” If the MCES remains inoperable, condenser vacuum continues to decrease to the TT setpoint and a TT would be initiated. The loss of condenser vacuum event is evaluated and addressed in FSAR Tier 2, Section 15.2, “Decrease in Heat Removal by the Secondary System.”

The MCES is tested during the initial plant testing program along with the main condenser (FSAR Tier 2, Section 14.2.12.7.7, Test No. 065). Testing, which will include hydrostatic tests of the condenser, tracer gas testing of both systems, and demonstration of proper operation of the vacuum pumps in design operating modes, is adequate and commensurate with the MCES safety classification.

As discussed above, the staff reviewed the design of the MCES in accordance with SRP Section 10.4.2 and finds the system conforms to GDC 60 and GDC 64 for controlling and monitoring releases of radioactive material to the environment.

10.4.2.5 *Combined License Information Items*

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.4.2-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
10.4-2	A COL applicant that references the U.S. EPR design certification will describe the site-specific design pressure and test pressure for the main condenser.	10.4.1.2

The staff finds the above listing to be complete. Also, the list adequately describes actions necessary for the COL applicant. No additional COL information items need to be included in FSAR Tier 2, Table 1.8-2 for main condenser evacuation system considerations.

10.4.2.6 *Conclusions*

The staff has concluded that sufficient information has been provided by the applicant in FSAR Tier 2, Section 10.4.2. In addition, the staff has compared the design information and the COL information items in the FSAR to the relevant NRC regulations, acceptance criteria defined in NUREG-0800, SRP Section 10.4.2, and other NRC regulatory guides. In conclusion, for the reasons set forth above, the design for the MCES is acceptable and meets the guidelines of SRP Section 10.4.2 and the requirements of GDC 60 and GDC 64 for controlling and monitoring releases of radioactive material to the environment.

10.4.3 Turbine Gland Sealing System

10.4.3.1 *Introduction*

The turbine gland sealing system (TGSS) provides a source of sealing steam to the space where the main turbine and large steam valve shafts penetrate their casings to prevent air leakage into and steam leakage out of these components.

10.4.3.2 *Summary of Application*

FSAR Tier 1: Section 2.8.3, “Turbine Seal System,” and Section 2.8.4, “Sealing Steam System,” both state that there are no FSAR Tier 1 entries for this system.

FSAR Tier 2: The TGSS is shown in FSAR Tier 2, Figure 10.4.3-1, “Turbine Gland Sealing System.” FSAR Tier 2, Section 10.4.3, “Turbine Gland Sealing System,” describes the design bases, system and component descriptions, inspection and testing and instrumentation for the TGSS of the FSAR.

The TGSS performs no safety-related function, and therefore has no nuclear safety-related design basis. The system is designed to meet the following functional criteria:

- Prevent atmospheric air leakage into the turbine casings and minimize steam leakage from the casings of the HP and LP turbines

- Collect leak-off steam from the glands of large turbine valves in the leak-off steam piping

- Return condensed steam to the main condenser and exhaust noncondensable gases to the vent system of the main condenser evacuation system

- Provide flow to and from all HP and LP turbine glands, assuming 1.5 to 2 times the normal gland clearances and the maximum allowable steam seal supply pressure

During startup and shutdown, and in the low-load power range, steam to the TGSS is supplied from the auxiliary steam system. During normal operation, steam is provided from the HP turbine shaft seals and pressure is regulated via a seal steam leak-off valve with a discharge path to the main condenser.

ITAAC: No ITAAC items are identified with the TGSS.

Technical Specifications: There are no TS requirements associated with the turbine gland sealing system.

Initial Plant Test Program: TGSS related preoperational and startup testing is performed via Test No. 064 as described in FSAR Tier 2, Section 14.2, "Initial Plant Test Program."

10.4.3.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.3 and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 10.4.3.

1. 10 CFR Part 50, Appendix A, GDC 60, "Control of Releases of Radioactive Materials to the Environment," as it relates to the TGSS design for the control of releases of radioactive materials to the environment.

2. GDC 64, as it relates to the TGSS design for monitoring of releases of radioactive materials to the environment during normal operation, including anticipated operational occurrences.

3. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

10.4.3.4 *Technical Evaluation*

The staff reviewed the design of the TGSS in accordance with SRP Section 10.4.3. Acceptance of the TGSS design is based on meeting the requirements of GDC 60 for controlling the releases of radioactive materials into the environment. Also, the acceptance of the TGSS is based on meeting the requirements of GDC 64 for monitoring the releases of radioactivity into the environment.

The TGSS has no safety-related design basis and, therefore, has no safety-related function and is not required to operate during or after a design basis accident. FSAR Tier 2, Sections 10.4.3.2.1 and 10.4.3.2.2 provide a general description of the TGSS and a description of its associated components. Also, FSAR Tier 2, Figure 10.4.3-1, depicts a flow diagram of the system. The system consists of a gland steam supply header, exhaust header, gland seal condenser, gland steam exhausters, steam traps, drain lines, and associated piping, valves, and controls. The TGSS is designed to Quality Group D and conforms to the guidance in RG 1.26, which the staff accepts since the system has no safety-related function. FSAR Tier 2, Section 3.2, "Classification of Structures, Systems and Components," describes how this guidance is implemented for the U.S. EPR.

The TGSS is designed to prevent air leakage into and steam leakage out of the casings of the main turbine-generator and large steam valves. During startup and shutdown, and low power operation, steam from the auxiliary steam system is supplied through a seal steam supply valve to maintain the gland steam header pressure. During normal operation, steam that escapes through the HP turbine shaft seals is used as the steam supply for the shaft seals of the LP turbines. The gland steam condenser receives the steam and noncondensable gases from the TGSS and condenses steam and routes it to the shell side of the LP condenser through a steam trap. Whereas, the air and noncondensable gases from the gland steam condenser are removed via one of two gland steam exhausters which discharge to the nuclear auxiliary building ventilation system (NABVS). Also, in FSAR Tier 2, Section 10.4.3.2.3, "System Operation," for normal operation, the applicant stated that excess steam is routed to the main condenser through a seal steam leak-off valve. The applicant further stated that leak-off steam from the seals of the main stop and control valves is also discharged into the TGSS header.

However, in its review of the TGSS flow diagram in FSAR Tier 2, Figure 10.4.3-1, the staff finds no depiction of these leak-offs from the main stop and control valves or other turbine valves. Also, the staff finds no gland steam exhaust fans and associated motors for discharging the air and noncondensable gases from the gland steam condenser to the NABVS. According to SRP Section 10.4.3, Item III.1, the staff should review the piping and instrumentation diagrams to verify the source of sealing steam and the disposition of steam and noncondensables vented from the gland seal. Therefore, in RAI 112, Question 10.04.03-1a, the staff requested that the applicant provide in FSAR Tier 2, Figure 10.4.3-1 the above missing information. In a January 28, 2009, response to RAI 112, Question 10.04.03-1a, the applicant indicated that each main steam stop valve and main steam control valve is connected to either the gland sealing steam supply header or the steam return line directed to the gland steam condenser. These lines do not represent an important source of steam for the system; therefore, for the purposes of clarity, they are not shown on FSAR Tier 2, Figure 10.4.3-1. The reheat steam stop and control valves are mechanically sealed and do not need gland seal system support.

The applicant further described that during plant startup, shutdown, and low load operation, the source of gland sealing steam is from the auxiliary steam system. During normal operation, steam escaping from the HP and IP gland seals, and steam from auxiliary steam or turbine extraction provide sealing steam to the LP turbine seals.

The applicant also responded that the gland steam exhaust fans and motors are shown in FSAR Tier 2, Figure 10.4.3-1 (Tag Nos. 30MAW20AN021 and 30MAW20AN031). Steam and noncondensable gases from the gland steam exhausters are routed to the turbine building air removal system as shown in FSAR Tier 2, Figure 10.4.3-1, where they are monitored for radioactivity and released into the nuclear auxiliary building ventilation system. The turbine building air removal system is shown in FSAR Tier 2, Figure 10.4.2-2, "Vent System for Air Removal." Finally, the applicant stated that FSAR Tier 2, Section 10.4.3 would be revised to reflect the above clarifications.

The staff reviewed the applicant's January 28, 2009, response to RAI 112, Question 10.04.03-1a, and the proposed FSAR changes to FSAR Tier 2, Section 10.4.3. Also, the staff further reviewed FSAR Tier 2, Figure 10.4.3-1 and evaluated the applicant's response to the above RAI and finds that the proposed clarifications are sufficient to conform to the guidance in SRP Section 10.4.3, Item III.1 regarding verification of the source of sealing steam. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 112, Question 10.04.03-1a resolved.

With respect to air and noncondensable gases exhausted from the TGSS, in FSAR Tier 2, Section 10.4.3.3, "Safety Evaluation," the applicant discussed how the system meets the GDC 60 and 64 requirements for controlling, as well as monitoring of the releases of radioactive materials to the environment respectively. The applicant stated that air and noncondensable gases from the TGSS are not normally radioactive during plant operation. While the possibility exists for the system to become contaminated in the event of significant primary-to-secondary water system leakage (due to an SGTR), the FSAR makes provision for TGSS radiation monitors as part of the NABVS, to monitor the radioactive effluents from the system. These monitoring provisions are identified in FSAR Tier 2, Table 11.5-1, "Radiation Monitor Detector Parameters." Further, the gaseous effluent monitoring and sampling systems are described in FSAR Tier 2, Section 11.5.3.1, "Gaseous Effluents." Thus, design features are in place to control and monitor releases of radioactive materials in the effluents of the turbine gland sealing system. Accordingly, the staff finds these sampling and monitoring provisions for the TGSS meet the requirements of GDC 60 and GDC 64, respectively, as they relate to control and monitoring of the releases of the radioactive materials to the environment. Section 11.5 of this report discusses the radiological monitoring adequacy and capabilities of the U.S. EPR design.

In FSAR Tier 2, Section 10.4.3.4, the applicant described the TGSS inspection and testing program. The TGSS components are inspected during construction and functionally tested as part of the initial plant startup testing. Test No. 064 will ensure proper valve operation, the ability of the system to perform its function during turbine startup, and normal plant operation as load increases on HP turbine steam. This test program will verify performance of the sealing steam exhauster blowers and gland steam condenser function. The staff finds the proposed testing is acceptable, since it verifies the design functions of the TGSS. However, during its review, the staff noted an apparent inconsistency: Test No. 064, Step 3.2 states that it will verify power operated valves fail upon loss of motive power as designed in accordance with FSAR Tier 2, Section 10.4.3. However, FSAR Tier 2, Section 10.4.3 did not provide details on the fail safe positions of any of the TGSS valves. Therefore, in RAI 112, Question 10.04.03-1b, the staff requested that the applicant provide clarification of why these features were not discussed in the application.

In a January 28, 2009, response to RAI 112, Question 10.04.03-1b, the applicant provided a detailed discussion regarding the fail positions of a motor-operated isolation valve in the auxiliary steam supply line and various pneumatically actuated pressure control valves in the TGSS, such as the seal steam seal leak off valve. Each control valve is an electro-pneumatic valve, which is equipped with an electronic positioner, a pneumatic actuator, an instrument air isolation valve, and an instrument air filter. The control valve position is measured by a position transmitter. The applicant also stated that the turbine-supplier will provide the TGSS and identified the fail positions of the power-operated valves in the system. The applicant further stated that FSAR Tier 2, Section 10.4.3 will be revised to reflect the details that are described in the January 28, 2009, response to RAI 112, Question 10.04.03-1b. The staff reviewed these proposed FSAR revisions, and finds the information sufficient to verify proper operation of the TGSS valves by the above cited testing. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 112, Question 10.04.03-1b resolved.

10.4.3.5 *Combined License Information Items*

For the TGSS, no COL information items have been identified in FSAR Tier 2, Table 1.8-2. The staff finds this acceptable because the initial plant test program assures that the TGSS will be constructed in accordance with the certified design.

10.4.3.6 *Conclusions*

The staff has concluded that sufficient information has been provided by the applicant in FSAR Tier 2, Section 10.4.3, as related to the TGSS. In addition, the staff has compared the design information and the COL information item in the FSAR application to NRC regulations, acceptance criteria defined in NUREG-0800, Section 10.4.3, and other NRC regulatory guides. In conclusion, for the reasons set forth above, the design for the TGSS is acceptable and meets the guidelines of SRP Section 10.4.2 and the requirements of GDC 60 and GDC 64 for controlling and monitoring of releases of radioactive materials to the environment.

10.4.4 Turbine Bypass System

10.4.4.1 *Introduction*

The TBS discharges main steam from the steam generators directly to the main condenser in a controlled manner, bypassing the main turbine. With one of the six bypass valves out of service, 50 percent of SG capacity can be bypassed to the main condenser. This process minimizes transient effects on the RCS during plant startup, hot shutdown and cooldown, step load reductions in generator load, or following a reactor trip.

10.4.4.2 *Summary of Application*

FSAR Tier 1: FSAR Tier 1, Section 2.8.2 states that the main steam system (MSS) provides the following non-safety-related function: The MSS and the turbine bypass system provide the capability to dump steam to the main condenser. FSAR Tier 1, Table 2.8.2-1, "MSS Equipment Mechanical Design," shows that the six turbine bypass valves are located in the Turbine Building, are not seismically qualified, and are designed to Quality Group E standards. The physical arrangement of the bypass valves is as shown in FSAR Tier 1, Figure 2.8.2-1.

FSAR Tier 2: The applicant provided a TBS description in Section 10.4.4.2, "System Description," which is summarized here, in part. The TBS performs no safety-related function and is designed to meet the following functional criteria:

- The combined capacity of the TBS is such that following a reactor trip, the system alone is sufficient to prevent actuation of a main steam relief train or MSSV following a turbine trip or full load rejection.

- The TBS dump valves automatically open when steam generation exceeds the consumption limit of the turbine.

- With one turbine bypass valve out of service, 50 percent of SG capacity can be dumped to the main condenser.

- Steam can be bypassed to the condenser during plant startup and to permit a normal cooldown of the RCS from hot shutdown to the point conformed to the initiation of the RHR system.

The TBS is part of the MSS and is described further in FSAR Tier 2, Section 10.3, "Main Steam Supply System." This system is shown in FSAR Tier 2, Figure 10.3-1.

ITAAC: FSAR Tier 1 ITAAC for the main steam system are shown in FSAR Tier 1, Table 2.8.2-3, "MSS ITAAC." With respect to the TBS, Item 2.1 and Item 2.2 in the above table require conformance to the basic configuration of Figure 2.8.2-1, "Main Steam Supply System Functional Arrangement," and the verification that TBS equipment is located in the Turbine Building.

Technical Specifications: There are no TS requirements associated with the TBS.

10.4.4.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.4 and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 10.4.4.

1. 10 CFR Part 50, Appendix A, GDC 4, in that failure of the TBS due to a pipe break or malfunction of the TBS should not adversely affect systems or components (i.e., those necessary for safe-shutdown or accident prevention or mitigation).

2. GDC 34, as it relates to the ability to use the system for shutting down the plant during normal operations. The operation of the TBS eliminates the need to rely solely on safety systems.

3. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

10.4.4.4 *Technical Evaluation*

The staff reviewed the TBS in accordance with SRP Section 10.4.4, and the acceptability of the system is based on meeting the requirements of the following GDC as described in the SRP:

1. GDC 4, as it relates to the system being designed such that a failure of the system due to a pipe break or system malfunction does not adversely affect safety-related systems or components.

2. GDC 34, as it relates to the ability to use the TBS for shutting down the plant during normal operations by removing residual heat without using the TG.

The TBS is designed to bypass 50 percent of the main steam from the SGs directly to the main condenser in a controlled manner. The system is designed to bypass steam to the main condenser during plant startup and also to permit a normal cooldown of the RCS from a hot shutdown to the point at which the RHR system can be placed in service. This design feature minimizes transient effects on the RCS during plant startup, hot shutdown and cooldown, step load reductions in generator load, and following a reactor trip.

In FSAR Tier 2, Section 10.4.4.2.1, “General Description,” the applicant described that the TBS consists of six valves located in the Turbine Building that dump steam from a manifold to the three condenser shells. The dump valves automatically open when steam generation exceeds consumption by the main turbine. Also, according to FSAR Tier 2, Section 10.4.4.2.2, “Component Description,” piping and components are classified as Quality Group E and have a non-seismic design classification. The bypass valves and associated piping are designed to codes and standards conformed to the design of the Turbine Building main steam line piping. The valves and actuators are designed to Turbine Building environmental conditions and to fail closed on loss of electrical signal or actuating fluid pressure. A drain pot is provided at the piping low point to avoid the collection of condensate during normal operation.

FSAR Tier 2, Section 10.4.4.2.3, “System Operation,” describes the TBS service for normal, shutdown, and abnormal plant operations. During power operation, the TBS is normally not used, except during mild pressure transients. During normal shutdown, main steam from the SGs is dumped to the main condenser through the turbine bypass valves. Steam flow is a function of reactor coolant pump (RCP) power and core decay heat. Therefore, cooldown from no load to the point of placing RHR in service is accomplished by gradually reducing main steam pressure. Once the RHR system is providing heat removal, the TBS and MSS can be taken out of service. The TBS also functions during the loss of external load abnormal operating event. Following the resulting turbine trip, steam is automatically dumped to the main condenser through the TBS. If a loss of condenser vacuum should occur, the TBS becomes unavailable for service. Additionally, failure of the TBS is also evaluated as part of the increased steam flow with MSIV failure to close event, where failure is initiated by failure or function error of the TBS controls. This event is bounded by the main steam line break event, and once conditions have stabilized, heat removal takes place via the MSRTs. Failure of TBS piping is considered within the main steam line break outside containment analysis in FSAR Tier 2, Chapter 15.

The TBS performs no safety-related function. FSAR Tier 1, Figure 2.8.2-1 and FSAR Tier 2, Figure 10.3-1 delineate the system and components of the TBS. The arrangement is similar to those used in TG applications in existing U.S. reactor designs. The staff finds the stated capacity of the TBS conform to the stated design functional criteria (i.e., to provide a system capable of preventing main steam relief train or main steam safety valve actuation following a reactor trip and a system capable of supporting normal startup and cooldown functions in conjunction with the RHR system).

FSAR Tier 2, Section 10.4.4.3, “Safety Evaluation,” describes that there is no safety-related equipment in the vicinity of the TBS. All high energy lines associated with the TBS are located in the Turbine Building. Also, the valve locations will be confirmed in the Turbine Building via FSAR Tier 1, ITAAC Table 2.8.2-3. Therefore, there are no safety-related systems to be affected by a break or failure of the TBS. Accordingly, the staff finds that the TBS meets GDC 4, as it relates to the adverse affects of a pipe break or malfunction on those components of the system necessary for safe-shutdown or accident prevention or mitigation, since such components do not exist in the Turbine Building.

In FSAR Tier 2, Section 10.4.4.5, "Instrumentation Requirements," the applicant stated that the TBS bypass valves automatically modulate to maintain variable main steam pressure as determined by the reactor controls. The turbine bypass valves close and are prevented from opening on high condenser backpressure or high hot well level. Also, the turbine bypass valves automatically open when steam generation exceeds the demand by the turbine. The TBS is designed such that reliance on safety-related systems such as the MSRT and MSSVs is minimized. The 50 percent bypass valve capacity is maintained with one turbine bypass valve out of service. Further, adequate controls are provided to support reliable TBS operation. Also, the staff finds that the design of the TBS in conjunction with the RHR system provides a reliable system for shutting down the plant during normal operations. Therefore, the staff concludes that the TBS meets the requirements of GDC 34, since the system is designed such that the plant can be shutdown during normal operations without using the TG.

ITAAC: FSAR Tier 1 ITAAC requirements for the MSS are shown in FSAR Tier 1, Table 2.8.2-3. With respect to the TBS, Item 2.1 and Item 2.2 require that the applicant conform to the basic configuration of Figure 2.8.2-1 and the verification that TBS equipment is located in the Turbine Building. The staff reviewed these ITAAC requirements of Table 2.8.2-3 and finds these requirements sufficient to demonstrate the essential features of the TBS.

Technical Specifications: There are no TS requirements associated with the TBS. This system is not provided in the standard TS; therefore, the staff finds that no TS are needed for the TBS.

Initial Plant Test Program: Inspection and testing of the TBS is performed prior to plant operation via Test No. 061 as described in FSAR Tier 2, Section 14.2. The TBS components are inspected and tested as part of the initial plant startup testing. Tests will ensure proper valve operation and position indication; thrust, opening and closing times; opening of the turbine bypass valves in response to a simulated steam pressure above setpoint signal; and confirmation of failure positions upon loss of motive power. Operational testing and inservice inspection can also be performed. The staff finds these test practices acceptable, since they demonstrate proper operation of the TBS and are commensurate with the TBS safety classification.

10.4.4.5 *Combined License Information Items*

For the TBS, no COL information items have been identified in FSAR Tier 2, Table 1.8-2. The staff finds this acceptable because the proposed ITAAC and initial plant test program assure that the TBS will be constructed in accordance with the certified design.

10.4.4.6 *Conclusions*

The staff basis for acceptance of the TBS is conformance of the design, design criteria, and design bases to NRC regulations set forth in GDC 4 and GDC 34. The TBS has met the requirements of GDC 4 with respect to the system being designed such that a TBS failure due to a pipe break or malfunction will have no adverse affect on the essential systems or components that are necessary for safe-shutdown or accident prevention or mitigation. The system has also met the requirements of GDC 34 with respect to the ability of the TBS for shutting down the plant during normal operations by removing residual heat without using the TG. Accordingly, the staff concludes that the applicant has provided sufficient information for satisfying GDC 4 and GDC 34 requirements, as described in the regulatory basis of this report, and this review may be considered closed.

10.4.5 Circulating Water System

10.4.5.1 *Introduction*

The circulating water system (CWS) is designed to provide a continuous supply of cooling water to the main condensers and auxiliary cooling water system (ACWS) to remove the heat rejected by the turbine cycle and ACWS. This heat removed from the main condensers and ACWS is subsequently transferred to the normal heat sink. For the U.S. EPR, the normal heat sink consists of mechanical cooling towers.

10.4.5.2 *Summary of Application*

FSAR Tier 1: The U.S. EPR has no FSAR Tier 1 entries for the CWS.

FSAR Tier 2: The FSAR Tier 2 system description is provided in Section 10.4.5.2; summarized here, in part, as follows:

The portions of the circulating water system that are outside the scope of the design certification are presented as conceptual design information in FSAR Tier 2, delineated by double brackets ([[ ]]), based upon a cooling tower approach. Those items in ([[ ]]) in FSAR Tier 2 are noted below. No evaluation of the bracketed information is provided in this section or the Technical Evaluation.

The layout of the CWS is shown in FSAR Tier 2, Figure 10.4.5-1, "Circulating Water System Flow Diagram." The design of the CWS outside of the Turbine Building is site-specific. A COL applicant that references the design certification will provide the description of the site-specific portions of the CWS.

During normal plant operation, circulating water is routed from the individual cooling tower basins into the respective circulating water sumps. The circulating water pumps discharge the circulating water into a common header, and from there into separate supply lines to the condenser water boxes. Downstream of the condenser water boxes in the outdoor area, the circulating water is routed back to the cooling towers through two separate return lines.

Abnormal operating conditions for which the CWS is designed include loss of one CWS pump or loss of one cooling tower, with either of these resulting in increased turbine backpressure, resulting in a decreased thermal power output. If all CWS pumps or all cooling towers fail, heat removal is provided by the main steam relief trains described in FSAR Tier 2, Section 10.3. On a loss of power, there is a loss of the non-emergency power supply, resulting in a loss of function of the CWS.

FSAR Tier 2, Table 3.2.2-1, "Classification Summary," provides the quality group and seismic design classification of components and equipment in the CWS. The CWS consists of [[circulating water pumps, mechanical draft cooling towers, cooling tower makeup system, chemical treatment system, cooling tower blow down system, associated piping, valves and instrumentation, vacuum priming system]], vacuum breaker, condenser tube cleaning system, and vents and drains.

The design has provisions for a vacuum breaker at the outlet water box of the condenser that is relied upon to prevent water hammer during transient operation. The vacuum breakers are shown on FSAR Tier 2, Figure 10.4.5-1.

Deposits that form on condenser tubes are removed by the condenser tube cleaning system (CTCS). Continuous cleaning of internal tube surfaces is accomplished by a constant circulation of sponge rubber balls having a diameter slightly larger than the tube and a density when wet similar to that of the circulating water. The condenser tube cleaning system is shown on FSAR Tier 2, Figure 10.4.5-1.

The CWS piping and condenser water boxes include high-point vents and low-point drains at appropriate locations for use during filling and draining of the system. The vents and drains are shown on FSAR Tier 2, Figure 10.4.5-1.

ITAAC: There are no ITAAC associated with the CWS.

Technical Specifications: There are no TS applicable to the CWS.

Conceptual Design: This section of the application contains the following conceptual design information that is outside the scope of the certification: Cooling towers, circulating water pumps, cooling tower makeup system, chemical treatment system, and cooling water blowdown system.

U.S. EPR Plant Interfaces: This section of the application contains information related to the following plant interfaces that will be addressed in the COL designs: Design details for the CWS including makeup water and water treatment.

10.4.5.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in SRP Section 10.4.5, “Circulating Water System,” and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 10.4.5.

1. 10 CFR Part 50, Appendix A, 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.

2. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

10.4.5.4 *Technical Evaluation*

The staff reviewed the CWS in accordance with SRP Section 10.4.5, and the acceptability of the system described in the FSAR is based on meeting the requirements of GDC 4, as they relate to provisions in the design to accommodate the effects of discharge water that may result from a failure of a component or piping in the CWS. The review of the CWS is also based on conforming to the guidance of the SRP acceptance criteria as described above in the Regulatory Basis section of this report.

The CWS is a non-safety-related system designed to provide a continuous cooling water supply to the main condensers and ACWS. The system consists of circulating water pumps, mechanical draft cooling towers, and associated piping, valves, and instrumentation. The layout of the CWS is shown in FSAR Tier 2, Figure 10.4.5-1, "Circulating Water System Flow Diagram." Since the design of the CWS may vary from site to site, in FSAR Tier 2, Section 10.4.5.2.1, "General Description," the applicant stated that the design of the CWS outside of the Turbine Building is site-specific and is outside the scope of the design certification. These site-specific features and subsystems associated with the CWS include: Cooling towers, circulating water pumps, cooling tower makeup system, chemical treatment system, vacuum priming system, cooling water blowdown system, and other components associated with the CWS. The COL applicant will determine the final system configuration. Further, FSAR Tier 2, Table 1.8-2, "U.S. EPR Combined License Information Items," identifies actions required by COL applicants to provide the description of site-specific portions of the CWS, including testing information. Additionally, FSAR Tier 2, Table 1.8-1, "Summary of U.S. EPR Plant Interfaces with Remainder of Plant," Item 10-1 requires the COL applicant to address the circulating water system design including makeup water and water treatment.

FSAR Tier 2, Section 10.4.5.2.2, "Component Description," describes the conceptual design of various components and piping and valves of the CWS, and also describes the subsystems that are identified above. The cooling tower that serves as a heat sink for the CWS is site-specific. The FSAR provides a reference design using mechanical draft cooling towers, each with a basin and circulating water pump sump. The sumps are designed to provide sufficient suction submergence to the circulating water pumps. There are four 25 percent capacity vertical shaft type circulating water pumps. Trash racks or suction screens are provided to prevent debris from entering the circulating water pump suction.

Also, FSAR Tier 2, Section 10.4.5.2.2 describes the provisions for vents in the CWS piping and condenser water boxes, vacuum breakers, and high-point vents and low-point drains in the CWS. The staff finds these design features acceptable, since these provisions will help prevent pressure transients such as water hammer and subsequent CWS piping or component failure from occurring on pump startup from initial system depressurization. Furthermore, under FSAR Tier 2, Section 10.4.5, "Piping and Valves," and COL Information Item 10.4-5A, the applicant stated that the COL applicant that references the design certification will provide the site-specific CWS piping design pressure. However, the FSAR does not provide reference design parameters for the CWS, including but not limited to, cooling tower inlet and outlet temperatures, inlet temperature at the condenser, and piping and valve design pressures. Higher circulating water temperature results in increased pressure in the condenser due to decreased rate of steam condensation. The reference design data in the FSAR will help the COL applicants in performing site-specific analysis to accommodate limiting site-specific weather conditions. Therefore, in RAI 83, Question 10.04.05-1, the staff requested that the applicant provide reference design parameters for the CWS and the major components of the system. The staff also requested that the applicant address freeze protection measures for the CWS operations during cold weather conditions for startup and normal plant operations.

In a November 10, 2008, response to RAI 83, Question 10.04.05-1, the applicant replied that the design bases for the main condenser (MC) and the CWS are provided in FSAR Tier 2: (1) Figure 10.1-1, "Design Heat Balance for Steam and Power Conversion System Cycle"; (2) Figure 10.1-2, "Valve Wide Open Heat Balance for Steam and Power Conversion System Cycle"; and (3) Table 10.1-1, "Major Steam System Parameters and Turbine Generator Design Data." The allowable pressure in the MC shell, during normal operation, will be limited to a specific set-point value defined by the turbine-generator supplier. The applicant also stated that the CWS will be designed to maintain site-specific condenser inlet water temperature during hot weather, so that the pressure in the MC shell remains below the set-point value. In addition, other conditions such as cooling tower inlet and outlet water temperatures and piping and valve design pressures are all site-specific and depend on site-climate conditions. Further, the design of the CWS depends on the site-specific elevation difference between the cooling tower basin and the MC, and the length and layout of piping in the CWS from the cooling tower basin to the MC and back to the tower. Regarding freeze protection, the COL applicant will develop proper measures for the CWS operations during cold weather conditions. The applicant further stated that such items will be addressed by the COL applicant and are within the purview of FSAR Tier 2, Table 1.8-2, Item 10.4-3A, which requires that the COL applicant address the site-specific portions of the CWS.

The staff reviewed the applicant's November 10, 2008, response to RAI 83, Question 10.04.05-1, and finds that the information provided in the FSAR for FSAR Tier 2, Figures 10.1-1 and 10.1-2, and FSAR Tier 2, Table 10.1-1, adequately addresses the requirements and guidance to COL applicants that incorporate the certified standard design into their COL applications and is, therefore, acceptable. The staff also reviewed FSAR Tier 2, Table 1.8-2, COL Information Items 10.4-3 and 10.4-5 which state that it is the COL applicant that adopts the design certification who will design the site-specific portions of the CWS and the CWS piping design pressure, respectively. The staff agrees that the design parameters are site-specific, and the CWS design will be based on the site-specific weather conditions and the piping layout equipment layout; therefore, the staff finds the applicant's response acceptable and considers RAI 83, Question 10.04.05-1 resolved.

For the CWS, the cooling tower makeup is site-specific, and the FSAR states that the COL applicant will design its makeup water system to provide an adequate supply of water to the cooling tower basins for evaporative losses in the system. In addition to the makeup water system, the FSAR states that the COL applicant will design a cooling tower blowdown system to maintain the concentration of dissolved solids in the CWS within acceptable limits. The FSAR also includes conceptual design for a chemical treatment system, and a COL applicant that references design certification for its CWS shall provide a chemical treatment system as determined by the site-specific water conditions. Also, COL Information Item 10.4-4A requires that the COL applicant address methods for control of water chemistry. The staff finds this provision acceptable, since it conforms to the guidance provided in SRP Section 10.4.5, Item III.3, as related to control of CWS water chemistry.

In FSAR Tier 2, Section 10.4.5.2.3, "System Operation," the applicant describes the normal and abnormal operations of the CWS. For abnormal operation, the FSAR indicates that flood protection is included in the design, so that the large leaks from the CWS piping do not result in the loss of all CWS pumps. Further, the FSAR states that the layout of the CWS design is such that a malfunction of any component or piping does not adversely affect the safe operation of the plant or any system that is important to safety. The staff finds this acceptable, since these provisions conform to the SRP acceptance criteria in Item II of the SRP Section 10.4.5.

Additionally, in FSAR Tier 2, Section 10.4.5.2.3, the applicant states that when the CWS is not available due to a malfunction of the CWS pumps or cooling tower, heat removal is provided by the MSRTs, which are described in FSAR Tier 2, Section 10.3, "Main Steam System." The staff finds this alternate cooldown method acceptable, because the CWS is not required for safe shutdown following an accident and the MSRTs are available for heat removal following an accident.

FSAR Tier 2, Section 10.4.5.3, "Safety Evaluation," states that design provisions for flooding control in response to a failure in the CWS are described in FSAR Tier 2, Section 3.4. The staff noted no such description in FSAR Tier 2, Section 3.4. There was also no COL information item identified in the FSAR for flood control due to cooling tower collapse or due to failure of yard piping. Therefore, in RAI 83, Question 10.04.05-2, the staff requested that the applicant revise the FSAR to (1) include design provisions for flooding control in response to a failure in the CWS in FSAR Tier 2, Section 3.4, and (2) include a COL information item to address the cooling tower and yard piping failure effects as related to the CWS flood control in order to comply with GDC 4 requirements.

In a November 10, 2008, response to RAI 83, Question 10.04.05-2, the applicant replied that FSAR Tier 2, Section 3.4.2 lists the external flood protection measures in the design, which preclude flood water from both natural phenomena and component failures from entering Seismic Category I structures. Since the CWS is located outside of any Seismic Category I structure, the flood protection measures preclude flooding of safety-related SSCs resulting from a failure of the CWS (see applicant's response to RAI 83, Question 10.04.05-1(2)). However, the applicant stated that COL Information Item 3.4-1 in the FSAR is intended to include protection against flooding due to site-specific component failures such as a failure in the CWS. To further clarify the need for a COL applicant to confirm that a failure of the site-specific CWS will not adversely affect safety-related SSCs, the applicant responded that FSAR Tier 2, Section 10.4.5.3 will be revised, and also COL Information Item 10.4-7 will be added to FSAR Tier 2, Table 1.8-2 requiring the COL applicants that reference the design certification to address the potential for flooding of safety-related equipment due to failures of the site-specific CWS. The applicant submitted the markups of FSAR Tier 2, Section 10.4.5.3 and FSAR Tier 2, Table 1.8-2 reflecting the proposed revisions as stated above. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.5.3 and Table1.8-2 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.05-2 resolved.

FSAR Tier 2, Section 10.4.5.4, "Inspection and Testing Requirements," indicates that the CWS is inspected and tested as part of the initial test program described in SRP Section 14.2. The CWS pumps are to meet the performance tests of the Hydraulic Institute Standard for pumps. Also, the CWS components are accessible during normal plant operation, which the staff finds acceptable as the CWS conforms to normal industry practices.

With respect to instrumentation, FSAR Tier 2, Section 10.4.5.5, "Instrumentation Requirements," addressed conceptual design information for the CWS. The COL applicants who reference the U.S. EPR design need to address the circulating water pump discharge pressure, condenser inlet and outlet pressure, and flow measuring devices in the CWS piping. Also, the FSAR calls for cooling tower basin level monitoring instrumentation to control makeup flow and blowdown adjustments to maintain the CWS water chemistry. The staff finds that the FSAR adequately addressed the conceptual design for CWS instrumentation, so that the COL applicants can provide plant-specific CWS instrumentation details in their applications.

The staff concludes that the portion of the CWS identified by the applicant as conceptual design information is appropriate to be addressed by the COL applicant.

Based on the above discussion, the staff finds that the FSAR adequately addressed the conceptual design information and the design provisions for the CWS, and the FSAR has provided sufficient information to guide COL applicants in satisfying GDC 4 requirements.

ITAAC: There are no ITAAC requirements associated with the CWS, since no regulatory considerations apply.

U.S. EPR Plant Interfaces: There are no plant interface requirements associated with the CWS, since no regulatory considerations apply.

Technical Specifications: There are no TS applicable to the CWS, and the staff finds this acceptable.

10.4.5.5 *Combined License Information Items*

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.4.5-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
10.4-3	A COL applicant that references the U.S. EPR design certification will provide the description of the site-specific portions of the CWS.	10.4.5.2.1
10.4-4	A COL applicant that references the U.S. EPR design certification will provide the specific chemicals used within the chemical treatment system as determined by the site-specific water conditions.	10.4.5.2.2
10.4-5	A COL applicant that references the U.S. EPR design certification will provide the site-specific CWS piping design pressure.	10.4.5.2.2
10.4-6	If a vacuum priming system is required, a COL applicant that references the U.S. EPR design certification will provide the site-specific information.	10.4.5.2.2
10.4-7	A COL applicant that references the U.S. EPR design certification will provide information to address the potential for flooding of safety-related equipment due to failures of the site-specific CWS.	10.4.5.3
14.2-5	A COL applicant that references the U.S. EPR design certification will provide site-specific test information for the circulating water supply system.	14.2.12.7.11

10.4.5.6 *Conclusions*

The staff concludes that sufficient information has been provided by the applicant in FSAR Tier 2, Section 10.4.5, which supports that the CWS can perform its non-safety function of providing a continuous supply of cooling water to the turbine condensers and auxiliary cooling water system and reject heat to the environment via the normal heat sink.

In addition, the staff compared the conceptual design information and the COL information items in the FSAR to NRC regulations and acceptance criteria defined in NUREG-0800, Section 10.4.5. The staff finds that the applicant has provided sufficient information to enable

COL applicants who reference the U.S. EPR design to satisfy GDC 4 requirements and SRP criteria, as described in the regulatory basis of this report.

10.4.6 Condensate Polishing System

The condensate polishing system (CPS) is part of the condensate cleanup system (CCS) and, as indicated in NUREG-0800, the purpose of the CCS is to remove dissolved and suspended impurities resulting from corrosion caused by condenser or steam generator leaks that could be introduced into the CCS by carryover from the main steam system. The CCS is not necessary for safe shutdown or mitigation of postulated accidents, but it is important in maintaining the secondary coolant quality in pressurized water reactors.

10.4.6.1 *Introduction*

The CPS is a non-safety system and is normally used during unit startup to bring condensate water quality into conformance to the plant water chemistry specification. There are four trains of deep mixed bed demineralizers in parallel with the hotwell sump which can take suction on the sump in a recirculation mode until the water quality complies with the plant water chemistry specification. The system can be aligned during power operation to function if a condenser tube leak occurs. A resin trap is located downstream of the demineralizer bed to trap resin fines. Each train of polisher is designed to operate with one third condensate flow. Used resin is transferred to a holding tank or directly to a truck for disposal or regeneration.

10.4.6.2 *Summary of Application*

FSAR Tier 1: There are no entries on the condensate system or the polishing system listed in FSAR Tier 1.

FSAR Tier 2: The applicant has provided an FSAR Tier 2 system description in Section 10.4.6 summarized here, in part, as follows:

Figure 10.4.6-1 is the Condensate Polishing System Flow Diagram. The CPS has four separate trains, each consisting of a deep mixed bed demineralizer, a resin trap and associated valves, piping, and instrumentation. The system, which is housed in the Turbine Building, is not safety-related and performs no safety function.

The system normally operates as the plant is starting up to clean up the condensate by circulating it between the hotwell sump and the demineralizer beds. The plant remains in the startup condition until the condensate meets the plant water chemistry specification.

The system is also designed to be placed online during power operations if deterioration in condensate water quality is detected. Such a condition could exist if a steam generator primary-to-secondary tube leak were to occur. Such a situation might also cause radioactive contamination to be trapped in the demineralizers. The system is capable of processing contaminated resin or of having shielding installed as necessary to store and process the spent resin. The system is capable of storing the spent resin or transferring it directly to trucks for subsequent disposal or regeneration.

ITAAC: There are no ITAAC associated with the condensate cleanup system including the polishing system.

Technical Specifications: There are no TS related to the condensate cleanup system or its associated polishing system.

10.4.6.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.6 and are summarized below. Review interfaces with other SRP sections can also be found in NUREG-0800, Section 10.4.6.

- GDC 14, "Reactor Coolant Pressure Boundary," contained in 10 CFR Part 50, Appendix A as it relates to the requirement that the reactor coolant pressure boundary be designed, fabricated, erected, and tested to ensure an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture. While GDC 14 does not directly apply to the CPS, the CPS controls the secondary side environment of the steam generator tubes, which are part of the reactor coolant pressure boundary (RCPB). Inappropriate control of secondary side water chemistry may cause degradation of steam generator tubes. Accordingly, control of secondary side water chemistry is necessary to assure compliance with GDC 14.

Acceptance criteria adequate to meet the above requirements include:

- EPRI report series, "PWR Secondary Water Chemistry Guidelines," Revision 6

10.4.6.4 *Technical Evaluation*

The staff reviewed the condensate polishing system in accordance with NUREG-0800, Section 10.4.6, "Condensate Cleanup System," Revision 3, March 2007. Staff acceptance of the condensate polishing system is based on the design meeting the requirements of GDC 14. The staff reviewed the information provided in FSAR Tier 2, Sections 10.4.6, "Condensate Polishing System," and 10.3.5, "Secondary Side Water Chemistry Program," against the requirements of GDC 14 and the EPRI PWR Secondary Water Chemistry Guidelines.

The principal function of the CPS is to maintain the purity of the feedwater for the steam generators by filtration to remove corrosion products and by ion exchange to remove condenser leakage impurities and other dissolved impurities. The CPS is primarily used during startup and shutdown to help speed up those operations. It is also used during power operation when abnormal secondary cycle conditions exist. This allows the plant to be operated while the abnormal secondary cycle condition is corrected. The CPS has a design capacity of up to one-third of the condensate flow.

The CPS consists of at least four trains of mixed bed demineralizers followed by resin traps to capture small fragments or fines of ion exchange resins. Instrumentation, including instruments to measure pressure drop and conductivity at the demineralizer outlet, are provided to determine when the CPS resin is exhausted or otherwise no longer capable of providing its impurity removal or filtration function. Exhausted resin is regenerated or disposed off site. A spent resin tank holds exhausted resin so that the ion exchange vessels can be recharged with fresh resin. Piping and associated connections are provided for disposal of the spent resin as either nonradioactive waste or, if necessary, as radioactive waste. FSAR Tier 2, Table 3.2.2-1 provides the quality group and seismic design classification of components and equipment in the CPS. The CPS performs no safety-related function and does not have any safety-related design basis.

There are no specific criteria for cleanup capacity of the CPS. The design capacity of one-third flow should be adequate to allow the plant to operate while abnormal secondary water chemistry conditions are corrected. In the event that the capacity is insufficient, the plant will be shut down in accordance with the secondary water chemistry control program.

FSAR Tier 2, Section 10.4.6.2.2 states that the CPS piping and components are constructed of carbon steel materials which are compatible with system conditions. For locations where protection from FAC is required, carbon steel containing a minimum of 0.1 percent chromium will be used.

While GDC 14 does not directly apply to the CPS, the CPS controls the secondary side environment of the steam generator tubes, which are part of the reactor coolant pressure boundary (RCPB). Inappropriate control of secondary side water chemistry may cause degradation of steam generator tubes. Accordingly, control of secondary side water chemistry is necessary to assure compliance with GDC 14. An acceptable method of controlling secondary side chemistry is for the applicant to meet the latest version in the EPRI PWR Secondary Water Chemistry Guidelines. FSAR Tier 2, Section 10.4.6.4 states that the secondary water chemistry program is based on the EPRI PWR Secondary Water Chemistry Guidelines. FSAR Tier 2, Section 10.3.5 provides a detailed description of the secondary chemistry program and associated chemistry control parameters. In addition to providing suitable water quality to minimize the likelihood of corrosion-induced failure of the pressure boundary, adequate instrumentation should be provided to verify the effectiveness of the CPS in order to conform to the recommendations of SRP Section 10.4.6. Additionally, SRP Section 10.4.6 recommends that the system be connected to radioactive waste disposal systems to allow disposal of spent resin or regenerant solutions when necessary.

The EPRI PWR Secondary Water Chemistry Guidelines provide several criteria for the secondary water chemistry control program including sampling frequency and other sampling recommendations, guidelines for continuously monitoring water chemistry parameters, and recommended operating limits for impurities and additives, as well as associated action responses to be carried out if recommended limits are exceeded.

The staff reviewed the instrumentation provided to monitor the effectiveness of the condensate cleanup system. FSAR Tier 2, Table 9.3.2-2 addresses secondary side sampling points and continuous monitors. In Revision 0 of the FSAR, the continuous monitors identified in FSAR Tier 2, Table 9.3.2-2 conform to the EPRI PWR Secondary Water Chemistry Guidelines, with the exception that continuous monitoring of pH was not specified in FSAR Tier 2, Table 9.3.2-2 in the condensate or blowdown as specified in the EPRI PWR Secondary Water Chemistry Guidelines.

In RAI 62, Question 10.04.06-2, the staff requested that the applicant describe the approach that will be used for continuous pH monitoring in the steam generator blowdown and condensate systems. With respect to pH monitoring of the condensate system, the EPRI PWR Secondary Water Chemistry Guidelines only call for continuous monitoring if the secondary system contains copper alloys. FSAR Tier 2, Section 10.3.5.1 states that secondary system components and piping are all-ferrous materials with the exception of the steam generator tubing. Therefore, continuous monitoring of the condensate pH is not necessary. With respect to continuous monitoring of the steam generator blowdown pH, Revision 1 of FSAR Tier 2, Table 9.3.2.2 was revised to add pH as a continuously monitored parameter for steam generator blowdown, and therefore, the staff considers RAI 62, Question 10.04.06-2 resolved.

The staff finds the instrumentation and sample points provided are acceptable, because they conform to those recommended by the EPRI PWR Secondary Water Chemistry Guidelines.

FSAR Tier 2, Tables 10.3-5 through 10.3-10 provide the limits for all measured parameters in the secondary chemistry control program. The parameters and their corresponding limits conform to the EPRI PWR Secondary Water Chemistry Guidelines. The FSAR specifies that power should be held at <25 percent power until certain conditions have been met. The EPRI PWR Secondary Water Chemistry Guidelines specify the hold point at <30 percent power. A lower power hold is more conservative with respect to steam generator corrosion concerns and, therefore, is acceptable.

FSAR Tier 2, Section 10.3.5 states that the secondary water chemistry program is based on the EPRI PWR Secondary Water Chemistry Guidelines. Additionally, FSAR Tier 2, Section 5.4.2.3 indicates that the steam generator program framework is based on Nuclear Energy Institute (NEI) 97-06. A commitment to NEI 97-06 ensures that the secondary water chemistry program will conform to the most current version of the EPRI PWR Secondary Water Chemistry Guidelines. The EPRI PWR Secondary Water Chemistry Guidelines recommend specific Action Level 1, 2, and 3 limits for many secondary water chemistry control parameters. Specific actions including reduced power and or shutdown are recommended if these limits are exceeded. FSAR Tier 2, Table 1.8.2, Information Item 13.5-1, requires the COL applicant to develop site-specific operating procedures which include chemistry control procedures. The commitment to NEI 97-06 and, thus, to the latest edition of the EPRI PWR Secondary Water Chemistry Guidelines will ensure that aspects of the secondary water chemistry program such as Action Levels, and pH control and optimization of the condensate/feedwater cycle are in accordance with the latest EPRI PWR Secondary Water Chemistry Guidelines.

The staff also finds the standards for effluent purity are acceptable, because water chemistry will be maintained within the limits recommended by the latest edition of the EPRI PWR Secondary Water Chemistry Guidelines. While the staff does not review or accept the EPRI PWR Secondary Water Chemistry Guidelines through a safety evaluation, these guidelines are recognized as representing the industry consensus on best practices in water chemistry control and have been proven to be effective via many years of successful operating experience. As such, the staff finds the provision of a system capable of maintaining the secondary water chemistry as recommended by the EPRI PWR Secondary Water Chemistry Guidelines and a commitment to implement a program to do so, to be an acceptable method for the applicant to ensure appropriate control of secondary side water chemistry.

The staff verified that the CPS system is connected to the radioactive waste disposal system to allow disposal of spent resin or regenerant solutions when necessary.

There are no associated TS for this system. FSAR Tier 2, Section 14.2.12.7.8 specifies the initial tests for the condensate system; no additional tests for the condensate polishing system are required.

10.4.6.5 *Combined License Information Items*

The following is a list of COL information item numbers and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.4.6-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
10.3-1	A COL applicant that references the U.S. EPR design certification will identify the authority responsible for implementation and management of the secondary side water chemistry program.	10.3.5
13.5-1	A COL applicant that references the U.S. EPR design certification will provide site-specific information for administrative, operating, emergency, maintenance and other operating procedures.	13.5

10.4.6.6 *Conclusions*

For the reasons set forth above, the staff concludes the condensate polishing system includes all components and equipment necessary for the removal of dissolved and suspended impurities that may be present in the condensate. Based on the staff's review of the applicant's proposed design criteria and design bases for the condensate polishing system and the criteria for operation of the system, as set forth above, the staff concludes that the design of the condensate polishing system and supporting systems is acceptable to control secondary side water chemistry, which enables the steam generator tubes to meet the applicable reactor coolant pressure boundary integrity requirements of GDC 14, as discussed in Section 5.4.2 of this report. This conclusion is based on the applicant having met the recommendations of the latest version of the EPRI PWR Secondary Water Chemistry Guidelines, with respect to maintaining acceptable secondary chemistry control during normal operation and anticipated operational occurrences by reducing corrosion of steam generator tubes and materials, thereby reducing the likelihood and magnitude of reactor piping failures and of primary-to-secondary coolant leakage.

10.4.7 Condensate and Feedwater System

10.4.7.1 *Introduction*

The condensate and feedwater system (CFS) provides feedwater at a set temperature, pressure, and flow rate to the steam generators. Condensate is pumped from the main condenser hotwell by the condensate pumps, is passed through the low-pressure feedwater heaters and the deaerator-feedwater storage tank to the main feedwater pumps, and then is pumped through the high-pressure feedwater heaters to the SG. The CFS includes a number of stages of regenerative feedwater heating and provisions for maintaining feedwater quality. It also includes extraction piping from the steam turbines and feedwater heater vents and drains, and drains from the moisture separator reheaters (MSRs). Included in the CFS is the startup/shutdown system (SSS), which supplies feedwater to the SGs for low-power operation. The CFS design is provided in FSAR Tier 2, Section 10.4.7, "Condensate and Feedwater System," and shown in FSAR Tier 2 Figure 10.4.7-1, "Condensate and Feedwater System." An optional (alternative) design of the CFS is provided in FSAR Tier 2, Section 10.4.7A, "Condensate and Feedwater System," and depicted on FSAR Tier 2, Figure 10.4.7-A, "Condensate and Feedwater System."

10.4.7.2 *Summary of Application*

FSAR Tier 1: There are no FSAR Tier 1 entries for the condensate system (CS). The main feedwater system (MFWS) is described in FSAR Tier 1, Section 2.8.6, "Main Feedwater System." It states that the MFWS is safety-related from the steam generator connections to the fixed seismic restraint in each main feedwater line and to the fixed seismic restraint in each startup/shutdown feedwater line. It further states that there is one safety-related function:
To shut off main feedwater supply and to startup and shutdown feedwater supply to the steam generators when required.

FSAR Tier 2: The CFS is described in FSAR Tier 2, Section 10.4.7. The system extends from the condenser through the LP feedwater heaters, deareator, main feedwater pumps, high pressure feedwater heaters, main feedwater isolation valve, main feedwater control valves, and up to the steam generator main feedwater inlet nozzles. The primary function of the system is to transfer condensate and low pressure heater drains from the condenser hotwell through four stages of low pressure feedwater heating to suctions of main feedwater pumps and deliver it to the steam generators during power operation. During plant startup and shutdown operation, the SSS supplies feedwater to the steam generators using a dedicated pump, with associated valves and controls. The CFS need not operate during or after an accident.

ITAAC: The ITAAC for the MFWS are given in FSAR Tier 1, Table 2.8.6-3, "MFWS Inspections, Tests, Analyses, and Acceptance Criteria (6 Sheets)." Among other tests, the ITAAC will confirm that the main feedwater full load isolation valves (MFWFLIVs) are energized to close via two closure lines and that the MFWFLIVs fail closed on loss of hydraulic pressure.

Technical Specifications: FSAR Tier 2, Chapter 16, Technical Specification 3.7.3 provides limiting conditions (LCO) for operation and surveillance requirements for the main feedwater valves.

10.4.7.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.7, "SRP for the Review of Safety Analysis Reports for Nuclear Power Plants," and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 10.4.7.

1. 10 CFR Part 50, Appendix A, GDC 2, as it relates to safety-related portions of the CFS designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

2. GDC 4, as it relates to the dynamic effects associated with possible fluid flow instabilities (e.g., water hammers) during normal plant operation, as well as during upset or accident conditions.

3. GDC 5, as it relates to sharing of SSCs of the steam and power conversion systems of different nuclear power units.

4. GDC 44, "Cooling water," as it relates to:

    - o The capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions.

- o Redundancy of components so that under accident conditions, the safety function can be performed assuming a single active component failure. (This may be coincident with the loss of offsite or onsite power for certain events.)

- o The capability to isolate components, subsystems, or piping if required so that the system safety function will be maintained.

5. GDC 45, “Inspection of cooling water system,” as it relates to design provisions to permit periodic inservice inspection of system components and equipment.

6. GDC 46, “Testing of cooling water system,” as it relates to design provisions to permit appropriate pressure and functional testing of the system and components to ensure structural integrity and leak-tightness, operability and performance of active components, and capability of the integrated system to function as intended during normal, shutdown, and accident conditions.

7. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

8. 10 CFR 20.1406, “Minimization of contamination,” as it relates to the design features that will facilitate eventual decommissioning and minimize, to the extent practicable, the contamination of the facility and the environment and the generation of radioactive waste.

10.4.7.4 *Technical Evaluation*

The staff reviewed the CFS design as described in the FSAR. FSAR Tier 1 and Tier 2 information was reviewed in accordance with SRP Section 10.4.7, “Condensate and Feedwater System,” Revision 4, March 2007. Conformance to the acceptance criteria of SRP Section 10.4.7 formed the basis for the evaluation of the CFS with respect to the applicable regulations. The results and conclusions of the staff’s review of the CFS are discussed below. The evaluation addresses compliance with the SRP acceptance criteria listed in Section 10.4.7.3 of this report.

The CFS supplies the SGs with heated feedwater in a closed steam cycle using regenerative feedwater heating. It includes all components and equipment from the condenser outlet through the containment isolation valves to the steam generators and then to the heater drain system. The CFS does not perform safety-related functions with respect to transferring heat from structures, systems, and components important to safety to the ultimate heat sink. That function is performed by the emergency feedwater system (EFWS) which is reviewed in Section 10.4.9 of this report. The only safety-related functions performed by the CFS are to shut off main feedwater supply and to startup and shutdown feedwater supply to the steam generators when required, and containment isolation. The safety-related portions of the CFS are located inside containment and valve rooms, which are part of the Safeguard Buildings.

GDC 2

The staff reviewed the CFS for compliance with the requirements of GDC 2. Compliance with the requirements of GDC 2 is based on adherence to RG 1.29, "Seismic Design Classification," Regulatory Position C.1 for the safety-related portions of the system, and RG 1.29, Regulatory Position C.2 for the non-safety-related portions of the system. RG 1.29, Regulatory Position C.1 states, among other things, that the safety-related portions of the system should be designed as Seismic Category 1. RG 1.29, Regulatory Position C.2 states, among other things, those portions of the system that do not perform safety functions and whose failure could reduce the functioning of a safety-related feature should be designed so that the safety functions are not affected.

The safety-related portion of the CFS is required to remain functional after a design-basis accident to provide containment and feedwater isolation. The FSAR indicates that the safety-related portions of the CFS provide containment isolation and include portions of the condensate system penetrating containment and associated containment isolation valves (CIVs) and associated piping in the feedwater system from the SG inlets outward through the containment and up to, and including, the fixed restraints in each of the Safeguard Buildings.

The portions of the CFS penetrating containment and associated CIVs are shown in FSAR Tier 2, Figure 10.4.7-1. CIVs and associated piping in the feedwater system and startup and shutdown feedwater system from the SG inlets outward through the containment and up to, and including the fixed restraints in each of the Safeguard Buildings are shown in FSAR Tier 1, Figure 2.8.6-1, "Main Feedwater System Functional Arrangement," and FSAR Tier 2, Figure 10.4.7-1. These piping portions and associated CIVs are designated Quality Group B and designed as ASME Section III, Class 2 components and Seismic Category I requirements. CFS piping upstream of the CIVs up to the fixed restraint is designated Quality Group C and designed as ASME Section III, Class 3 components subject to the requirements of Subsection ND, and are Seismic Category I. Therefore, the CFS design conforms to the guidance of RG 1.29, Regulatory Position C.1 for the safety-related portion of the CFS.

The safety-related portions of the CFS are located either inside containment or inside valve rooms located in Safeguard Buildings 1 and 4. Both the Reactor Building and the Safeguard Buildings are Seismic Category I structures that are located and designed to provide protection from floods, hurricane/tornado winds, and external missiles. FSAR Tier 2, Sections 3.3, "Wind and Tornado Loadings"; 3.4, "Water Level (Flood) Design"; 3.5, "Missile Protection"; 3.7, "Seismic Design"; and 3.8, "Design of Category I Structures," provide the bases for the adequacy of the structural design of these buildings with respect to natural phenomena. Reviews of these buildings with respect to natural phenomena are included in the corresponding sections of this report.

Internal flooding does not prevent the condensate and feedwater system from performing its safety-related functions, because the safety-related components are inside four separate valve rooms. FSAR Tier 2, Section 3.4 provides a discussion of flooding in the feedwater valve rooms. FSAR Tier 2, Section 3.4 states that each feedwater valve compartment is separated from the others by building structures. There are no connections between the different valve compartments via the building drain system. The motors of the feedwater isolation and control valves are located above a level where flood relief panels are installed for water relief from the room due to a pipe break. FSAR Tier 2, Section 10.4.7.3, "Safety Evaluation," states that outside the valve rooms, critical components of the CFS are located at a sufficient elevation to be protected from flooding events. The staff noticed that the applicant did not include any requirements for the COL applicant to verify that critical components outside the valve room are located at a sufficient elevation to be protected from flooding events. Therefore, in RAI 83, Question 10.04.07-1, the staff requested that the applicant establish a requirement that the COL applicant verify that as-built plant critical CFS components outside the valve rooms be located at sufficient elevation to be protected against flooding. This should be met by creating an ITAAC to verify by walkdown that critical CFS components located outside the valve room are located at a sufficient elevation to be protected from flooding events.

In a November 10, 2008, response to RAI 83, Question 10.04.07-1, the applicant stated that there are no critical main feedwater components located outside the feedwater valve rooms; only main feedwater (MFW) piping is located in this area. The only other critical CFS components that could be affected by flooding are the CIVs in the portion of the condensate system that cools the first stage of the steam generator blowdown (SGB) cooler. These valves are described in FSAR Tier 2, Section 10.4.7.2.2. The outside CIVs are located in the valve room for the SGB system. Flooding protection for these valves is described in FSAR Tier 2, Section 3.4.3.4. In the November 10, 2008, response to RAI 83, Question 10.04.07-1, the applicant indicated that FSAR Tier 2, Section 10.4.7.3 will be revised to clarify that the critical components of the CFS are located in the valve rooms, and the applicant provided a markup of the FSAR showing the proposed revisions. Since there are no critical main feedwater components located outside the feedwater valve rooms, the staff concludes that no ITAAC is required. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.7.3 was revised as committed in the RAI response and clarifies the flooding protection is provided for the CFS components. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.07-1 resolved.

The condensate system piping inside containment or valve rooms that is not designed to Seismic Category I is designed to Seismic Category II requirements. These classifications are indicated in the piping class breaks shown on FSAR Tier 1, Figure 2.8.6-1, and FSAR Tier 2, Figure 10.4.7-1. FSAR Tier 1, Table 2.8.6-1 indicates that the MFW isolation and control valves are ASME Section III valves, as well as Seismic Category I. SRP Section 14.3.2, "Structural and Systems Engineering - Inspections, Tests, Analyses, and Acceptance Criteria," Acceptance Criteria Number 6, for Seismic II over I contains recommendations applicable to the non-seismic to seismic (II/I) interaction, and conformance to the recommendations cannot be evaluated until the plant has been constructed. Because of this, the COL applicant should describe the process for completion of the design of balance-of-plant and non-safety-related systems to minimize II/I interactions and proposed procedures for an inspection of the as-built plant for II/I interactions. The staff's concern is that the Seismic II/I design is not adequately addressed in the FSAR. Therefore, in RAI 83, Question 10.04.07-2, the staff requested that the applicant describe the process for completion of the design of balance-of-plant and non-safety-related systems to minimize II/I interactions and to specify how they would verify that the CFS as-built design satisfies the SRP Section 14.3.2 acceptance criteria for Seismic II/I.

In a November 10, 2008, response to RAI 83, Question 10.04.07-2, the applicant stated that the seismic design classification of the condensate and feedwater system components is provided in FSAR Tier 2, Table 3.2.2-1, and conforms to the guidance provided in SRP Section 3.2.1, "Seismic Classification." The applicant stated that designation of a particular non-safety-related component as Seismic Category II (as stated in RG 1.29, Regulatory Position C.2) is dependent on the potential failure modes and consequences of that component, the proximity of Seismic Category I/safety-related components, and the vulnerability of those components to the consequences of the failure mode of the particular non-safety-related component in question.

Failure of the non-safety-related non-seismic portions of the CFS does not prevent or degrade the safety function of any safety-related Seismic Category I component of the CFS.

Non-seismic lines and associated equipment are routed, to the extent possible, outside of safety-related structures and areas to avoid potentially adverse interactions. In the event that this routing is not possible and non-seismic lines must be routed in safety-related areas, the non-seismic items are evaluated for seismic interactions (refer to FSAR Tier 2, Section 3.7.3.8, "Interaction of Other Systems with Seismic Category I Systems"). Since the Seismic II/I interaction evaluation process is described in FSAR Tier 2, Section 3.7.3.8, no additional COL information items or ITAAC are needed.

The staff concurs that FSAR Tier 2, Section 3.7.3.8 clarifies the process for considering seismic interactions for the CFS components and considers RAI 83, Question 10.04.07-2 closed, with no changes to the FSAR needed. Based on the above review, the staff concludes that the CFS design satisfies the guidance in SRP Section 10.4.7 for meeting the requirements of GDC 2, as they relate to protecting the system against seismic and other natural phenomena.

GDC 4

The staff reviewed the CFS for compliance with the requirements of GDC 4, as related to the dynamic effects associated with possible fluid flow instabilities, including induced water hammer and the effects of pipe breaks. Acceptance of the design is based on identification of the essential portions of the system as protected from dynamic effects including internally and externally generated missiles, and pipe whip and jet impingement due to high and moderate energy line breaks, and conforming to BTP 10-2, "Design Guidelines for Avoiding Water Hammers in Steam Generators." The CFS is designed to preclude the potential for damaging instabilities (water hammer). The U.S. EPR design has feedwater pump check valves with piston assist to reduce the potential for water hammer on pump trips. Also, to reduce the potential for water hammer due to a feedwater line break, there is a damped check valve inside the Reactor Building. These features would minimize, but not necessarily eliminate, water hammer occurrence in the feedwater system. This is because there is no information provided in FSAR Tier 1 or Tier 2 describing design features of the feedwater piping system or steam generator feed rings that have been incorporated in accordance with the guidance of BTP 10-2. FSAR Tier 2, Section 14.2 describes the initial test program which includes flow testing to detect possible feedwater hammer in the feedwater piping.

FSAR Tier 2, Section 10.4.7.3 states that the steam generators have features that minimize the potential for water hammer and refers the reader to FSAR Tier 2, Section 5.4.2 for a description of these features. FSAR Tier 2, Section 5.4.2 does not contain a discussion of feedwater system water hammer but only discusses SG tube vibration. While the staff determined that the CFS design meets the requirements of GDC 4 with respect to startup testing for water hammer occurrences, the staff also determined that there was insufficient information presented in the FSAR to conclude that the design features will minimize the occurrence of water hammer events. Additionally, the guidelines presented in SRP Section 10.4.7, Subsection IV.2 regarding addressing feedwater control valve and controller designs with respect to water hammer potential had not been addressed in the FSAR (e.g., fast closing of feedwater isolation valves causing rapid decrease in flow velocity). Also, SRP Section 10.4.7, Subsection IV.2 has guidelines for the COL applicant to review operating and maintenance procedures to ensure that precautions taken will minimize or avoid water hammers.

The staff also noted that there was no COL information item for applicants to review operating and maintenance procedures to ensure that they include precautions to minimize or eliminate water hammer. Therefore, in RAI 83, Question 10.04.07-3, the staff requested that the applicant provide a discussion of design features of the feedwater system to preclude damage by water hammer events, and to propose a COL information item to provide operating and maintenance procedures to address water hammer issues.

In a November 10, 2008, response to RAI 83, Question 10.04.07-3, the applicant stated that the following design and operating features reduce the potential for water hammer in the condensate and feedwater system:

- A tilting disc check valve on the discharge of each condensate pump prevents back flow in the upstream system. The tilting disc type has a lower pressure pulse upon closing than some other valve types.
- The feedwater system (FWS) has a smaller startup and shutdown feedwater pump that reduces the potential for water hammer.
- A piston-assisted check valve on the discharge of each feedwater pump prevents reverse flow with a low pressure pulse upon closing.
- A damped check valve upstream of each SG feedwater nozzle prevents reverse flow with low pressure pulse upon closing.
- Main feedwater flow to each SG is controlled through three flow paths with different flow capacities. The three flow paths are staggered in startup and shutdown. The motor operated feedwater control valves do not open or close rapidly, and they fail as is. Each control valve is individually modulated by a dedicated proportional integral derivative (PID) step controller. As described in FSAR Tier 2, Section 7.7.2.3, the very low load control valve has a minimum valve position to provide a minimum flow rate to reduce the potential for thermal stratification and water hammer phenomena.
- In the condensate supply line to the SGB cooler, valve opening and closing times are chosen to reduce water hammer effects. The SG feedwater nozzle and internal feedwater distribution header are designed to reduce the potential for thermal stratification and minimize the effects of water hammer under normal operating conditions and transients. To address the guidelines of NRC BTP 10-2, Revision 4, “Design Guidelines for Avoiding Water Hammers in Steam Generators,” the feedwater header is an all-welded construction with a top discharge design that prevents draining of the header if the water level drops below the header.

In response to RAI 83, Question 10.04.07-3, the applicant stated that FSAR Tier 2, Section 10.4.7.3 and FSAR Tier 2, Section 5.4.2.2, “Overpressure Protection,” will be revised to include a description of the design and operating features that reduce the potential for water hammer in the condensate and feedwater systems.

The applicant also stated that FSAR Tier 2, Table 1.8-2—U.S. EPR Combined License Information Items, Item 13.5-1 requires the COL applicant that references the design certification to address procedures, including operating and maintenance procedures. Due to this COL information item and the revised FSAR Tier 2, Sections 10.4.7.3 and 5.4.2.2, the applicant stated that it is not necessary to add a new COL information item in the FSAR requiring the COL applicant to provide operating and maintenance procedures to address water hammer issues for the FWS. The staff concurs that the revised FSAR Tier 2, Sections 10.4.7.3 and 5.4.2.2 which address the need for plant procedures that provide operating and maintenance procedures to address water hammer issues for the FWS, eliminate the need to add a new COL information item in the FSAR. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.7.3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.07-3 resolved.

Regarding other requirements of GDC 4 with respect to the effects of missile and high-energy line breaks on the system, the safety-related portions of the CFS are protected by building structures. FSAR Tier 1, Section 2.8.6, paragraph 2.3 states that physical separation exists between the safety-related MFW divisions because the safety-related valves are located in separate valve rooms. In the event of failure of the externally routed non-safety-related portions of the CFS due to missile impact, the SG boundary is maintained by the SG isolation valves. Another requirement of GDC 4 is to address the environmental design bases of the safety-related equipment. Portions of the CFS located inside containment and at the valve stations are maintained at acceptable ambient conditions by plant ventilation systems. Electrical equipment listed in FSAR Tier 1, Table 2.8.6-2, “MFWS Equipment I&C and Electrical Design (2 Sheets),” is qualified for harsh environments.

Based on the foregoing, the staff concludes that the CFS meets the requirements of GDC 4 with respect to the environmental and dynamic effects design bases.

GDC 5

The U.S. EPR is designed as a single facility, so the requirement of GDC 5 for sharing of systems between units does not apply.

GDC 44

GDC 44 applies to the U.S. EPR, because the system must be designed to remove heat from the reactor during normal operation, thus limiting fuel cladding temperature from exceeding design limits. Initial startup Test No. 59 described in FSAR Tier 2, Section 14.2 will be performed to demonstrate that the MFWS, including startup feedwater pump, is capable of supplying feedwater to the SGs for normal operation. Test No. 66 will be performed to show that the condensate system is designed to supply adequate water flow for heat removal.

The CFS does not perform the safety function of heat removal during accident conditions. During accident conditions, heat removal is accomplished using the EFWS, which is discussed in FSAR Tier 1, Section 2.2.4, and FSAR Tier 2, Section 10.4.9. The staff’s evaluation of EFWS is included in Section 10.4.9 of this report.

The staff reviewed the single-failure analysis of the CFS presented in FSAR Tier 2, Table 10.4.7-2. Suitable redundancy of components and power supplies is provided to assure containment isolation under accident conditions. Diversity in containment isolation is provided by motor operated valves in series with check valves in the feedwater lines to the SGs. Inside the valve rooms, the feedwater piping is routed in individual and separate divisions so that failure of one division of the CFS cannot affect another division. Accordingly, the staff concludes that the CFS meets the requirements of GDC 44 with respect to heat removal from the reactor during normal operation, and that containment isolation can be accomplished during accident conditions, assuming a single active component failure and loss of offsite power.

GDC 45

The staff reviewed the CFS design to ensure design provisions are provided for periodic inspection of systems, components, and equipment, as required by GDC 45. The applicant states that inservice inspection of CFS components is performed in accordance with the ASME Boiler and Pressure Code, Section XI. The CFS design includes material selection, limits on flow velocity, and other measures to reduce flow accelerated corrosion and erosion and corrosion of piping and piping components. The applicant states that the design conforms to the guidance contained in NRC GL 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," concerning acceptable inspection programs for erosion and corrosion, which are described in Section 10.3.4.4.3 of this report, and which is in accordance with guidance in SRP Section 10.4.7, Acceptance Criteria on number 7. Based on conforming to these recommendations, the staff concludes that the CFS design satisfies the guidance of SRP Section 10.4.7 for meeting the requirements of GDC 45 as it relates to inspection of cooling water systems.

GDC 46

The design of the safety-related portions of the CFS was reviewed by staff to ensure there are provisions for the performance of periodic functional testing of the system and components, as required by GDC 46. The FSAR states that inservice testing is performed in accordance with the requirements of ASME Section XI. Plant Technical Specification 3.7.3 provides surveillance requirements for the MFWS valves. CIVs are tested for leak-tightness as part of containment leak rate testing as required by 10 CFR Part 50, Appendix J. The applicant lists a series of initial plant startup tests in FSAR Tier 2, Section 10.4.7.4. The staff reviewed the test descriptions contained in FSAR Tier 2, Section 14.2. Based on the above, the staff concludes the CFS design meets the requirements of GDC 46. The staff evaluation of the startup testing is provided in Section 14.2 of this report.

<u>10 CFR 20.1406</u>

10 CFR 20.1406 requires, in part, that each design certification applicant shall describe how the facility design and procedures for operation will minimize, to the extent practicable, contamination of the facility and the environment, as well as the generation of radioactive waste. The CFS, along with the MSS, makes up the secondary cooling system. Usually, the CFS system does not contain radioactive fluids. However, since the CFS provides cooling on the secondary side of the steam generator tubes, there is the potential for the CFS fluid to become contaminated if significant primary-to-secondary leakage occurs across the SG tubes.

The CFS design has a feedwater storage tank integrated in the cycle to deaerate and heat the condensate. The deaerator-feedwater storage tank inventory is maintained by demineralized water supply from the demineralized water distribution system (DWDS). The CFS has no direct connections with any system that carries radioactive effluents, therefore, contamination of the CFS through interface with other system is not expected to occur.

In case of primary-to-secondary leakage of radiation into the CFS, TS 3.4.12 limits the allowable leakage to 568 l/day (150 gal/day) through any one SG. Also, TS 3.7.17, "Secondary Specific Activity," limits the specific activity in the secondary coolant to less than 0.10 uCi/g I-131 equivalent.

In the case of an SGTR, the CFS is designed to prevent the release of contaminated fluid from the affected SG, by isolating the SG if a partial cooldown signal is present and either high SG water level is detected, or high main steam activity is detected. The isolation will retain the activity in the affected SG, therefore minimizing the release of reactor coolant to other parts of the secondary side cooling system.

Steam line N-16 monitors and condenser offgas monitors provide a means for continuous monitoring of the CFS and MSS for excessive primary-to-secondary leakage. In addition, SR 3.4.12.2 requires the primary-to-secondary leakage be verified to be less than 567.8 lpm (150 gal) at least once every 72 hours, and, SR 3.7.17.1 requires that the specific activity of the secondary coolant be verified to be less than 0.0037 MBq (0.1uCi) I-131 equivalent at least once every 31 days.

Even in the absence of significant primary-to-secondary leakage, some small amount radioactive effluents may be present in the CFS fluid. The CFS contains no underground piping. The CFS design is such that the system piping will be accessible for inspection and maintenance, so if leaks occur in the system, the leaks can be readily identified and corrective actions can be taken.

Based on the above discussion, the staff concludes that the CFS design, as described in the FSAR, complies with 10 CFR 20.1406, "Minimization of contamination," since it provides for monitoring and controls of allowable primary-to-secondary leakage and isolates the affected steam generators in the event of a steam generator tube rupture, thus limiting radioactive leakage to the effective steam generator, therefore, preventing the spread of additional contamination to the rest of the CFS.

The staff reviewed FSAR Tier 2, Chapter 16, TS 3.7.3 for applicability to the MFWS. TS 3.7.3 provides LCO and surveillance requirements for the MFWS valves. The TS Bases 3.7.3 Background description conforms to the FSAR Tier 2 description of MFWS valves. The staff concludes that TS 3.7.3 appropriately addresses the LCO and surveillance requirements for the MFWS valves. The staff evaluation of the startup testing is provided in Chapter 16 of this report.

10.4.7.5 *Combined License Information Items*

For the CFS, no COL information items have been identified in FSAR Tier 2, Table 1.8-2. The staff finds this acceptable.

10.4.7.6 *Conclusions*

The standard design of the CFS in FSAR Tier 2, Section 10.4.7, is acceptable, because, as set forth above, it meets appropriate regulatory requirements including GDC 2 on protection from natural phenomena, GDC 4 on protection against missiles and effects of pipe break, GDC 5 on shared systems, GDC 44 on transferring heat to the ultimate heat sink, GDC 45 on inspections, GDC 46 on periodic testing, 10 CFR 20.1406, and 10 CFR 52.47(b)(1) on ITAAC.

10.4.8 Steam Generator Blowdown System (PWR)

The steam generator blowdown system (SGBS) assists in maintaining the chemical characteristics of the secondary water within permissible limits. The system is intended to remove particulate and dissolved impurities from the steam generator secondary-side, thus assisting in maintaining optimum secondary-side water chemistry during normal operation, including anticipated operational occurrences such as primary-to-secondary leakage.

10.4.8.1 *Introduction*

The SGBS provides the capability for continuous hot blowdown of the secondary side of the SGs. The SGBS includes equipment for heat recovery, purification, and reuse of SG blowdown. The SGBS has the safety-related function of providing blowdown system isolation and containment system isolation during design-basis events. Therefore, the system is classified as safety-related inside containment up to and including the isolation valves outside containment. The rest of the system is non-safety-related.

10.4.8.2 *Summary of Application*

FSAR Tier 1: The steam generator blowdown system is covered in FSAR Tier 1, Section 2.8.7. In that section the applicant states that the SGBS is partly safety-related and partly non-safety-related. Everything inside containment up to and including the isolation valves outside containment is treated as safety-related. The system provides isolation for the SGBS and the containment as safety-related functions. The safety-related portion of the system is constructed in accordance with the ASME Code Section III.

FSAR Tier 2: The applicant has provided an FSAR Tier 2 system description in Section 10.4.8 summarized here, in part, as follows:

FSAR Tier 2, Figure 10.4.8-1, “Steam Generator Blowdown System Flow Diagram,” and Figure 10.4.8-2, “Demineralizing Steam Generator Blowdown System,” provide schematic diagrams of the SGBS. Each SG is equipped with its own blowdown line with the capability of blowing down the hot leg and cold leg of the SG shell side. (The hot and cold legs are blown down at low plant loads; otherwise, only the hot leg is blown down.) The blowdown is directed into a flash tank where the flashed steam is returned to the cycle via the deaerator/feedwater storage tank. The liquid portion flows to heat exchangers cooled in two stages by the main condensate system in the first stage and the component cooling system in the second stage before going to the SG blowdown demineralizer. The SGBS also conveys the water from the exit of the SG blowdown demineralizer to the main condenser.

SG Blowdown Isolation Valves

The applicant has provided safety-related, electric motor operated, blowdown isolation valves on the hot and cold leg blowdown lines of each SG and a safety-related, electric motor operated, and redundant valve on the common blowdown line from each SG. The common blowdown line isolation valves have a diverse power supply from the upstream hot and cold leg blowdown isolation valves. Closing the blowdown isolation valves prevents loss of SG secondary inventory.

SG Transfer Lines

The design includes safety-related piping and valves inside containment for connecting SG 1 to SG 2 and SG 3 to SG 4. The purpose of these lines is to depressurize a stagnant SG during a steam generator tube rupture (SGTR) with loss-of-offsite-power event (LOOP), and transfer the contents of the stagnant SG to the unaffected SG.

Blowdown Flash Tank

A flash tank is provided in the Reactor Building with an internal volume sufficient to control the flash tank pressure and level within a narrow range. Nozzles are provided in the vertical shell, top and bottom. Four of the nozzles on top of the tank are for the SG blowdown inlet. The flashed steam is removed by a separate nozzle on the top head. The liquid drains from a nozzle in the lower head. There is an impurity trap on the bottom of the flash tank. The tank is protected against overpressure by the flash tank safety relief valve, in conformance to the ASME B&PV Code, Section III, Subsection NC.

First and Second Stage Steam Generator Blowdown Coolers

The first stage SG blowdown cooler is a duplex cooler located in the Reactor Building. The blowdown liquid flows through the tubes with the main condensate on the shell side. Nozzles are welded into the shell and water chamber. The tube side of the heat exchanger is protected together with the flash tank against overpressure by the flash tank safety relief valve. The shell side is protected against overpressure by one or more safety relief valves. The second stage SG blowdown cooler is a duplex cooler located in the Nuclear Auxiliary Building. The blowdown liquid flows through the tubes with the component cooling water on the shell side. Nozzles are welded into the shell and water chamber. The tube side of the heat exchanger is protected against overpressure by one or more relief valves. The shell side is protected against overpressure by one or more valves.

SG Blowdown Demineralizer

The SG blowdown demineralizer treats SG blowdown with filtration and ion exchange, and then returns it to the power cycle. It is located in the Nuclear Auxiliary Building. The main components of the blowdown demineralizer are the cartridge filter, cation exchanger, and mixed bed exchanger. Other minor components include compressed air buffer tanks for backwashing the cation and mixed bed exchangers and operating solenoid valves, a drain buffer tank and pump to send backwash effluents to the liquid radwaste storage system, and a resin trap to collect any resin bits that escape from the mixed bed and cation exchangers.

ITAAC: The ITAAC associated with FSAR Tier 2, Section 10.4.8 are given in FSAR Tier 1, Section 2.8.7, Table 2.8.7-3.

Technical Specifications: TS applicable to the SGBS are found in FSAR Tier 2, Chapter 16, Section 3.7.22.

10.4.8.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.8 and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 10.4.8.

1. 10 CFR Part 50, Appendix A, GDC 1, “Quality standards and records,” as it relates to system components being designed fabricated, erected, and tested for quality standards.

2. GDC 2, “Design bases for protection against natural phenomena,” as it relates to the system components designed to Seismic Category 1 requirements.

3. GDC 13, “Instrumentation and control,” as it relates to monitoring system variables that can affect the reactor coolant pressure boundary and maintaining them within prescribed operating ranges.

4. GDC 14, “Reactor coolant pressure boundary,” as it relates to secondary water chemistry control to maintain the integrity of the RCPB.

5. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed inspections, tests, analyses, and acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

Applicable guidance includes RG 1.143. Beyond the first isolation valve outside the containment, the design should satisfy the guidance of RG 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” Regulatory Position C.1.1.

Acceptance criteria adequate to meet the above requirements include:

- EPRI PWR Secondary Water Chemistry Guidelines

10.4.8.4 *Technical Evaluation*

The staff reviewed the SGBS in accordance with NUREG-0800, Section 10.4.8, “Steam Generator Blowdown System.” Acceptance of the steam generator blowdown system is based on the design meeting the requirements of GDC 1, GDC 2, GDC 13, and GDC 14.

The principal function of the SGBS is to maintain the water chemistry of the SGs within permissible limits. The SGBS continuously performs a blowdown of all four SGs, purifies the blowdown, and returns it to the steam cycle through the deaerator and condenser.

The design of the SGBS is such that each of the four steam generators can be blown down simultaneously from the shell side of its hot legs at up to one percent of the main steam flow rate. At low power levels, each steam generator can also be blown down from the shell side of the cold leg. If necessary, a single steam generator can be blown down at up to two percent of the main steam flow rate, while the blowdown from the other three steam generators is isolated.

The combined blowdown from all four steam generators is routed to a flash tank located in the Reactor Building. Flashed steam returns to the steam cycle via the dearator/feedwater storage tank. Condensate and component cooling water cool the flash tank water in two stages to approximately 48.9 °C (120 °F). The blowdown water passes through a cartridge filter to remove particulates. A cation ion exchanger then removes the pH control additive used in the secondary system. FSAR Tier 2, Section 10.4.8.2.2 indicates that the cation exchanger removes ammonia dissolved in the system. Most PWRs use an amine such as ethanolamine or dimethylamine instead of ammonia for pH control; however, the cation exchanger will also remove these amines in addition to any ammonia produced as a decomposition product in the system. The water passes through a mixed bed ion exchanger to remove any residual cation and anion dissolved impurities before the water returns to the steam cycle via the main condenser. A resin trap downstream of the mixed bed ion exchanger captures any resin fines that pass through the ion exchangers.

FSAR Tier 1, Section 2.8.7 and FSAR Tier 2, Section 10.4.8.1 discuss the design bases for the SGBS. Compliance with GDC 1 and GDC 2 is based on SGBS components and piping from the connection inside the primary containment up to and including the first isolation valve outside containment being designed as Seismic Category I and Quality Group B. RG 1.29, "Seismic Design Classification," specifies the design requirements to protect against seismic events. RG 1.26, "Quality Group Classifications and Standards for Water, Steam, and Radioactive Waste Containing Components of Nuclear Power Plants," specifies the quality group requirements for the system. Finally, RG 1.143 specifies the quality group standards for the non-safety-related portions of the SGBS downstream of the outermost containment isolation valves. The staff reviewed FSAR Tier 1, Section 2.8.7, FSAR Tier 2, Table 3.2.2.1, and Figures 10.4.8.1 and 10.4.8.2, which show the piping and equipment inside containment are designed to ASME B&PV Code Section III and Seismic Category I.

In Revision 5 of the FSAR, the applicant proposed a design change (SG transfer lines) that introduced piping and valves inside containment to connect the SGBS lines of SG 1 to those of SG 2, and the lines of SG 3 to those of SG 4. FSAR Tier 2, Table 3.2.2-1 provided the design information for the valves but not for the associated piping. Therefore, in RAI 610, Question 10.04.08-5, the staff requested that the applicant provide the classification information for the transfer piping. In a May 15, 2014, response, the applicant provided a revision to FSAR Tier 2, Table 3.2.2-1 that includes the transfer piping. The staff confirmed that the applicant incorporated the change in Revision 6 of the FSAR. Accordingly, the staff considers RAI 610, Question 10.04.08-5 resolved.

The staff also observed that Revision 5 of the FSAR changed the commercial codes listed in Table 3.2.2-1 for the SGBS piping and valves downstream of the outer containment isolation valves. Therefore, in RAI 610, Question 10.04.08-6, the staff requested that the applicant provide the basis for changing the design requirements in certain cases from RG 1.143 to RG 1.29 and ANSI/ASME B16.34. In a May 15, 2014, response, the applicant explained that RG 1.29 applies because these SSCs are classified as Seismic Category II, and that this is an enhancement to the seismic requirement compared to RG 1.143. The staff confirmed that U.S. EPR Seismic Category II SSCs are designed to withstand safe-shutdown earthquake (SSE) seismic loads, whereas, U.S. EPR Radwaste Seismic SSCs are designed to withstand one-half SSE seismic loads in accordance with RG 1.143. The response also stated that specifying ANSI/ASME B16.34 is consistent with the Quality Group D designation. The staff confirmed that ANSI/ASME B16.34 is the applicable design code for valves designated Quality Group D and designed in accordance with RG 1.26. Since the use of RG 1.29 and ANSI/ASME B16.34 in these cases meets the criteria in SRP Section 10.4.8, the staff finds the response to RAI 610, Question 10.04.08-6 acceptable. The applicant also made other corrections to the referenced codes for the SGBS in FSAR Tier 2, Table 3.2.2-1. The staff finds this acceptable because the changes conform to the guidance in SRP Section 10.4.8. The staff confirmed that all of the changes associated with RAI 610, Question 10.04.08-6 were incorporated in Revision 6 of the FSAR. Accordingly, the staff considers RAI 610, Question 10.04.08-6 resolved. Since RAI 610, Questions 10.04.08-5 and 10.04.08-6 are resolved, the staff finds that the design of the SGBS meets the seismic and quality design requirements of GDC 1 and GDC 2.

GDC 13 requires the SGBS design to include provisions to monitor system parameters and maintain them within a range that allows the system to perform its safety function. The SGBS performs an impurity removal function for the secondary side, and thereby assists in maintaining the integrity of the reactor coolant boundary. FSAR Tier 2, Section 10.4.8.4 indicates that the blowdown system is sampled continuously to monitor its demineralization and cleanup performance. FSAR Tier 2, Section 10.4.8.4 references FSAR Tier 2, Section 9.3.2.2.1.2, which specifies the details of the SGBS sampling system and continuous monitors. FSAR Tier 2, Section 9.3.2 and FSAR Tier 2, Table 9.3.2.2 specify that continuous monitors are provided for cation conductivity, specific conductivity, and sodium in the SGBS. These parameters can be used to determine the performance of the demineralizers if the monitors are installed in the effluent of the mixed bed demineralizers. To assess the effectiveness of the monitoring, in RAI 62, Question 10.04.08-2, the staff requested that the applicant identify the locations of the monitors. In an October 20, 2008, response, the applicant identified the location of the monitors with respect to the flash tank and demineralizers and proposed a corresponding revision to FSAR Tier 2, Section 10.4.8.2.1. The staff finds the response acceptable because sampling locations include sodium and conductivity downstream of the mixed-bed exchanger. The staff confirmed that the changes were incorporated in Revision 1 of the FSAR. Accordingly, the staff considers RAI 62, Question 10.04.08-2 resolved.

BTP 5-1 provides an acceptable way of monitoring the secondary-side water chemistry in PWR SGs. BTP 5-1 indicates that the FSAR should describe the implementation of a secondary water chemistry monitoring and control program that conforms to industry guidelines such as the U.S. EPRI PWR Secondary Water Chemistry Guidelines. The staff reviewed the EPRI PWR Secondary Water Chemistry Guidelines to determine the specific recommendations related to the SGBS. FSAR Tier 2, Table 9.3.2.2, indicated that the SG blowdown is continuously monitored for activity, cation conductivity, specific conductivity, and sodium; however, the design did not incorporate continuous pH monitoring as recommended in the EPRI PWR Secondary Water Chemistry Guidelines. Therefore, in RAI 62, Question 10.04.08-1, the staff requested that the applicant provide the methodology for the continuous pH monitoring for the steam generator blowdown. In an October 20, 2008, response, the applicant explained that the details of the secondary water chemistry program are provided by the COL applicant. The staff also confirmed that Revision 1 of FSAR Tier 2, Table 9.3.2.2 added pH as a continuously monitored parameter for steam generator blowdown. Accordingly, the staff considers RAI 62, Question 10.04.08-1 resolved.

FSAR Revision 5 introduced a design basis for the SGBS identifying the radiation monitors used to isolate the SGBS on high activity coupled with a partial cooldown signal. Due to some apparent inconsistencies in the description of the use of these monitors in FSAR Tier 1, Section 2.8.7 and FSAR Tier 2, Section 10.4.8.3, in RAI 610, Question 10.04.08-7, the staff requested that the applicant provide clarification. In a May 15, 2014, response, the applicant proposed changes to FSAR Tier 1 and FSAR Tier 2 to clarify the safety-related and non-safety-related application of radiation monitors. The response also proposed removing the references to specific monitoring locations, since this information is provided in FSAR Tier 2, Chapter 11. The proposed FSAR changes included references to the application section and table in Chapter 11. The staff confirmed that the referenced section and table contain the monitoring information. The staff finds these changes acceptable because they clarify the radiation monitoring discussions in the FSAR. RAI 610, Question 10.04.08-7 is being tracked as a confirmatory item.

The staff concludes that the SGBS complies with GDC 13 because the instrumentation provided is adequate to monitor the system parameters and maintain them within a range that allows the system to appropriately perform its impurity removal function.

Control of secondary side water chemistry is necessary to assure compliance with GDC 14. Secondary side water chemistry can be appropriately controlled when the SGBS design includes provisions to control secondary water chemistry to maintain the integrity of the SG tubes, which are part of the primary coolant boundary. Specifically, the SGBS should be designed to accommodate the blowdown flowrate needed to maintain secondary coolant chemistry under both normal and anticipated operations. FSAR Tier 2, Section 10.4.8.3.1

states that under normal conditions, the blowdown flow rate of each steam generator is adjustable up to one percent of the maximum full-power steam flow rate per SG. This blowdown rate is consistent with the design of current PWRs operating within the U.S. commercial nuclear power industry. The full-power steam flow rate is also comparable to U.S. operating plants. Therefore, the staff finds that the SGBS design provides adequate assurance that the SG water quality can be maintained within specifications during normal operating conditions and, therefore, the design complies with GDC 14.

The capability to blow down one SG at a higher rate (up to two percent) provides additional assurance that, under abnormal conditions where one SG has an unusually high impurity rate, the affected steam generator can be cleaned up rapidly. Under abnormal conditions, such as the temporary ingress of contaminants in the secondary system through a condenser leak or condensate polisher failure, protection of the SGs is provided by conformance to the EPRI PWR Secondary Water Chemistry Guidelines, which recommend reduced power and/or plant shutdown if impurity levels exceed a specified threshold. Therefore, under abnormal conditions, the SGBS is not relied on solely to protect the integrity of the primary coolant boundary. However, the blowdown capacity and purification capabilities of the SGBS previously described are adequate to ensure interim control of the steam generator chemistry while the plant power level is reduced or plant shutdown is commenced as specified by the EPRI PWR Secondary Water Chemistry Guidelines. In addition, the design of the SGBS itself includes the provisions to bypass individual components in the purification system, as well as routing the effluent to the radwaste system if the SGBS purification cannot remove the impurities from the steam generator blowdown. Therefore, even under the extreme conditions where the purification system is not operating properly, the design of the SGBS ensures that the overall quality of water in the secondary system will not be adversely impacted.

SRP Section 10.4.8 also recommends that temperature limits not be exceeded for heat sensitive processes. The SGBS contains both cation and mixed bed demineralizers that use ion exchange resins. Conventional anion exchange resins break down at temperatures in excess of approximately 60 °C (140 °F), rendering them incapable of performing their impurity removal function. The SGBS includes two stages of coolers to reduce the temperature of the water entering the purification system to less than 48.9 °C (120 °F). FSAR Tier 2, Section 10.4.8.3.2 indicates that isolation valves close to protect the ion exchange resin, if the temperature between the second-stage coolers and the demineralizers exceeds 55 °C (131 °F). Accordingly, the staff finds that the SGBS design provides adequate assurance that the temperature limits for heat sensitive processes will not be exceeded.

The applicant added blowdown transfer lines to the design for FSAR Revision 5, including safety-related piping and valves. In RAI 610, Question 10.04.08-8, the staff requested that the applicant provide a discussion of the change in FSAR Tier 2, Section 10.4.8.4, “Safety Evaluation.” In a May 5, 2014, response, the applicant stated that the acceptance criteria already discussed in FSAR Tier 2, Section 10.4.8.4 apply to the blowdown transfer components. The response also proposed FSAR changes to address the single-failure criterion for the transfer lines. The proposed changes state that the single-failure criterion applies to the transfer valves and points to FSAR Tier 2, Section 8.3.1.2.11, “Branch Technical Positions,” for a description of how BTP 8-4 is applied to the design against a single failure for electrically operated valves. The staff finds this acceptable because the applicant provided the safety evaluation of the blowdown transfer lines in Tier 2, Section 10.4.8.4. **RAI 610, Question 10.04.08-8 is being tracked as a confirmatory item.**

In its review of FSAR Revision 5, the staff identified some inconsistencies between the SGBS information in FSAR Tier 1, Section 2.8.7, and the corresponding information in FSAR Tier 2, Section 10.4.8. For example, the safety-related function of SG isolation based on high main steam activity and a partial cooldown signal was discussed in FSAR Tier 1 but not discussed in FSAR Tier 2. Therefore, in RAI 610, Question 10.04.08-9, the staff requested that the applicant discuss how they intended to make the information consistent. In a May 5, 2014, response, the applicant proposed changes to FSAR Tier 1 (Section 2.8.7) and FSAR Tier 2 (Section 10.4.8). For example, the applicant proposed changes in FSAR Tier 1, Table 2.8.7-3, to ensure that the safety-related functions described in FSAR Tier 2, Section 10.4.8, have corresponding ITAAC. The applicant also clarified in FSAR Tier 1 (Section 2.8.7.4.4 and Table 2.8.7-3) that the temperature sensor for protecting demineralizer resin from high temperature is located downstream of the second-stage blowdown cooler, rather than downstream of the demineralizer. The staff finds these changes acceptable because they clarify the design of the system, including the bases for the safety-related and non-safety-related functions. RAI 610, Question 10.04.08-9 is being tracked as a confirmatory item.

RAI 610 also included Question 10.04.08-10 because the FSAR Tier 1 tables of mechanical, electrical, and I&C information (Tables 2.8.7-1 and 2.8.7-2) excluded some of the SGBS transfer valves. In a May 15, 2014, response, the applicant proposed a revision that included all of the transfer valves. The staff considers the changes editorial and finds them acceptable because all of the transfer valves should be included in the Tier 1 tables based on the functions described in the FSAR. RAI 610, Question 10.04.08-10 is being tracked as a confirmatory item.

Based on the discussion above, the staff finds that the SGBS conforms to the guidance in SRP Section 10.4.8. Specifically, the design seismic and quality requirements are met, the monitoring and cleanup capability is adequate for normal and upset conditions, and the system provides for protection of temperature-sensitive elements. Therefore, the staff concludes that the U.S. EPR design meets the requirements of GDC 1, GDC 2, GDC 13, and GDC 14, as they relate to the SGBS.

FSAR Tier 1

FSAR Tier 1, Section 2.8.7 describes the SG blowdown system including Table 2.8.7-1 (equipment mechanical design), Table 2.8.7-2 (electrical system design), Table 2.8.7-3 (ITAAC requirements), and Figure 2.8.7-1 (functional arrangement diagram). As discussed in the preceding section, the applicant revised some FSAR Tier 1 information in response to staff RAIs regarding radiation monitors and the actions they initiate, completeness of the information in FSAR Tier 1 equipment tables, and completeness in the description of the blowdown system isolation functions. The FSAR Tier 1 information for the SGBS is adequate because it describes – for the safety-related part of the system – the applicable information discussed in SRP Section 14.3.7 for plant systems.

ITAAC

ITAAC for the steam generator blowdown system are listed in FSAR Tier 1, Table 2.8.7-3, “SGBS Inspections, Tests, Analyses, and Acceptance Criteria (4 Sheets).” The purpose of these ITAAC is to ensure the safety-related function of isolating the secondary side of SGs in accordance with 10 CFR 52.47(b)(1). The ITAAC address the following topics: Functional arrangement of the as-built SGBS; ASME Code Section III requirements; seismic category requirements; electrical requirements, I&C requirements; environmental qualifications; and functional testing. As discussed above in the technical evaluation of FSAR Tier 2, the applicant modified some of the ITAAC based on RAI 610, Questions 10.04.08-7 and 10.04.08-9. The staff reviewed these tests and inspections and determined they provide adequate criteria to assure that future plants will be built in accordance with the design certification, because the ITAAC verify the FSAR Tier 1 design aspects of the SGBS, and because the ITAAC verify the system can perform its safety functions.

Technical Specifications

TS related to the SGBS are found in FSAR Tier 2, Chapter 16, Section 3.7.22, "Steam Generator Blowdown Transfer Valves and Isolation Valves." The LCO states that the blowdown transfer valves and blowdown isolation valves shall be operable and that the transfer valves shall be closed with power removed from the valve operators. The staff is documenting its review of this section of the Technical Specifications (3.7.22) and the associated Bases (B 3.7.22) is documented in Chapter 16 of this report.

Preoperational Testing

Startup Test No. 067 (FSAR Tier 2, Section 14.2.12.7.9) tests the proper operation of the SGBS. The purpose of Startup Test No. 072 (FSAR Tier 2, Section 14.2.12.7.14) is to verify the ability of the steam generator blowdown demineralizing system (SGBDMS) to clean the steam generator blowdown by a combination of filtration and ion exchange. The preoperational testing of the SGBS and SGBDMS is adequate; no additional preoperational testing is required.

10.4.8.5 *Combined License Information Items*

FSAR Tier 2, Table 1.8-2 identifies no COL information items for the SGBS. The staff finds this acceptable, because the standard design information is adequate for the staff to conclude that the design meets the acceptance criteria listed in SRP Section 10.4.8.

10.4.8.6 *Conclusions*

Pending resolution of the four confirmatory items, the staff concludes that the SGBS satisfies the requirements of GDC 1, GDC 2, GDC 13, and GCD 14, and the guidelines of SRP Section 10.4.8. This conclusion is based on the SGBS design being adequate to control the concentration of chemical impurities and radioactive materials in the secondary coolant.
In addition, the SGBS design meets the primary boundary material integrity requirements of GDC 13 and GDC 14 related to monitoring and maintaining acceptable water chemistry, respectively. Finally, the SGBS meets the quality standard requirements of GDC 1 and the seismic requirements of GDC 2.

10.4.9 Emergency Feedwater System

The EFWS supplies water to the SGs to restore and maintain water level and to remove decay heat following the loss of normal feedwater during design-basis transient and accident conditions. The EFWS removes heat from the RCS, which is first transferred to the secondary-side via the SGs, then discharged as steam to the condenser or, via the SG, through the main steam relief valves (MSRVs).

10.4.9.1 *Introduction*

The EFWS is a safety-related system and is not required to operate during normal plant operation. During normal power operation, the heat removal function is performed by the

MFWS or the SSS. Upon a loss of the MFWS or the SSS, the EFWS provides the following safety-related functions:

- Provide sufficient flow to the SGs to recover and maintain SG water inventory and remove residual heat from the RCS via the SGs and MSRVs to assist in the cooldown and depressurization of the RCS to RHR conditions under design-basis transient and accident conditions.

- Isolate EFWS flow to the affected SG following a MSLB to prevent overcooling the RCS and avoid the associated positive reactivity.

- Isolate emergency feedwater (EFW) pump flow to the SG with a tube rupture upon SG high water level to prevent SG overfill and mitigate the potential radiological consequences of a SGTR event.

- Provide sufficient water inventory in the storage pools to support cooldown.

Additionally, safety-related portions of the EFWS are capable of automatic initiation under conditions indicative of an anticipated transient without scram (ATWS). The EFWS is also capable of providing sufficient decay heat removal during an SBO.

10.4.9.2 *Summary of Application*

FSAR Tier 1: In FSAR Tier 1, Section 2.2.4, "Emergency Feedwater System," the applicant states that the EFWS is a safety-related system. The functional arrangement of the EFWS is as shown in FSAR Tier 1, Figure 2.2.4-1, "Emergency Feedwater System Functional Arrangement." FSAR Tier 1, Table 2.2.4-1, "EFWS Equipment Mechanical Design" states that the EFWS pumps, as well as the valves, are designed and tested to ASME Code Section III requirements. Other mechanical design features including location, safety function, and seismic category are also shown in FSAR Tier 1, Table 2.2.4-1. Piping indicated in Figure 2.2.4-1 as ASME Code Section III is designed, welded, and tested in accordance with ASME Code Section III.

EFWS equipment tag numbers, location, IEEE Class, EQ Classification, displays, and controls are as shown in FSAR Tier 1, Table 2.2.4-2. The components designated as Class 1E in FSAR Tier 1, Table 2.2.4-2 are powered from the Class 1E division as listed in FSAR Tier 1, Table 2.2.4-2 in a normal or alternate feed condition.

FSAR Tier 2: The applicant has provided an FSAR Tier 2 system description in Section 10.4.9.2, summarized here, in part, as follows:

FSAR Tier 2, Figure 10.4.9-1 is the emergency feedwater system flow diagram. The EFWS has four separate trains, each consisting of a water storage pool, electric motor driven pump, control valves, isolation valves, piping and instrumentation. One EFWS train is located in the lower level of each of the Safeguard Buildings, which provides separation and physical protection from external and internal hazards for each train. All four EFWS trains are powered from separate emergency buses, each backed by an emergency diesel generator (EDG), with trains 1 and 4 also capable of being powered from the diverse station blackout diesel generators (SBODGs). Component descriptions for the EFW pumps, storage pools, active valves, piping, and electrical power supplies are discussed in FSAR Tier 2, Section 10.4.9.2.2. FSAR Tier 2, Table 10.4.9-1 lists emergency feedwater system component data; FSAR Tier 2, Table 10.4.9-2 contains emergency feedwater material specification information.; FSAR Tier 2, Table 10.4.9-3 presents the emergency feedwater system failure analysis, contains the emergency feedwater system indicating, alarm, and actuation control devices; and FSAR Tier 2, Table 10.4.9-4 contains the emergency feedwater system indicating, alarm, and actuation control devices; and FSAR Tier 2, Table 10.4.9-5 lists EFWS unreliability results (i.e., failure rate probabilities).

Abnormal operating conditions for which the EFWS is designed include loss of normal feedwater and short-term loss of offsite power. Provisions are included to detect excessive check valve leakage that might cause steam binding of pumps. These are discussed in FSAR Tier 2, Section 10.4.9.2.3.2.

Accident conditions to which the EFWS responds are discussed in FSAR Tier 2, Section 10.4.9.2.3.3 and include small break loss-of-coolant accident (SBLOCA), SGTR, MSLB, and main feedwater line break (MFWLB).

The EFWS design bases capabilities include provisions to respond to an SBO and provisions for automatic initiation in an ATWS.

ITAAC: The ITAAC associated with FSAR Tier 2, Section 10.4.9.4, “Inspection and Testing Requirements,” are given in FSAR Tier 1, Table 2.2.4-3, “EFWS Inspections, Tests, Analyses, and Acceptance Criteria.”

Technical Specifications: The TS applicable to the emergency feedwater system can be found in FSAR Tier 2, Chapter 16, Sections 3.7.5, and B 3.7.5. The TS applicable to the emergency feedwater storage pools can be found in FSAR Tier 2, Chapter 16, Sections 3.7.6, and B 3.7.6.

10.4.9.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 10.4.9 and are summarized below. Review interfaces with other SRP can also be found in NUREG-0800, Section 10.4.9.

1. GDC 2, contained in 10 CFR Part 50, Appendix A, as it relates to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, and hurricanes.

2. GDC 4, as it relates to the capability of the system and the structure housing the system to withstand the effects of pipe breaks and external missiles.

3. GDC 5, as it relates to sharing of SSCs of the steam and power conversion systems of different nuclear power units.

4. GDC 19, “Control room,” as it relates to the design capability of system instrumentation and controls for prompt hot shutdown of the reactor and potential capability for subsequent cold shutdown.

5. GDC 34 and 35, as it relates to the capability of the system to transfer heat loads from the reactor system under both normal operating and accident conditions, assuming any single active failure, coincident with the loss of offsite power for certain events, and the capability to isolate components, subsystems, or piping if required to maintain system safety function.

6. GDC 44, as it relates to safety systems that transfer heat to the ultimate heat sink.

7. GDC 45, as it relates to design provisions made to permit periodic inservice inspection of system components and equipment.

8. GDC 46, as it relates to design provisions made to permit appropriate functional testing of the system and components.

9. GDC 60, as it relates to design provisions for tanks handling radioactive material in liquids.

10. 10 CFR 50.62, "Requirements for Reduction of Risk from ATWS Events for Light-Water-Cooled Nuclear Power Plants," as it relates to the design provisions for automatic initiation of the EFWS in an ATWS event.

11. 10 CFR 50.63, "Loss of all Alternating Current Power," as it relates to the design provisions for withstanding and recovering from a station blackout.

12. 10 CFR 52.47(b)(1), as it relates to the requirement that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a COL plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

13. 10 CFR 20.1406, "Minimization of contamination," as it relates to the design features that will facilitate eventual decommissioning and minimize, to the extent practicable, the contamination of the facility and the environment and the generation of radioactive waste.

Acceptance criteria adequate to meet the above requirements include:

1. NRC Office of Inspection and Enforcement (IE) Bulletin 85-01, "Steam Binding of Auxiliary Feedwater Pumps," October 29, 1985.

2. NRC Nuclear Regulation (NUREG)-0611, "Generic Evaluation of Feedwater Transients and Small-Break Loss-of-Coolant Accidents in Westinghouse Designed Operating Plants," January 1980.

10.4.9.4 *Technical Evaluation*

The staff reviewed the EFWS and EFWS storage pools in accordance with the review procedures in SRP Section 10.4.9, "Auxiliary Feedwater System (PWR)," Revision 3 for the EFWS, and SRP Section 9.2.6, "Condensate Storage Facilities," Revision 3 for the EFWS storage pools. Conformance to the acceptance criteria of SRP Sections 10.4.9 and 9.2.6 formed the basis for the evaluation of the EFWS and its associated EFWS storage pools with respect to the applicable regulations. The results of the staff's review are provided below. The evaluation addresses compliance with the SRP acceptance criteria listed in Section 10.4.9.3 above.

The EFWS is a safety-related system that supplies water to the SGs to maintain water level and remove decay heat following the loss of normal feedwater supplies due to anticipated operational transients and design-basis accident conditions. The EFWS storage pools are the preferred source of water for the EFWS and serve as the safety-related water supply source for the EFWS. The EFWS design description is presented in FSAR Tier 1, Section 2.2.4; FSAR Tier 2, Section 10.4.9; FSAR Tier 2, Section 14.2 Initial Tests (Test Abstracts No. 020, No. 021, No. 146, No. 154, and No. 195); and FSAR Tier 2, Chapter 16, TS 3.7.5 and Bases 3.7.5.

The EFWS is comprised of four separate trains located in the Safeguard Buildings and in the Reactor Building, and supplied by four independent electrical divisions. Among the EFWS components contained in the Safeguard Buildings are the EFWS storage pools, which are stainless steel lined concrete pools which are part of each Safeguard Building structure, EFW supply header isolation valves, EFWS motor driven pumps, EFWS flow control valves, EFWS steam generator level control valves and isolation valves, and EFWS minimum flow check valves. The EFWS containment isolation valves are located in the Reactor Building and Safeguard Buildings. There are two headers in each Safeguard Building, one connecting the EFWS tank to each train upstream of the pumps, and one connecting the injection lines to the pump discharge nozzles.

GDC 2

The staff reviewed the EFWS (including the storage pools) for compliance with the requirements of GDC 2 with respect to its design for protection against the effects of natural phenomena such as earthquakes, tornados, hurricanes, and floods. Compliance with the requirements of GDC 2 is based on adherence to RG 1.29, Regulatory Position C.1, “Seismic Design Classification,” for the safety-related portions of the system and RG 1.29, Regulatory Position C.2 for non-safety-related portions of the system.

The Reactor Building and Safeguard Buildings that house the EFWS, including the EFWS storage pools, are Seismic Category I designed structures that are also located and designed to provide protection from flood, hurricane/tornado winds, and missiles. FSAR Tier 2, Sections 3.3, 3.4, 3.5, 3.7, and 3.8 provide the bases for the adequacy of the structural design of these buildings with respect to natural phenomena and are reviewed in the corresponding sections of this report.

The staff reviewed the EFWS design and determined the system piping and components to be designed to quality standards commensurate with the importance of their safety functions. As indicated in FSAR Tier 1, Table 2.2.4-1, the EFWS pumps and valves are designed and tested to ASME Code Section III requirements. EFWS safety-related piping and components are designed and constructed in accordance with Quality Group C, except containment isolation boundary piping and valves, which are Quality Group B as discussed in FSAR Tier 2, Section 10.4.9.2.2 and indicated in FSAR Tier 1, Figure 2.2.4-1. Piping from the storage pools to the steam generators and pool vent piping indicated in Figure 2.2.4-1 as ASME Code Section III are designed, welded, and tested in accordance with ASME Code Section III. The staff finds the Quality Group Classification conforms to the system and component classifications specified in RG 1.26 and, accordingly, complies with the requirements of ASME Code Section III.

Some U.S. pressurized water reactors use a condensate storage tank (CST) as the preferred source of water for the EFW pumps. For the U.S. EPR design, there is no CST source of water for the EFW pumps, because the EFWS storage pools serve as the water supply source. The EFW storage pools are connected by a common suction header, and each pool can be aligned to the common header by opening a normally closed (see discussion below) manual isolation valve, if necessary. In FSAR Tier 2, Section 10.4.9.2.1, the applicant states that the storage pools are part of each Safeguard Building structure, so they will be Seismic Category I as well. The pools are shown on FSAR Tier 2, Figure 10.9.1, and FSAR Tier 1, Table 2.2.4-1 as Seismic Category I. The pools have vent lines, which are Seismic Category I. However, the staff noted during the review of the original FSAR, that the storage pool manual isolation valves are normally open and not listed in FSAR Tier 1, Table 2.2.4-1. Therefore, in RAI 83, Question 10.04.09-1, the staff requested that the applicant provide additional information on the storage pool manual cross connect valves and their normal operating position. In addition, the staff requested that the applicant justify not listing the storage pool manual cross connect valves in FSAR Tier 1, Table 2.2.4-1, since they are relied upon for storage pool water volume capability.

In a December 29, 2008, response to RAI 83, Question 10.04.09-01, the applicant stated that the normally open supply header isolation valves do not impact the capability of the system to mitigate design-basis events; however, the operator response to beyond-design-basis events and the definition of TS requirements are affected by the open valves. The supply header isolation valves will be changed to normally closed valves. FSAR Tier 2, Sections 10.4.9.2 and 10.4.9.3 will be revised to reflect that the supply header valves are maintained in the closed position and that the EFWS storage pool cross connect valves will be listed in FSAR Tier 1, Table 2.2.4-1. In the revised table, they will be labeled as EFW Supply Header Isolation Valves 30LAR13, 23, 33, 43AA001, and are ASME Code Section III, Seismic Category I, and have both open and closed functions. The supply header isolation valves are safety-related manual valves that may have to be opened to fulfill their safety function. FSAR Tier 1, Figure 2.2.4-1, Sheets 1 through 4 will be revised to show the supply header isolation valves. With the pool header isolation valves normally closed, there is no possibility of an internal hazard resulting from a EFWS pipe break in one of the EFWS supply lines adversely affecting the other trains. The applicant also stated in the December 29, 2008, response to RAI 83, Question 10.04.09-1 that storage pool or supply header piping leakage was considered a passive failure in the failure modes and effects analysis (FMEA), and that passive failures are not required to be considered for the initial 24 hours for the events included in the FMEA. In response to RAI 83, Question 10.04.09-5 (see discussion below), the applicant states that cold shutdown conditions are reached at approximately 20.3 hours after reactor trip. The staff considers it appropriate that passive failure need not be considered for the initial 24 hours, because the 24-hour timeframe for passive failures conforms to the guidance contained in American National Standards Institute/American Nuclear Society's document ANSI/ANS-58.9-1981, "Single-failure Criteria for LWR Fluid Systems." The staff recognizes these guidelines as consensus standards with respect to certain passive failures in balance of plant fluid systems. In view of the above discussion, the staff finds the applicant's approach acceptable.

With the addition of the storage pool cross connect valves to FSAR Tier 1, Figure 2.2.4-1, Sheets 1 through 4 and Table 2.2.4-1, and FSAR Tier 2, Sections 10.4.9.2 and 10.4.9.3, along with changing the valves from normally open to normally closed, and for the reasons stated above, the staff concludes that the concerns identified in RAI 83, Question 10.04.09-1 are resolved. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 1, Figure 2.2.4-1, Sheets 1 through 4 and Table 2.2.4-1, and FSAR Tier 2, Sections 10.4.9.2 and 10.4.9.3 were revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-1 resolved.

The safety-related EFWS and EFWS storage pool components are designed as Seismic Category I in accordance with RG 1.29, Regulatory Position C.1, as indicated in FSAR Tier 2, Section 10.4.9.3, and FSAR Tier 1, Table 2.2.4-1. In addition, as indicated in FSAR Tier 2, Section 10.4.9.3, the non-safety-related portions of the EFWS are designed in conformance to RG 1.29, Position C.2. Based on the above review, the staff concludes that the EFWS design conforms to the guidelines of RG 1.29, Regulatory Positions C.1 and C.2, and the requirements of GDC 2, as they relate to protecting the system against natural phenomena.

GDC 4

The staff reviewed the EFWS for compliance with the requirements of GDC 4 with respect to the capability of the system and the structure housing the system to withstand the effects of pipe breaks and internally and externally generated missiles, and pipe whip and jet impingement due to high and moderate energy pipe breaks. Compliance with the requirements of GDC 4 is based on identification of the essential portions of the system as protected from dynamic effects including internal and external missiles and conformance with the guidance in BTP 10-2, "Design Guidelines to Avoid Water Hammer in Steam Generators."

In the design, the safety-related portions of the EFWS are located inside the Safeguard Buildings and the Reactor Building. Since the Safeguard Buildings and the Reactor Building are designed to withstand the effects of severe natural phenomenon, including external missiles, as discussed in Section 3.5 of this report. The safety-related portions of the EFWS are protected from external missiles. With respect to internal hazards, each of the four divisions, with the exception of the portion of the system inside containment, is located in a separate Safeguard Building. Since each Safeguard Building is designed to withstand the affects of these internal hazards, as discussed in Section 3.6 of this report, such hazards will be confined to the building in which it originates, and only one EFWS train can be physically affected by a single internal hazard. The EFWS containment isolation valves in each division consist of an inboard and outboard isolation valve. The outboard isolation valves are contained in the separate Safeguard Buildings which prevents both valves from being affected by any single internal hazard. FSAR Tier 2, Section 10.4.9.1 includes in its design basis the statement that "safety-related portions of the EFWS are designed to withstand the effects of the postulated hazards of internal missiles, pipe whipping, and discharging fluids." FSAR Tier 2, Section 10.4.9.3 states that "the analysis of postulated high-energy line failures is provided in Section 3.6.1 and Section 3.6.2," and "the analysis for missiles is provided in Section 3.5." Based on its initial review of the information in the FSAR, the staff determined that the information provided in regard to the provisions and plant-designed features to ensure adequate protection against the effects of pipe breaks and internally and externally generated missiles, and pipe whip and jet impingement due to high and moderate energy pipe breaks was insufficient. Therefore, in RAI 83, Question 10.04.09-2, the staff requested that the applicant describe the provisions and design features used to ensure adequate protection against internal hazards and compliance with GDC 4.

In a November 10, 2008, response to RAI 83, Question 10.04.09-2, the applicant stated that the EFWS components are located in the Safeguard Buildings and the Reactor Building. The applicant further stated that no piping has been identified which could result in internally generated missiles, pipe whip, or jet impingement forces that could impact operation of the EFWS. FSAR Tier 2, Section 3.6.1 contains information regarding the plant design for protection against postulated piping failures in fluid systems outside of containment. In addition, the applicant provided proposed revisions to FSAR Tier 2, Section 10.4.9.3 to explain how components in the EFWS satisfy the requirements of GDC 4. The staff confirmed that Revision 1 of the FSAR dated May 29, 2009, was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-2 resolved. The staff concludes that the GDC 4 requirements have been met relative to protection for the EFWS components from internal hazards.

In FSAR Tier 2, Section 10.4.9.3, the applicant states that an occurrence of an internal hazard does not prevent the EFWS from performing its safety functions or result in a common mode failure of redundant trains, because each of the four EFWS trains outside of the containment is located in a separate Safeguard Building; therefore, only one train can be physically affected by an internal hazard (fire, flood, or pipe break). The applicant further states in FSAR Tier 2, Section 10.4.9.2.3.1 that the pool supply header isolation valves are open for normal operation. Since the pool header isolation valves are open during normal operation, communication between the storage pools exists and, therefore, it may be possible for an internal hazard in one train to have an impact on other trains. Therefore, in RAI 83, Question 10.04.09-1, the staff requested that the applicant explain how the system design, with the pool header isolation valve normally open, precludes the possibility of an internal hazard that results in a EFWS pipe break in one of the EFSW supply lines, would not be capable of effecting the other trains.

As discussed above, the applicant's response to RAI 83, Question 10.04.09-1 stated that the normally open supply header isolation valves will be changed to normally closed. With the pool header isolation valves normally closed, there is no possibility of an internal hazard resulting from a EFWS pipe break in one of the EFWS supply lines adversely affecting the other trains. Accordingly, the staff finds that RAI 83, Question 10.04.09-1 is closed with respect to internal flooding.

BTP 10-2 and NRC GL 2008-01, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," contain design guidelines and recommendations to reduce or eliminate piping damage caused by water hammer transients. The discussion of design provisions to mitigate water hammer is presented in FSAR Tier 2, Section 10.4.9.2.2.4.

The EFWS piping is routed to minimize the potential for destructive water hammer during startup. Within the SGs, the EFW flow is routed through a split ring header and exits the ring header via vertical tubes so that the ring header is maintained full of water. The EFW piping is sloped inside containment. The MFW piping does not interface with the EFW piping, so transients in the MFW system do not affect EFW piping. In FSAR Tier 2, Section 14.2, Test Abstract No. 195, the applicant instructs the COL holder to check for water hammer noise using appropriately placed personnel or check for water hammer vibration using suitable instrumentation. The staff reviewed the design and test provisions, and considered them to be appropriate for minimizing water hammer events, because they conform to the guidance in NUREG-0927, "Evaluation of Water Hammer Occurrence in Nuclear Power Plants." However, the staff determined there was no information presented in the FSAR that will ensure development of operating and maintenance procedures by the COL applicant that will minimize the potential for water hammer in EFWS during operation. Additionally, there was no mention that lines need to be water-solid to prevent air entrainment, as discussed in GL 2008-01. Therefore, in RAI 83, Question 10.04.09-3, the staff requested that the applicant provide an explanation of how the procedures to prevent or minimize water hammer will be included in the FSAR, and how the lines will be maintained water-solid. The staff also requested that the applicant propose a COL information item to provide operating and maintenance procedures to address water hammer issues for the EFWS.

In a November 10, 2008, response to RAI 83, Question 10.04.09-3, the applicant described the procedure requirements intended to prevent or minimize water hammer that will be included in the FSAR. The applicant revised FSAR Tier 2, Section 10.4.9.2.2.4 to include a discussion on the need to maintain the EFWS piping full of water to minimize the occurrence of water hammer. The applicant responded that procedures call for the piping in the EFWS to be properly filled, vented, and maintained full of water. Furthermore, system maintenance and operating procedures will include guidance and precautions during system and component testing, changing valve alignments, or starting or stopping pumps. FSAR Tier 2, Table 1.8-2, "U.S. EPR Combined License Information Items," Item 13.5-1 requires a COL applicant that references the design certification to address procedures, including operating and maintenance procedures. Due to this COL information item, and revised FSAR Tier 2, Section 10.4.9.2.2.4, the applicant stated that it is not necessary to add a new COL information item in the FSAR requiring the COL applicant to provide operating and maintenance procedures to address water hammer issues for the EFWS. With the changes to FSAR Tier 2, Section 10.4.9.2.2.4, and the existing COL Information Item 13.5-1 contained in FSAR Tier 2, Table 1.8-2, the staff concurs that the procedures will address the potential for water hammer issues for the EFWS. The staff confirmed that Revision 1 of the FSAR dated May 29, 2009, Tier 2, Section 10.4.9.2.2.4 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, the staff considers RAI 83, Question 10.04.09-3 resolved.

In Revision 5 of the FSAR, a connection between the fire water distribution center and the EFWS discharge cross-connect header was added to the design. This connection makes it possible to use the diesel-driven fire pumps to deliver water from the fire water storage tanks to the SG in the event of an SBO. When the fire water system is used to supply water to the SGs, the potential for water hammer may exist due to actions that result in condensation of steam or abrupt changes to the system flow. In an October 22, 2013, response to RAI 605, Question 10.04.09-14, the applicant addressed water hammer concerns related to the addition of the fire water distribution system connection to the EFWS. In the response, the applicant stated that system design features and proper operational procedures will be used to minimize the occurrence of water hammer events. Specific actions that the applicant identified to minimize the occurrence of water hammer included: (1) Ensuring that the fire water system piping and components that interface with the EFWS are properly filled and vented; (2) starting diesel-driven pump with associated discharge files in close position to eliminate abrupt changes in system flow; and (3) requiring that the system valves in the flow path from the tanks to the SGs are opened and closed slowly so that abrupt changes in system flow does not occur. The proposed actions are consistent with the recommendation in NUREG-0927; therefore, the staff finds that the water hammer issue has been adequately addressed.

The staff concludes that the EFWS and EFWS storage pools meet the requirements of GDC 4 with respect to the environmental and dynamic effects design basis.

GDC 5

The U.S. EPR is designed as a single facility, so the requirement of GDC 5 for sharing of systems between units does not apply.

GDC 19

The staff reviewed the EFWS for compliance with the requirements of GDC 19, as the system relates to the design capability of system instrumentation and controls for prompt hot shutdown of the reactor and potential capability for subsequent cold shutdown. Compliance with the requirements of GDC 19 is based on conformance to BTP 5-4, "Design Requirements of the Residual Heat Removal System," in regard to cold shutdown from the control room using only safety grade equipment. In a February 20, 2009, response to RAI 83, Question 10.04.09-5, the applicant stated that the U.S. EPR conforms to the guidance of BTP 5-4 with exception. This exception includes cases where an EFW pump is unavailable due to single-failure or maintenance, where action outside of the control room may be necessary to realign the manual supply header valves to provide access to the inventory from all four storage pools. Sufficient water inventory is available for 6 to 8 hours of EFWS operation before this action is necessary. As part of the response to RAI 83, Question 10.04.09-5, the applicant revised FSAR Tier 2, Section 5.4.7.3.3 to provide a discussion of the exception to BTP 5-4. The staff concurs that the U.S. EPR does not conform to the guidance of BTP 5-4 in regard to cold shutdown from the control room using only safety grade equipment. However, BTP 5-4, Table 1, "Possible Solution for Full Compliance with BTP 5-4 and Recommended Implementation for Class 2 Plants Design Requirements," has a statement in Design Requirement 1.b that limited action outside the control room to meet the single-failure criterion is acceptable for meeting the functional requirement for taking the plant to cold shutdown. The staff determined that the action of realigning the manual supply header valves to provide access to the inventory from all four storage pools within 6 to 8 hours of EFWS operation is a limited action outside the control room that is acceptable because sufficient time is available for operator action. Therefore, with this limited action, the guidance in BTP 5-4 is met, and the staff finds that the design of the safety-related portions of the EFWS satisfies GDC 19. The overall acceptance of the applicant's response to RAI 83, Question 10.04.09-5 is discussed below in the evaluation of EFWS compliance with GDC 34 and GDC 44. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 5.4.7.3.3 was revised as committed in the response to RAI 83, Question 10.04.09-5.

In FSAR Tier 2, Section 10.4.9.3 (Page 10.4-90, Revision 1), the applicant stated that only safety-related and Seismic Category I equipment are used to perform the cooldown, and operator actions are performed from the MCR. This statement conflicts with FSAR Tier 2, Section 5.4.7.3.3, revised as part of RAI 83, Question 10.04.09-5, which states that action outside the control room may be necessary. Therefore, in follow-up RAI 305, Question 10.04.09-13, the staff requested that the applicant explain the inconsistency between these two FSAR sections. RAI 305, Question 10.04.09-13 was being tracked as an open item.

In a February 25, 2010, response to RAI 305, Question 10.04.09-13, the applicant proposed a revision to FSAR Tier 2, Section 10.4.9.3, that eliminated the inconsistency between FSAR Tier 2, Sections 10.4.9.3 and 5.4.7.3.3. The applicant indicated that FSAR Tier 2, Section 10.4.9.3 would be revised to state that the "Required actions can be performed from the MCR, with the exception that the manual supply header isolation valves may need to be realigned to provide access to the inventory of the four storage pools. Sufficient water inventory is available for 6 to 8 hours of EFWS operation before action is necessary." As indicated above, the staff considered realigning of the manual header isolation valves acceptable, based on it being limited action outside the control room to meet the single-failure criterion as allowed by BTP 5-4, Design Requirement 1.b. The staff confirmed that Revision 2 of the FSAR, dated August 31, 2010, Tier 2, Section 10.4.9.3 was revised as committed in the response to RAI 305, Question 10.04.09-13. Revision of the FSAR as specified in the RAI response, eliminates the inconsistency between FSAR Tier 2, Sections 10.4.9.3 and 5.4.7.3.3 and, thus, resolves the concern raised by RAI 305, Question 10.04.09-13. Therefore the staff considers RAI 305, Question 10.04.09-13, resolved and it is no longer being tracked as an open item.

Based on the above described capability to monitor and control the EFWS from the MCR using only safety-related equipment, the staff finds the plant design provides an acceptable means of compliance with GDC 19 and BTP 5-4.

GDC 34 and GDC 44

The staff reviewed the EFWS for compliance with the requirements of GDC 34 and 44, with respect to the capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions, assuming any single active failure, coincident with the loss of offsite power for certain events, and the capability to isolate components, subsystems, or piping if required to maintain system safety function. To demonstrate compliance with GDC 34 and GDC 44, SRP Section 10.4.9 states, in part, that the system design should conform to the guidance of BTP 10-1, "Design Guidelines for Auxiliary Feedwater System Pump Drive and Power Supply Diversity for Pressurized Water Reactor Plants," as it relates to EFW pump drive and power supply diversity.

The staff reviewed the EFWS for compliance with the guidance in BTP 10-1, as related to EFW pump drive and power supply diversity. BTP 10-1, Guideline B.1 states that the EFWS should have at least two full-capacity, independent systems with diverse power sources. Typically for EFW systems, BTP 10.1, Guideline B.1 is met by use of a turbine-driven (steam driven) EFWS pump to ensure that the EFWS is capable of supplying feedwater to the steam generators independent of all offsite or onsite ac power supplies. The U.S. EPR EFWS consists of four independent divisions each dedicated to one of the four steam generators. Each division contains a motor-driven feedwater pump and is powered by an independent geographically segregated electrical division. The EFWS design for the U.S. EPR uses only motor driven pumps. Upon review of the FSAR, the staff determined that the applicant had not discussed whether the design conformed to the diversity guidance in the BTP, nor had the applicant discussed what steps would be taken to provide for protection against common mode failures. Therefore, in RAI 83, Question 10.04.09-4, the staff requested that the applicant explain the system design not conforming to BTP 10.1, including a discussion on diversity of equipment and power supplies.

In a November 10, 2008, response to RAI 83, Question 10.04.09-4, the applicant explained the EFWS design with regard to meeting the diversity guidance in the BTP. The applicant stated that diversity in power supplies is provided by the EDGs and SBODGs. Two EFW pumps and associated room cooling and required motor-operated valves can be powered from one of two SBODGs.

Diversity and redundancy in the EFWS and its support systems enhances the system's capability to address a loss of normal power supplies. This diversity includes:

- The EDGs are housed in two separate buildings. There are two units per building, with each unit in a different fire area. The buildings do not share control power; heating, ventilation, and air conditioning (HVAC); or engine cooling.

- The diversity that exists between the EDGs and the SBODGs includes the difference in nominal size and models and that they are located in separate areas. They do not share control power, HVAC, engine cooling, or fuel systems. There is diversity in the jacket water cooling systems for the EDGs and SBODGs in that the EDGs are water-cooled, and the SBODGs are air-cooled. There are no environment-related events or single active failures that can simultaneously disable both the SBODGs and EDGs. Because of their diversity, the SBODGs and EDGs are assigned to different common-cause groups in the probabilistic risk assessment (PRA).

- The EFWS supply and discharge headers allow any EFW pump to feed different SGs from different storage pools. This redundancy in the EFWS design also reduces the risk of common mode failures.

Common cause failures can be grouped into the following categories: Hardware (including design); maintenance; operations; and operating environment. In response to the staff's request to explain the protection of the EFWS against common-mode failures, the applicant provided the following information:

- The EFWS normal and makeup water supplies are clean water stored in tanks or pools that are not susceptible to CCFs caused by blockage.

- Detailed equipment specifications and quality assurance (QA) programs, combined with testing, and preservice and inservice inspection will reduce the risk of hardware-related common-cause factors.

The applicant provided a discussion about the redundancy and diversity related to the type of hardware (pump, driver, or control system) used. In particular, the applicant stated that the incremental diversity added by including a turbine-driven pump and direct current (dc) controls to the EFWS design is offset by other factors, such as:

- The use of a turbine-driven pump will not eliminate hardware-related, common-cause concerns, because the electric motor and turbine driven trains can still use common components.

- The heat and humidity associated with the steam piping and the turbine introduce additional heat loads in equipment rooms where the turbine is located.

- Inherent problems associated with trips, such as overspeed and other valve and turbine malfunctions result in numerous failures to start or run.

- The reliability of turbine-driven pumps is lower than electric-driven pumps.

- Turbine-driven pumps have a higher level of maintenance than electric motor-driven pumps.

The applicant further stated that while diversity could be improved by including a turbine-driven pump, the inclusion of the turbine-driven pump is not likely to improve the overall system reliability. The results of the EFWS reliability analysis, which are provided in FSAR Tier 2, Table 10.4.9-5, "EFWS Unreliability Results," show that the reliability target is met.

The staff reviewed the applicant's response to the RAI and the EFWS design and concluded that while the type of energy supplies is not diverse, the system design does provide for EFWS operation in case of a loss of all EDGs. This is achieved by powering two of the four EFW pumps, and associated room cooling and required motor-operated valves using one of the two SBODGs. In response to RAI 83, Question 10.04.09-4, the applicant indicates that diversity exists between the EDGs and the SBODGs, including differences in nominal size and models, location in separate areas, and exclusion of shared control power, HVAC, engine cooling, and fuel oil systems. The applicant also states that there are no environmental-related events or single active failures that can simultaneously disable both the SBODGs and the EDGs.

While the use of the SBODGs provides diversity in the available diesel power supply and provides greater assurance that power will be available to the motor-driven feedwater pumps in the cases where the EDGs are not available, the staff determined that the FSAR and RAI response did not sufficiently address providing diversity in pump motive power sources, controls and valves, and essential instrumentation. The FSAR also stated that incorporating non-electric EFW pumps into the design is not expected to significantly improve EFW system reliability or core damage frequency (CDF), but no basis for the conclusion was given. Therefore, the staff determined that the concerns, raised in RAI 83, Question 10.04.09-4, had not been completely resolved. Therefore, in follow-up RAI 238, Question 10.04.09-12, the staff requested that the applicant address these concerns.

In follow-up RAI 238, Question 10.04.09-12, the staff requested that the applicant discuss how the EFWS complied with the guidance contained in BTP 10-1, NUREG-0611, "Generic Evaluation of Feedwater Transients and Small-Break Loss-of-Coolant Accidents in Westinghouse Designed Operating Plants," and NUREG-0635, "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accidents in Combustion Engineering-Designed Operating Plants," related to the EFWS diversity, and the ability of the EFWS to perform its safety function assuming a single-failure. The staff also requested that the applicant provide additional information on its proposed use of station blackout diesels including justification for crediting the use of non-safety-related SBO diesels for operation of the EFWS, and the applicant was requested to provide the time duration that the EFWS would be unavailable if it was necessary to use the SBO diesels, and to justify the acceptability of the delayed start. Finally the staff requested that the applicant discuss and quantify the improvement in EFWS reliability that could be obtained if the design incorporated diverse EFW pumps. RAI 238, Question 10.04.09-12, was being tracked as an open item.

In an October 26, 2009, response to RAI 238, Question 10.04.09-12, the applicant provided additional information on the EFW system regarding the extent in which diversity was incorporated in the EFW design. The applicant also addressed the availability of the EDGs, and SBO diesels credited by the EFWS for system operation in response to accidents, transient, and SBO events. Information provided included a sensitivity study to evaluate what impact the use of turbine driven pumps would have on system reliability and a discussion on how the EFWS will be available, and able to provide sufficient cooling in the case of an SBO event.

In the October 26, 2009, response to RAI 238, Question 10.04.09-12, regarding the EFWS diversity and compliance with the guidance contained in BTP 10-1, the applicant stated that the U.S. EPR design includes diversity in power sources for essential I&C comprised of safety-related alternate current (AC) power, safety- related dc power, and non-safety-related backup power. The applicant also states that the U.S. EPR design complies with all regulatory requirements relevant to the EFW and alternate AC (AAC) source of power, including GDC 34, related to EFWS redundancy; 10 CFR 50.34(f)(ii) related to EFWS reliability; and 10 CFR 50.63 related to SBO mitigation.

The applicant stated that the use of four AC powered EFW trains, four EDGs, and AAC supply of power, consisting of two SBO diesels, were selected based on years of experience with the equipment, higher reliability, compatibility with the plant design, and adequate diversity to address loss of normal AC power while decreasing the risk of CCFs. The applicant also stated that the AAC power supply diesels would have the capability and quality requirements to support their use to address beyond design basis SBO and CCF events, and that if the design were to include turbine-driven pumps in addition to motor driven pumps to achieve diversity, the resulting EFWS reliability would be approximately equivalent to that of the current design. The results of the sensitivity study, which the applicant stated demonstrated that equivalent reliability, would result if turbine-driven EFW pumps were used in the design, is shown in revised FSAR Tier 2, Table 10.4.9.12-1. Additionally, sensitivity results comparing the CDF for the U.S. EPR EFWS design to one that utilize both motor driven and turbine drive pumps were provide in FSAR Tier 2, Table 10.4.9-12-3.

In the October 26, 2009, response to RAI 238, Question 10.04.09-12, regarding the capability for EFW to meet the guidelines of Generic Short Term Recommendation No. 5 (GS-5) and Generic Long Term Recommendation No. 3 (GL-3) of NUREG-0611 and NUREG 0635 to provide the capability of EFW flow for 2 hours without AC power, the applicant stated that U.S. EPR does not meet that recommendation. However, the applicant states in the unlikely event the EFWS is unavailable due to a CCF, the large volume of water in the SGs provides approximately one and one-half hours before dry-out, and the U.S. EPR design includes the safety-related capability of removing heat by feed and bleed. The applicant also indicated in the October 26, 2009, response to RAI 238, Question 10.04.09-12, that equivalent protection can be provided by the AAC power sources (two SBO diesels) that can provide EFWS trains 1 and 4 power at 30 minutes and support EFWS operation for greater than 2 hours. In the event of an SBO, the applicant states that two EFW pumps are manually actuated and aligned to provide flow to all four SGs at 30 minutes. The SGs level will be at approximately 45 percent of wide range when the pumps are actuated and the large volume of water in the SGs provide for approximately one and one-half hours to dry-out.

The staff reviewed the EFWS design and the information provided in the applicant's October 26, 2009, response to RAI 238, Question 10.04.09-12, to determine if the EFWS design with only motor–driven EFW pumps provide the necessary capability, and reliability, to transfer the required heat loads from the reactor system under both normal operating and accident conditions, assuming any single active failure, coincident with the loss of offsite power. To determine whether the design was acceptable, the staff reviewed the design against the following regulations: 10 CFR 50.34(f)(ii) as it pertains to the required evaluation of the AFW system design, capability, and reliability; GDC 33 and GDC 44, with respect to the requirement of suitable redundancy in components and features; and 10 CFR 50.63 as it pertains to loss of all alternate current power (SBO).

Based the requirements of 10 CFR 50.34, GDC 34, and GDC 44 regarding the EFWS design acceptability, the staff found that although the EFWS does not have EFW pump drive diversity, as recommended by BTP 10.1, Guideline B.1, there is sufficient redundancy and diversity in the system to meet the requirements of 10 CFR 50.34, GDC 34, and GDC 44. Notably, the four train design provides additional redundancy compared to current designs, and the capability of powering two of the four EFW pumps with the diverse AAC power supply makes the design less susceptible to CCF related to loss of emergency power. The staff also recognized that the applicant performed PRA evaluations using an alternate design that diverse (turbine-driven) EFW pumps shows no risk reduction benefits.

As described in FSAR Tier 2, Section 10.4.9, and in the applicant's response to RAI 238, Question 10.04.09-12, the EFWS is designed such that with two of the four EFW pumps capable of being powered by the plants AAC power supply, the EFW system will be available and can operate following a loss of AC power with concurrent failures of EDGs to satisfy SBO requirements. Since the U.S. EPR design only uses electric-driven EFW pumps, if the EDGs become unavailable, there will be no EFWS flow to the SGs until the SBO diesels are started and loaded. The applicant indicated in the RAI response that in the case of an SBO that the

EFWS will be available 30 minutes after the onset of the SBO since the AAC power source can provide EFWS trains 1 and 4 with power at 30 minutes.

The applicant indicated in the October 26, 2009, response to RAI 238, Question 10.04.09-12 that after 30 minutes without EFW flow, the SGs levels will be approximately 45 percent of wide range when the pumps actuate. The applicant also indicated that because of the SG's large water inventory, SG dryout would not occur for approximately one and one-half hours under no flow conditions. The staff verified the steam generator dryout time to be approximately one and one-half hours by performance of an independent evaluation. Therefore, the staff concludes that since EFWS flow will be available in 30 minutes for the SBO, steam generator dryout will not occur, and the design will be able to remove decay heat from the reactor coolant system during an SBO. The staff confirmed that FSAR Tier 2, Revision 2, Section 10.4.9.3, was revised as committed in the RAI response. With the revision to FSAR Tier 2, Section 10.4.9.3, the staff finds that the applicant adequately addressed the concerns raised by the staff in RAI 238, Question 10.04.09-12, since the application now clearly describes how diversity was incorporated into the design of the EFWS.

Based on the above discussion, the staff finds that the concern raised in RAI 238, Question 10.04.09-12, has been adequately addressed, and considers this RAI resolved, and is no longer being tracked as an open item.

The applicant indicates that redundancy of the EFWS system is maintained by using four independent divisions, each dedicated to one of the four SGs. The applicant describes the following EFWS design features as providing for redundancy in regard to cooling for the RCS:

- There are four complete trains, each normally aligned to a separate SG. The supply and discharge headers can be configured to allow the pumps to feed any combination of SGs.
- Each EFWS train receives power from a separate IEEE Class 1E emergency power system. In the event of loss of normal onsite and offsite power, power is supplied by the EDGs. The level control valves, SG isolation valves, and discharge header cross-connect valves are also provided uninterruptible vital battery power.
- The system has suitable redundancy, as demonstrated by a single active failure analysis to withstand a single active failure and still perform its safety functions. Refer to FSAR Tier 2, Table 10.4.9-2, "Emergency Feedwater Failure Analysis," for a summary of the single-failure evaluation.
- EFWS trains 1 and 4, including pump room cooling, are dedicated SBO trains and can be powered from the two SBODGs, if necessary.

The applicant describes the system as follows: Each EFWS is designed to supply an independent source of water to its respective steam generator during accident and transient conditions in the event of a loss of MFW. The major components of the EFWS are four 1,514 liters per minute (400 gpm) safety grade motor-driven pumps (one per train) each of which is supplied with water from one of four concrete storage pools with stainless steel liners (one in each Safeguard Building). The pools supplying trains 1 and 4 have a usable volume of 4.16×10^5 L (110,000 gal) each, and the pools supplying trains 2 and 3 have a useable volume of 3.62×10^5 L (95,600 gal) each.

For the case of a design-basis accident (DBA), two EFWS trains are relied upon to provide the necessary cooling. The EFWS design flow is 1514 L/min (400 gpm) to a minimum of two SGs following a main feedwater line break when pumping against the MSRV setpoint pressure. FSAR Tier 2, Table 10.4.9.1 gives the minimum net positive suction head (NPSH) and the available NPSH to be 4.26 m (14 ft) and 11.9 m (39 ft), respectively. Confirmation that the as-built plant has sufficient NPSH for the EFW pumps is accomplished with ITAAC 7.1 in FSAR Tier 1, Table 2.2.4-3.

In FSAR Tier 2, Section 10.4.9.3, the minimum water inventory for the bounding cases with or without offsite power is given as less than 1.14×10^6 L (300,000 gal). The applicant indicated that this inventory is sufficient to remove heat over the entire range of reactor operation and cool the plant to the RHR system cut-in temperature, assuming a single active failure with a loss of offsite power. While conducting its review, the staff was unable to find sufficient information for the basis for the calculation of the water volume needed for cooldown. Therefore, in RAI 83, Question 10.04.09-5, the staff requested that the applicant provide the basis for using 1.14×10^6 L (300,000 gal) as the minimum EFWS water volume to be supplied to the SGs under all conditions.

In an April 23, 2009, response to RAI 83, Question 10.04.09-5, the applicant stated the basis for using 1.14×10^6 L (300,000 gal) as the minimum EFWS water volume supplied to the SGs under all conditions. In the response, the applicant revised the minimum water volume to 1.38×10^6 L (365,000 gal) based on the following: The analysis was performed in accordance with BTP 5-4 to determine the bounding cooldown and the minimum EFWS water inventory (1.14×10^6 L [300,000 gal), and was based on natural circulation cases where all four SGs were fed. These analyses were shown to be bounding since the results indicated that this was the minimum amount of water needed to return the SGs to normal level. It has since been determined that scenarios including a single-failure that result in an unfed SG are more limiting. The limiting case considered the failure of an EFW level control valve (LCV) in the closed position, which results in the inability to feed that SG, and a stagnant RCS loop. The stagnant RCS loop conditions call for a slow and controlled cooldown and depressurization to RHR entry conditions. A cooldown rate of 25 °F/hr (13.89 °C/hr) and a core exit subcooling margin of 27.78 °C (50 °F) were used to control the pressurizer level surges during depressurization. The minimum EFWS inventory for this case is approximately 1.38×10^6 L (365,000 gal), which includes the inventory of all four storage pools.

As discussed above, the U.S. EPR conforms to BTP 5-4 with the following exception:

In cases where an EFW pump is unavailable due to single-failure or maintenance, action outside of the control room may be necessary to realign the manual supply header valves to provide access to the inventory from all four storage pools. Sufficient water inventory is available for 6 to 8 hours of EFWS operation before this action is necessary. The non-safety demineralized water distribution system, with more than 9.8×10^5 L (260,000 gal) of water available, provides the normal makeup supply for the EFW storage pools. If needed, the fire protection system, which is designed to remain functional during and following a SSE, can be used to provide approximately 1.06×10^6 L (280,000 gal) of additional makeup water to the EFW storage pools from standpipes located in each Safeguard Building.

As a result of performing new cooldown analyses, the following changes were made to the FSAR, and are summarized below:

- FSAR Tier 2, Section 5.4.7.3.3 was revised to include a description of the new cooldown analyses. This included the addition of six new figures, FSAR Tier 2, Figures 5.4-13 through 5.4-18.

- FSAR Tier 2, Section 10.4.9.3 was revised to remove the existing description of cooldown details, describe the exception to BTP 5-4 for makeup to the EFW storage pools, and reference FSAR Tier 2, Section 5.4.7.3.3 for a description of the bounding BTP 5-4 cooldown analyses. FSAR Tier 2, Table 10.4.9-2, "Emergency Feedwater System Failure Analysis," has been revised to reflect the above noted changes.

- FSAR Tier 2, Section 15.0.4 was revised to remove the existing description of cooldown details and analytical results, limit the details to Chapter 15 events, provide clarification of cooldown following Chapter 15, Transient and Accident Analysis," events, and reference FSAR Tier 2, Section 5.4.7.3.3 for a description of the bounding BTP 5-4 cooldown analyses. This change included the deletion of existing FSAR Tier 2, Figures 15.0-13 through 15.0-18.

- FSAR Tier 1, Table 2.2.4-3, "EFWS ITAAC," Item 7.3 was revised to reflect the change in the minimum EFW storage pool volume to 1.38 x 10^6 L (365,000 gal).

The staff confirmed that Revision 1 of FSAR dated May 29, 2009, was revised as committed in the RAI response, except for the review of changes to Chapter 5, "Reactor Coolant and Connected Systems," and Chapter 15. Accordingly, the staff finds that the applicant has adequately addressed this issue with respect to Chapter 10 and, therefore, considers RAI 83, Question 10.04.09-5 resolved.

The total minimum water based on the calculation is less than the combined available water inventory of the four storage pools. FSAR Tier 1, Table 2.2.4-3, lists ITAAC 7.3 to verify by inspection and analysis that the combined storage pool volume of 1.38 x 10^6 L (365,000 gal). A FMEA demonstrated that the system has suitable redundancy to withstand a single active failure and loss of offsite power (LOOP) and still perform its safety functions (FSAR Tier 2, Table 10.4.9-2, "Emergency Feedwater System Failure Analysis"). In a November 10, 2008, response to RAI 83, Question 10.04.09-2, the applicant stated that no piping has been identified which could result in internally generated missiles, pipe whip, or jet impingement forces that could impact operation of the EFWS. The staff's review did not identify any single active failure that would prevent the EFWS from performing its safety functions.

FSAR Tier 2, Section 10.4.9.2.1 states that the EFWS design flow is 1514 L/min (400 gpm) to a minimum of two SGs following a main feedwater line break when pumping against the MSRV setpoint pressure. The staff examined TS Bases Section 3.7.5 for MSRVs and determined that there are two different lift settings for the MSRVs, a high-set and a low-set. In RAI 83, Question 10.04.09-6, the staff requested that the applicant provide clarification as to which of the two MSRV lift setpoints was used in the EFWS analysis when the pumps are pumping against the MSRV setpoint pressure, and justification for its use.

In a November 10, 2008, response to RAI 83, Question 10.04.09-6, the applicant stated that FSAR Tier 2, Section 10.4.9.1 refers to the MSRT, which is the correct valve terminology. The MSRT consists of the MSRIV and the MSRCV. FSAR Tier 2, Chapter 16, TS Bases 3.7.5 and 3.7.6 refer to the MSRVs. A description of these valves is provided in FSAR Tier 2, Section 10.3.3. FSAR Tier 2, Section 10.4.9.2.1, Section 10.4.9.2.3.2, and Chapter 16 TS B 3.7.5 and B 3.7.6 will be revised to reflect the correct valve terminology. The staff concurs that the revised FSAR sections and TS Bases sections identified above provide clarification that the EFWS pumps are pumping against the MSRT setpoint pressure, which is listed in FSAR Tier 2, Table 10.3-1 as 1370 psig. Therefore, the staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.9.2.1, Section 10.4.9.2.3.2, and Chapter 16 TS B 3.7.5 and B 3.7.6 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-6 resolved.

To ensure that the design can deliver the minimum flow specified in the accident analysis, confirmation of the delivery capability will be required by an EFWS ITAAC as specified in FSAR Tier 1, Table 2.2.4-3, in which ITAAC 7.2 requires the COL applicant to verify by test and analysis that the EFWS delivers water to the SGs at the minimum flowrate to restore and maintain SG water level and remove decay heat following the loss of the normal feedwater supply due to a design-basis event.

The EFWS automatically initiates upon a system actuation. FSAR Tier 1, Table 2.2.4-2 shows that the priority actuation and control system (PACS) automatically actuates the EFW pumps, flow control valves, SG level control valves, SG isolation valves, and discharge header isolation valves. In FSAR Tier 2, Section 10.4.9.2.2.3, the applicant states that the SG isolation valve and the SG level control valves will close automatically on high SG level to prevent SG overfill following an SGTR. The applicant also stated that those valves can be manually closed from the MCR.

As discussed below, the EFWS satisfies the recommendations of RG 1.62, “Manual Initiation of Protective Actions,” regarding the capability of manual initiation of protective actions. RG 1.62 recommends that such manual action be accomplished at the system level. RG 1.62 further recommends that the switches for the manual initiation of protective actions at the system level should be located in the control room.

In FSAR Tier 2, Section 10.4.9.5.2, the applicant stated that in addition to the automatic functions, the EFWS system is designed to allow operators to manually initiate the following safety-related functions:

- EFWS actuation and control
- EFWS isolation of the affected loop following a MSLB
- EFWS pump injection to another unaffected SG following a MFWLB

The EFWS is designed to conform to the generic recommendations of NUREG-0611, and NUREG-0635, for pump endurance testing. In FSAR Tier 2, Section 14.2, Test Abstract No. 020, the applicant states that pump performance during an endurance test is to be verified within design limits. A 48-hour endurance run is specified by the applicant, which conforms to the NUREGs. Since this conforms to the guidance in the NUREGs, the staff considers the endurance testing specified by the applicant acceptable.

Storage pool leakage can be detected, collected, and controlled and portions of the system can be isolated in the event of excessive leakage or component malfunctions. The storage pools have level indicators and drains as shown on FSAR Tier 1, Figure 2.2.4-1. Normally closed manual isolation valves are provided for each storage pool, so a leak in one pool would not result in drainage of the other pools. The staff considers that appropriate features have been provided for detecting, collecting, and controlling storage pool leakage.

Based on the above review, the staff finds that the EFWS design complies with generic recommendations of NUREG-0611 and NUREG-0635, and satisfies the requirements of GDC 34 and GDC 44, in that it has the capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions, assuming any single active failure, coincident with the loss of offsite power, and the capability to isolate components, subsystems, or piping if required to maintain system safety function.

GDC 45 and GDC 46

The staff reviewed the EFWS for compliance with the requirements of GDC 45 as related to design provisions to permit periodic inservice inspection of system components and equipment, and GDC 46 regarding provisions to permit appropriate functional testing of the system and components. Since EFWS components are located in accessible areas to allow for periodic inspections, the staff finds that with respect to the requirements of GDC 45 and GDC 46, the design provides sufficient capability for inservice inspection of safety-related components and equipment as well as operational functional testing. The staff finds that the EFWS pumps and the appropriate system valves are included in the plant IST program as identified in FSAR Tier 2, Section 3.9.6. There is a flow test line that allows pump flow back to the storage pool (SP) for testing. Instrumentation identified on FSAR Tier 2, Figure 10.4.9-1 includes pump flow rate and differential pressure developed by the pump, which are necessary for testing. Based on the above considerations, the staff finds that the requirements of GDC 45 and GDC 46 are satisfied.

The staff reviewed the EFWS for compliance with the requirements of 10 CFR 50.62 for automatic EFWS initiation in an ATWS. In FSAR Tier 2, Section 10.4.9.1, the applicant stated that safety-related portions of the EFWS are capable of automatic initiation under conditions of an ATWS. In FSAR Tier 2, Section 10.4.9.3, the applicant further stated that a diverse low SG level EFWS actuation signal is provided for ATWS mitigation. The diverse actuation subsystem, which is part of the process automation system, automatically initiates the EFWS and initiates a turbine trip under conditions indicative of an ATWS. Therefore, the staff finds that the design of the EFWS system satisfies 10 CFR 50.62 regarding provisions for automatic initiation in an ATWS.

The staff reviewed the EFWS for compliance with the requirements of 10 CFR 50.63 regarding the capability for responding to an SBO. Compliance with this regulation is reviewed according to the EFWS design providing for sufficient decay heat removal in an SBO in accordance with RG 1.155, “Best-Estimate Calculations of Emergency Core Cooling System Performance,” Regulatory Positions C.3.2.2, C.3.3.2, and C.3.3.4. Trains 1 and 4 of the EFWS, including the air recirculation fans of the room coolers for these EFWS pumps, are powered from the SBODGs. The cooling medium for these coolers is supplied by the safety chilled water system (SCWS), which is also powered by the SBODGs. In FSAR Tier 2, Section 10.4.9.3, the applicant states that these two trains have sufficient capability and capacity to remove decay heat for an SBO duration of 8 hours. FSAR Tier 2, Section 8.4 describes the SBO event and lists EFWS trains 1 and 4 as designated for an SBO. RG 1.155, Section 3.3.2, specifies that condensate storage be sufficient to remove decay heat for the duration of an SBO. The staff was unable to find information in the FSAR specifying the EFWS minimum water inventory for decay heat removal to support the system during the SBO coping duration. Therefore, in RAI 83, Question 10.04.09-7, the staff requested that the applicant provide the SBO water inventory requirements and the basis used for the inventory calculation.

In a November 10, 2008, response to RAI 83, Question 10.04.09-7, the applicant stated that EFWS water inventory needed to cope with an SBO is 6.3 x 10^5 L (166,000 gal). This is based on the EFWS providing the necessary flow for decay heat removal while remaining in the hot standby conditions for 8 hours. FSAR Tier 2, Section 10.4.9.3 will be revised to specify the EFWS water inventory necessary for decay heat removal that supports the system during the SBO event duration. The staff concurs that the revised FSAR Tier 2, Section 10.4.9.3 provides the minimum SBO water inventory and the basis used for the inventory calculation. The staff considers the minimum water inventory of 6.3 x 10^5 L (166,000 gal) for the design adequate because a typical U.S. PWR with capacity of about 1000 MWE plant needs a minimum of about 3.8 x 10^5 L (100,000 gal) of water for cooldown to cope with an SBO. Accordingly, the staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.9.3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-7 resolved.

Design provisions have been made for the safety-related function of containment isolation. In FSAR Tier 2, Section 10.4.9.2.2.3, the applicant states that the SG isolation valves provide the outside containment isolation boundary, and the EFWS containment isolation check valves provide the inside containment isolation boundary. These valves appear as containment isolation valves in FSAR Tier 2, Table 6.2.4-1, “Containment Isolation Valve and Actuator Data.”

The design includes features to detect and mitigate steam binding of the EFWS pumps due to back-leakage from the SG to the EFWS. Steam leakage from the SG to the EFWS pumps during standby conditions is prevented by two check valves (i.e., the EFW minimum flow check valve and the EFW containment isolation check valve), as shown in FSAR Tier 1, Figure 2.2.4-1. In FSAR Tier 2, Section 10.4.9.2.3.2, the applicant states that if leakage should occur that temperature instrumentation detects the resulting high-temperature condition and provides an alarm in the MCR to alert the operators to close the EFWS isolation valve and promptly perform any other actions to return the affected pump train to service. The EFWS design and the use of appropriate operating procedures for recognizing the effects of steam binding of EFW pumps and restoring the system to an operable status sufficiently address the concerns of steam binding and Generic Safety Issue (GSI)-93, “Steam Binding of Auxiliary Feedwater Pumps.” In RAI 83, Question 10.04.09-11, the staff requested that the applicant propose a COL information item to provide operating and maintenance procedures to address steam binding issues for the EFWS.

In a November 10, 2008, response to RAI 83, Question 10.04.09-11, the applicant stated that FSAR Tier 2, Section 10.4.9.2.2.1 will be revised to address the need for plant procedures that outline prompt operator action regarding the potential for unacceptable EFWS pump suction conditions. This revision calls for operating and maintenance procedures to include specific guidance and precautions to preclude the occurrence of steam binding of the EFWS pumps. As described in FSAR Tier 2, Section 10.4.9.2.2.1, temperature instrumentation is provided to indicate in the MCR that leakage past the check valve is occurring. FSAR Tier 2, Table 1.8-2, “U.S. EPR Combined License Information Items,” Item 13.5-1, states: “A COL applicant that references the design certification will provide site-specific information for administrative, operating, emergency, maintenance and other operating procedures.” The revision of FSAR Tier 2, Section 10.4.9.2.2.1 and the inclusion of Table 1.8-2, COL Information Item 13.5-1 eliminates the need to add a new COL information item in the FSAR requiring the COL applicant to provide operating and maintenance procedures to address steam binding issues for the EFWS. The staff concurs that the revised FSAR Tier 2, Section 10.4.9.2.2.1, which addresses the need for plant procedures that outline prompt operator action regarding the potential for unacceptable EFWS pump suction conditions eliminates the need to add a new COL information item in the FSAR. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.9.2.2.1 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-11 resolved.

The staff reviewed design provisions that have been incorporated to provide minimum flow for EFWS pump cooling. A minimum flow check valve for each EFWS pump is listed in FSAR Tier 1, Table 2.2.4-1 and depicted in Figure 2.2.4-1. A minimum flow recirculation line back to each storage pool is provided for each EFW pump. There is no discussion in the FSAR about pump minimum flow addressed in NRC IE Bulletin (IEB) 88-04, "Potential Safety-Related Pump Loss." This bulletin discusses, in part, pump minimum flow as it relates not only to pump cooling due to fluid temperature rise, but also to hydraulic instability due to insufficient minimum flow, resulting in pump cavitation and potential damage of the impeller. This bulletin recommends that the limitations associated with these hydraulic phenomena be considered when specifying minimum flow capacity. However, no mention of IEB 88-04 was located in the FSAR. Accordingly, in RAI 83, Question 10.04.09-8, the staff requested that the applicant address the pump minimum flow recommendations of IEB 88-04.

NRC IEB 88-04 identifies two concerns associated with pump minimum flow protection designs: Pump dead-heading due to common discharge lines and inadequate minimum flow capacity to protect against temperature rise and hydraulic instability. In a November 10, 2008, response to RAI 83, Question 10.04.09-8, the applicant stated that the design for EFWS does not have common discharge minimum flow lines, so there is no concern for pump dead-heading while on minimum flow. In determining pump minimum flow, the objective is to use the minimum recirculation flow that provides stable flow conditions with respect to rotor and hydraulic stability, as well as acceptable thermal conditions. FSAR Tier 2, Section 10.4.9.2.2.3 was revised to explain how the design addresses the concerns identified in NRC IEB 88-04. FSAR Tier 2, Section 10.4.9.2.2.3 currently specifies a pump minimum recirculation flow of 333 Lpm (88 gpm). Pump minimum flow will be confirmed by vendor analysis and/or testing. The staff concurs that the revised FSAR Tier 2, Section 10.4.9.2.2.3 provides the explanation of how the pump minimum flow recommendations of IEB 88-04 were addressed. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Section 10.4.9.2.2.3 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-8 resolved.

Based on the above review the staff finds that the EFWS satisfies the requirements of GDC 45 and GDC 46, since design provisions are provided to permit periodic inservice inspection of EFWS components and equipment, and operational testing of the EFWS during normal plant conditions.

10 CFR 20.1406 requires, in part, that each design certification applicant shall describe how the facility design and procedures for operation will minimize, to the extent practicable, contamination of the facility and the environment, as well as the generation of radioactive waste. The EFWS supplies water to the SGs to maintain water level and remove decay heat following the loss of normal feedwater supplies due to anticipated operational transients and design-basis accident conditions. Usually, the EFWS does not contain radioactive fluids. The U.S. EPR EFWS design utilizes dedicated EFW storage pools as a non-radioactive source, rather than a potentially radioactive water source, such as the condensate storage tank. The EFW storage pools are located inside the safeguards building. The pools do not contain radioactive water and do not interface with systems carrying radioactive fluids so contamination of the EFW pools through interface with other system is not expected to occur.

In the case of an SGTR, the EFWS is designed to prevent the release of contaminated fluid from the affected SG, by isolating the SG if a partial cooldown signal is present and either high SG water level is detected, or high main steam activity is detected. The isolation will retain the activity in the affected SG, thus minimizing the release of reactor coolant to other parts of the secondary side cooling system.

Accordingly, the staff concludes that the EFWS design as described in the FSAR, complies with 10 CFR 20.1406, “Minimization of contamination,” provides for monitoring and controls of allowable primary-to-secondary leakage and isolates the affected steam generators in the event of a steam generator tube rupture. Furthermore, limiting radioactive leakage to the affected steam generator prevents the spread of additional contamination to the rest of the EFWS.

ITAAC: Proposed ITAAC for the EFWS are given in FSAR Tier 1, Table 2.2.4-3 (ITAAC). Table 2.2.4-3, contains test and inspection requirements for the EFWS. These tests and inspections confirm: (1) The qualification of EFWS components designated as IEEE Class 1E to perform in a harsh environment [Item No. 6.1]; (2) Adequate NPSH to the system pumps [Item No. 7.1]; (3) Design flow rates to SGs for design conditions [Item No. 7.2]; (4) Adequate EFWS storage pool volume [Item No. 7.3]; (5) Maximum flowrate to a depressurized SG [Item No. 7.4]; (6) EFWS cross-connections allow alignments of EFWS pump suction to all EFWS storage pools and EFWS pump discharge to any SG [Item No. 7.5]; (7) EFWS pumps can be aligned with any SG from the control room [Item No. 7.6]; (8) The ability of system valves to reposition in accordance with the design [Item No. 7.7]; and (9) The capability of the pumps to be tested at flow during plant operation [Item No. 7.8]. Based on a detailed review of FSAR Tier 1, Table 2.2.4-3, the staff concluded that the ITAAC will adequately confirm EFWS and storage pool systems design capabilities, design features, and systems interfaces.

The staff also reviewed ITAAC requirements in FSAR Tier 1, Table 2.2.4-3 and FSAR Tier 2, Section 14.3. The staff finds the ITAAC acceptance criteria contained in FSAR Tier 1, Table 2.2.4-3 appropriate.

Technical Specifications: The staff reviewed the TS requirements for the EFWS (FSAR Tier 2, Chapter 16). In MODES 1, 2, and 3, the EFWS including the storage pools is required to be OPERABLE so that it will function in the event the MFW or the SSS are lost. In addition, the EFWS and storage pools are required to supply enough makeup water to replace the SG secondary inventory needed to achieve and maintain MODE 4 conditions. EFWS is addressed in proposed TS Section 3.7.5 and Bases 3.7.5. Similarly, EFW storage pools are addressed in proposed TS Section 3.7.6 and Bases 3.7.6. In MODE 5 or 6, the SGs are not normally used for heat removal, and the EFWS is not required.

The applicable EFWS LCO are provided in FSAR Tier 2, Section 16, LCO 3.7.5. Surveillance Requirements for the following parameters are provided: (1) Valve position confirmation; (2) Verify EFW pump suction and supply header isolation valves locked open; (3) Periodically cycle discharge header cross-connect valves; (4) IST of pumps; (5) Verification of automatic valve and pump actuation; and (6) Flow path verification from SP to SG.

The staff reviewed the LCO and the associated Bases for the storage pools and determined that they were not acceptable. The storage pool design function is to provide a water source to the EFW pumps. The applicable EFW storage pools’ LCO is provided in FSAR Tier 2, Chapter 16, LCO 3.7.6. The LCO includes two action levels for the following conditions:

One EFW SP inoperable (Immediately verify usable volume in three remaining pools ≥ 1.14 x 10^6 L (300,000 gal), and declare associated EFWS train inoperable). The staff determined that this was not acceptable because all the storage pool suction sources are aligned to a common header, so the inoperable storage pool is not associated with a specific EFWS train.

Two or more EFW storage pools inoperable, or usable volume in EFW storage pools < 1.14 x 10^6 L (300,000 gal) (Be in Mode 3 in 6 hours and Mode 4 in 24 hours without reliance on SGs for heat removal). The staff determined this to be not acceptable, because if there is not sufficient storage pool volume available in MODE 1, 2, or 3, the unit is in a seriously degraded condition with no safety-related means for conducting a cooldown. In such a condition, the unit should not be perturbed by any action, including a power change that might result in a trip. The seriousness of this condition should require action similar to what is required for EFWS LCO 3.7.5.D.1. That is, the OPERABLE status of the storage pool should be restored immediately.

Therefore, in RAI 83, Question 10.04.09-9, the staff requested that the applicant address the apparent inconsistency.

In an April 23, 2009, response to RAI 83, Question 10.04.09-9, the applicant stated as described in the response to RAI 83, Question 10.04.09-5, that the required EFW storage pool inventory has been increased to 1.38 x 10^6 L (365,000 gal). As a result, all four EFW storage pools are required to be operable. FSAR Tier 2, Chapter 16, TS, LCO 3.7.6, SR 3.7.6.1, and TS Bases 3.7.6 will be revised to include this increase in the EFW storage pool inventory. The applicant revised the Bases to discuss that the bounding BTP 5-4 natural circulation cooldown provides the basis for the required EFW storage pool inventory. The staff concurs that the EFW storage pool inventory has been increased to 1.38 x 10^6 L (365,000 gal), conforming to the discussion provided in the applicant's response to RAI 83, Question 10.04.09-5. The staff confirmed that Revision 1 of FSAR dated May 29, 2009, Tier 2, Chapter 16, TS, LCO 3.7.6, SR 3.7.6.1, and TS Bases 3.7.6 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-9 resolved.

SRs for the following parameters for the storage pools are provided: (1) Storage pool volume, and (2) EFW SP supply cross-connect valves locked open. Since locking open the cross tie valves removes the train independence, in RAI 83, Question 10.04.09-10, the staff requested that the applicant provide justification for locking open the storage pool cross tie valves.

In a December 29, 2008, response to RAI 83, Question 10.04.09-10, the applicant stated as follows: As described in the April 23, 2009, response to RAI 83, Question 10.04.09-1, the storage pool cross tie valves will be changed to normally closed manual valves. FSAR Tier 2, Chapter 16, TS SR 3.7.5, Bases 3.7.5, SR 3.7.6, and Bases 3.7.6 will be revised to reflect this new valve alignment. The staff concurs that the valve alignment for the storage pool cross tie valves will be normally closed, conforming to the discussion provided in the applicant's April 23, 2009, response to RAI 83, Question 10.04.09-01. The staff confirmed that Revision 1 of the FSAR dated May 29, 2009, Tier 2, Chapter 16, TS SR 3.7.5, Bases 3.7.5, SR 3.7.6 and Bases 3.7.6 was revised as committed in the RAI response. Accordingly, the staff finds that the applicant has adequately addressed this issue and, therefore, considers RAI 83, Question 10.04.09-10 resolved. Based on a detailed review of revised TS Sections 3.7.5 and 3.7.6, and Bases 3.7.5 and 3.7.6, the staff finds the EFWS and storage pools will be operated in accordance with their design bases.

Startup testing for the EFWS and storage pools is performed in accordance with FSAR Tier 2, Section 14.2, Test No. 020 and No. 021, respectively. The objective of the testing is to verify proper operation of the EFWS and SPs in accordance with FSAR Tier 2, Section 10.4.9. Testing of EFWS includes checks and data on pump head versus flow curves, pump endurance runs, valve positions on loss of motive power, and valve stroke times. Testing of the storage pool includes verifying design flow paths, verifying oxygen content in water, and verifying control logic. Other startup testing includes Test Abstract No. 146, No. 154, and No. 195. These tests include verifying operation of the EFWS when testing Integrated Engineered Safety Features/LOOP, Safe-shutdown, and MFW, SSS, and EFWS testing, respectively. Test Abstract No. 195 checks for water hammer noise. The staff reviewed the test abstracts and they address all of the important aspects of system operation. Accordingly, the staff concluded that the startup tests are sufficient to verify proper EFWS and storage pool operations.

When combined with the ITAAC testing of FSAR Tier 1, Table 2.2.4-3, the EFWS design requirements and operational performance will be adequately demonstrated.

10.4.9.5 *Combined License Information Items*

The following is a list of COL information items and descriptions from FSAR Tier 2, Table 1.8-2:

Table 10.4.9-1 U.S. EPR Combined License Information Items

Item No.	Description	FSAR Tier 2 Section
13.5-1	A COL applicant that references the U.S. EPR design certification will provide site-specific information for administrative, operating, emergency, maintenance and other operating procedures.	13.5

10.4.9.6 *Conclusions*

The staff finds that the review of the FSAR application supported that the EFWS functional design is acceptable for the reasons set forth above. The design meets the requirements of GDC 2, GDC 4, GDC 5, GDC 19, GDC 34, GDC 35, GDC 44, GDC 45, GDC 46, and GDC 60, ATWS requirements of 10CFR 50.62, SBO requirements of 10 CFR 50.63(a)(2), 10 CFR 20.1406, and the requirements of 10 CFR 52.47(b)(1) on ITAAC.

As set forth above, the staff finds that the ITAAC, TS, and COL information items specified in FSAR Table 1.8-2 ensure that site-specific information not provided in the FSAR is identified and addressed with respect to the EFWS, and that the EFWS can be properly inspected, tested, and operated in accordance with the FSAR.