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9 Auxiliary Systems

Korea Hydro and Nuclear Power Co. (KHNP) and Korea Electric Power Corporation (KEPCO) submitted a design control document (DCD) to the U.S. Nuclear Regulatory Commission (NRC or Commission) for design certification. This chapter describes the evaluation of the applicant's DCD analyses of the APR1400 responses to the auxiliary systems found in Chapter 9 of the APR1400 DCD, Revision 1, submitted on March 10, 2017.

9.1 Fuel Storage and Handling

9.1.1 Criticality Safety of Fresh and Spent Fuel Storage and Handling

9.1.1.1 Introduction

The staff reviewed DCD Tier 2, Section 9.1.1, Revision 1, "Criticality Safety of New and Spent Fuel Storage," and the associated technical report APR1400-Z-A-NR-14011, Revision 1, "Criticality Analysis of New and Spent Fuel Storage Racks," to ensure that subcriticality is maintained when storing and handling new and spent fuel in the onsite storage facilities. The new and spent fuel storage facilities are located within the fuel handling area of the auxiliary building which is a seismic Category I structure. The new fuel storage racks are installed in a dry new fuel storage pit. The spent fuel storage racks incorporate neutron absorber panels and are installed in a spent fuel pool (SFP) filled with borated water. The SFP consists of two regions; region I may be used to store fresh or spent fuel assemblies, while region II may only contain spent fuel assemblies meeting certain enrichment and burnup requirements.

To assess whether the new and spent fuel storage facilities maintain subcriticality for all credible storage conditions, the staff's review focused primarily on the inputs, assumptions, and methodology used in the applicant's criticality analysis and the acceptability of the analysis results. The staff also reviewed information related to criticality during fuel handling.

9.1.1.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Sections 2.7.4.1, "New Fuel Storage," and 2.7.4.2, "Spent Fuel Storage."

DCD Tier 2: The applicant provided a DCD Tier 2 system description in Section 9.1.1, "Criticality Safety of Fresh and Spent Fuel Storage and Handling." The applicant also referenced technical reports APR1400-Z-A-NR-14011, Revision 1; WCAP-17889, Revision 0, "Validation of SCALE 6.1.2 with 238-Group ENDF/B-VII.0 Cross Section Library for APR1400 Design Certification"; and APR1400-H-N-NR-14012, Revision 2, "Mechanical Analysis of New and Spent Fuel Storage Racks," in DCD Tier 2, Section 9.1.1 and Section 9.1.2, "New and Spent Fuel Storage." Safety Evaluation Report (SER) Section 9.1.2 provides the staff's evaluation of the content of APR1400-H-N-NR-14012. The information in DCD Tier 2 and these technical reports relevant to criticality safety of new and spent fuel storage is summarized as follows:

DCD Tier 2, Section 9.1.1 provides the design bases, descriptions, and safety analysis conclusions for new and spent fuel storage for the APR1400 design. The applicant stated that adequate design, mainly geometrically safe configurations, and administrative control procedures will prevent criticality in the new and spent fuel storage facilities.

The new fuel storage racks maintain criticality control through geometric spacing of fuel assemblies and moderator exclusion. According to technical report APR1400-H-N-NR-14012, the two 7x8 new fuel storage racks are fabricated from Type 304 stainless steel plates formed into tubes that rest upon Type 630 stainless steel support studs (support feet). The racks are bolted to the floor of the dry new fuel storage pit to prevent tipping or sliding. The racks can hold 112 new fuel assemblies, corresponding to one refueling batch plus additional margin assuming an 18-month refueling cycle.

The high-density spent fuel storage racks maintain criticality control through a combination of chemical additions of boron to the SFP water, the use of Metamic™ neutron absorbing material, and geometric spacing of fuel assemblies. The spent fuel storage racks are freestanding with feet that rest on embedments in the SFP floor, allowing the racks to slide. The spent fuel storage racks are fabricated from the same types of stainless steel as the new fuel storage racks. The Metamic™ neutron absorbing material is inserted into stainless steel sheaths welded to the sides of the fuel assembly tubes to ensure the neutron absorber covers the length of the active fuel. The overall capacity of the spent fuel storage racks is 1,792 fuel assemblies.

The SFP is divided into two regions, region I and region II. Region I is designed to store either new or spent fuel assemblies with a maximum initial enrichment of 5.0 weight percent (wt%) U-235 as well as damaged fuel. Region I has a storage capacity for one full core, one refueling batch, and five damaged fuel assemblies. The region I racks incorporate Metamic™ material on all sides of the fuel assembly tubes and a “flux trap” between fuel assemblies, which increases both neutron leakage and the effectiveness of the Metamic™ material. Spacer bars, as shown in DCD Tier 2, Figure 9.1.2-2A, “Spent Fuel Storage Rack Region I,” ensure uniform spacing between fuel assemblies.

Only fuel that meets specified burnup and enrichment requirements may be stored in region II, which is capable of holding twenty years’ worth of spent fuel assemblies assuming an 18-month cycle. The region II racks are similar to the region I racks except that the region II racks do not have spacer bars separating fuel assembly tubes, and the fuel assembly tubes in the region II racks are arranged in a checkerboard pattern. The checkerboard pattern creates a gap between fuel assembly tubes into which a spent fuel assembly may be inserted. This loading pattern results in one Metamic™ neutron absorber plate between adjacent spent fuel assemblies compared to two in the region I racks.

DCD Tier 2, Section 9.1.2 describes the applicant’s neutron absorber monitoring program. Fourteen coupons will be placed into the spent fuel racks adjacent to freshly discharged fuel assemblies. A COL licensee referencing the APR1400 DCD shall remove coupons in accordance with DCD Tier 2, Table 9.1.2-2, “Recommended Coupon Measurement Schedule.” The following aspects of the Metamic™ coupons will be inspected to determine if an active degradation mechanism for this material exists in the SFP:

- Visual examination of the coupon surface including taking photographs;
- Neutron attenuation testing;
- Dimensional measurements (length, width, and thickness); and
- Weight and specific gravity.

Technical report APR1400-Z-A-NR-14011 documents the detailed criticality analyses. The technical report describes the applicant's analytical and uncertainty methodology, analysis assumptions, and analysis results. The applicant used the CSAS5 and TRITON sequences of the SCALE 6.1.2 computer code with the ENDF/B-VII 238-group cross section library for the criticality and fuel depletion calculations, respectively. As described in WCAP-17889, the applicant used critical experiment data to validate the code following the guidance in NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology." The applicant credited fuel reactivity reduction due to fuel depletion and buildup of fission products (burnup credit) for 28 isotopes in the criticality analysis for the region II spent fuel storage racks and credited soluble pool boron for postulated accident scenarios.

Chapter 2 of APR1400-Z-A-NR-14011 presents the criticality analysis of the new fuel storage racks, including design input data, layout drawings, calculation assumptions and methodology, and results; Chapter 3 presents this information for the spent fuel storage racks. Chapter 3 also provides a minimum burnup versus initial fuel enrichment curve for the region II spent fuel storage racks. Chapter 4 of APR1400-Z-A-NR-14011 describes and presents the results for accident analyses in the spent fuel storage racks. According to the applicant, the criticality analyses demonstrate that the new and spent fuel storage racks comply with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Section 50.68(b) and General Design Criterion (GDC) 62, "Prevention of criticality in fuel storage and handling."

ITAAC: The inspections, tests, analyses, and acceptance criteria (ITAAC) associated with DCD Tier 2, Section 9.1.1 are given in DCD Tier 1, Section 2.7.4, "New and Spent Fuel Handling System," Sections 2.7.4.1 and 2.7.4.2.

Technical Specifications: The Technical Specifications (TS) associated with DCD Tier 2, Section 9.1.1 are given in DCD Tier 2, Chapter 16, "Technical Specifications," Sections 3.7.15, "Spent Fuel Pool Boron Concentration," 3.7.16, "Spent Fuel Assembly Storage," and 4.3, "Fuel Storage."

9.1.1.3 Regulatory Basis

The relevant requirements for the Commission regulations for criticality safety of fresh and spent fuel storage and handling, and the associated acceptance criteria, are identified in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [light water reactor] Edition" (SRP), Section 9.1.1, "Criticality Safety of Fresh and Spent Fuel Storage and Handling," and are summarized below. Review interfaces with other SRP sections can be found in NUREG-0800, Section 9.1.1. The requirements governing ITAAC related to new and spent fuel storage and handling are provided in NUREG-0800, Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria."

1. GDC 62, "Prevention of criticality in fuel storage and handling," as it relates to the prevention of criticality by physical systems or processes, preferably by using geometrically safe configurations.

2. 10 CFR 50.68, "Criticality accident requirements," as it relates to preventing a criticality accident and to mitigating the radiological consequences of a criticality accident.

In addition, 10 CFR 52.47, "Contents of applications; technical information," Item (a)(17) requires the application to provide information demonstrating how the applicant will comply with the requirements for criticality accidents in 10 CFR 50.68(b)(2) – (b)(4).

The related acceptance criteria are as follows:

1. The criteria for GDC 62 are specified in American National Standards Institute (ANSI)/American Nuclear Society (ANS) 57.1, "Design Requirements for Light Water Reactor Fuel Handling Systems," ANSI/ANS 57.2, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants," and ANSI/ANS 57.3, "Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants," as they relate to the prevention of criticality accidents in fuel storage and handling.

2. Compliance with 10 CFR 50.68 requires that the licensee either maintain monitoring systems capable of detecting a criticality accident as described in 10 CFR 70.24, "Criticality accident requirements," thereby reducing the consequences of a criticality accident, or comply with the requirements specified in 10 CFR 50.68(b), thereby reducing the likelihood that a criticality accident will occur.

9.1.1.4 Technical Evaluation

The staff reviewed DCD Tier 2, Section 9.1.1 and technical report APR1400-Z-A-NR-14011 in accordance with NUREG-0800, Section 9.1.1 to ensure compliance with the regulatory requirements listed in Section 9.1.1.3 of this report. The staff evaluated key aspects of the applicant's criticality analysis, including the fuel assembly and storage rack design data, computational methods and data, validation of the computational method, the uncertainty analysis, assumptions such as depletion parameters, the assumed normal and accident conditions, fuel handling considerations, and the analysis conclusions. The staff also reviewed the effectiveness of the neutron absorbing materials in the spent fuel racks.

In addition to requests for additional information (RAIs) addressing specific technical issues related to the criticality safety of the new and spent fuel storage racks, discussed in detail below, the staff prepared several editorial RAIs to clarify certain descriptive statements made by the applicant. This technical evaluation does not discuss these editorial RAIs because they do not alter the substantive technical information provided by the applicant.

In its review of the Tier 1 information and ITAAC identified in Section 9.1.1.2 of this report, the staff noted that the design descriptions in DCD Tier 1, Revision 0, Sections 2.7.4.1 and 2.7.4.2 did not adequately describe the design features that will ensure the as-built systems for new and spent fuel storage and handling will comply with GDC 62 and 10 CFR 50.68(b) in a manner that is fully consistent with the information in the design certification. In addition, the new and spent fuel storage ITAAC in DCD Tier 1, Revision 0, lacked the clarity and completeness desired for the ITAAC closure process per the established guidance on ITAAC in RIS 2008-05, Revision 1, "Lessons Learned to Improve Inspections, Tests, Analyses, and Acceptance Criteria Submittal." Therefore, the staff issued RAI 179-8190 (ML15245A819), Question 09.01.01-18, dated September 1, 2015, and follow-up RAI 454-8561 (ML16090A121), Question 09.01.01-35, dated March 30, 2016.

The applicant's August 16, 2016, response (ML16229A351) included a markup of the Tier 1 information in Sections 2.7.4.1 and 2.7.4.2. The markup provided enhanced design descriptions that capture the essential design details of the new and spent fuel storage facilities, such as features that maintain the necessary water level in the SFP. In addition, the markup of the ITAAC included several revisions that increase its clarity and completeness, including identification of the criticality limits as those in 10 CFR 50.68 and the use of an as-built inspection to verify that the as-built dimensions and materials and their tolerances are consistent with values used in the criticality and structural analysis reports to ensure 10 CFR 50.68 is met, rather than relying on an analysis. The staff concludes the response is acceptable because it addresses each of the staff's concerns related to clarity and completeness, consistent with the guidance in RIS 2008-05, Revision 1. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD, so RAI 454-8561, Question 09.01.01-35 is resolved and closed.

With the closure of that RAI, the staff finds the Tier 1 information related to new and spent fuel storage criticality 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 Atomic Energy Act (AEA) of 1954, as amended, and the NRC's regulations.

The staff notes that the TS identified in Section 9.1.1.2 of this report cover the necessary areas with respect to criticality safety and are generally consistent with the design information related to DCD Tier 2, Section 9.1.1, which the staff finds acceptable with respect to the applicant's criticality safety analysis. Chapter 16 of this report contains the detailed review of the TS.

9.1.1.4.1 Fuel Assembly Modeling

The staff reviewed the fuel assembly parameters and information in APR1400-Z-A-NR-14011 to ensure completeness and conservatism regarding all fuel designs to be stored. The staff finds that the fuel assembly parameters are consistent with the design information for PLUS7 fuel. In addition, the fuel assembly parameters are generally consistent with expected values based on the current operating fleet. Because the design certification application intends to support potential new construction, consideration of legacy fuel designs is not necessary.

The new fuel storage rack criticality analysis assumes 5.0 wt% U-235 enrichment in all fuel rods without zoning of enrichment, burnable poison, or axial blankets. This is acceptable to the staff because it maximizes reactivity. The same assumptions and enrichment are used for the region I spent fuel storage racks, which hold new or spent fuel. Because new fuel is more reactive than spent fuel, it is conservative and bounding to perform the region I criticality analysis assuming all new fuel.

The applicant credited burnup for the region II spent fuel storage racks. The depletion and criticality calculations consider a range of fuel enrichments that bounds the actual fuel rod enrichments presented in DCD Tier 2, Section 4.3, "Nuclear Design." The applicant assumed no axial blankets or burnable poison for the region II depletion and criticality analyses. Neglecting axial blankets is acceptable since lower enrichment should yield lower reactivity. The applicant demonstrated this to be true for the region II racks by calculating the effective neutron multiplication factor (k_{eff}) for non-blanketed fuel to be equal to or greater than blanketed fuel. It is also acceptable to ignore burnable absorber rods based on the results of a computational study that Oak Ridge National Laboratory (ORNL) performed for Combustion

Engineering (CE) fuel of similar design and loading to PLUS7 fuel in NUREG/CR-6760, "Study of the Effect of Integrable Burnable Absorbers for PWR [pressurized water reactor] Burnup Credit."

The staff finds that the applicant used appropriate fuel assembly design data that conservatively consider all possible PLUS7 fuel assembly types in the new and spent fuel storage rack criticality analyses.

9.1.1.4.2 Storage Rack Modeling

The staff reviewed the design inputs and material compositions for the new fuel storage racks in Tables 2.1-1 and 2.1-2 of APR1400-Z-A-NR-14011 as well as layout drawings to ensure the information is complete and conservatively incorporated into the criticality analysis. The staff also examined drawings of the new fuel storage rack criticality model in Figures 2.1-1 and 2.1-2 of APR1400-Z-A-NR-14011 and a drawing of the new fuel storage racks in DCD Tier 2, Figure 9.1.2-1, "New Fuel Storage Racks." The staff noted that the criticality model assumes a significantly smaller space between the bottom of active fuel and the concrete floor of the new fuel storage pit than shown in DCD Tier 2, Figure 9.1.2-1. Therefore, on September 1, 2015, staff issued RAI 179-8190, Question 09.01.01-24, requesting the applicant to perform an analysis to assess the limiting k_{eff} for the modeled versus actual elevation of the racks in the new fuel storage pit and provide conclusions on the conservatism of the modeling assumption.

On December 10, 2015, the applicant provided a response to RAI 179-8190, Question 09.01.01-24 (ML15344A136). The applicant compared the k_{eff} of the modeled separation distance (15 cm) to that for the actual distance shown in DCD Tier 2, Figure 9.1.2-1 (34.4 cm) for both the optimum moderation and full density flooding conditions. The larger distance caused a small reduction in k_{eff} for optimum moderation, which the applicant noted was conservative, and a very small increase for full density. The applicant determined the increase to be negligible and that the modeled separation distance is appropriate. The staff notes that the increase in k_{eff} is a fraction of the calculation uncertainty and is therefore negligible. As a result, the staff finds the response to RAI 179-8190, Question 09.01.01-24, acceptable, so that question is resolved and closed.

In addition, the staff observed that the new fuel storage rack layout is such that spaces between the fuel racks and between the racks and pit walls are large enough to fit one or more new fuel assemblies. This is contrary to the guidance in SRP Section 9.1.1, which states that the designs should be such that a fuel assembly can only be inserted in the design locations (storage tubes) in the racks. As a result, on September 1, 2015, staff issued RAI 179-8190, Question 09.01.01-21, requesting the applicant to provide information showing that the design is such that a fuel assembly can only be inserted in the design locations in the new fuel racks or to justify the acceptability of the current design.

On May 23, 2016, the applicant provided a response to RAI 179-8190, Question 09.01.01-21 (ML16144A814). The applicant performed two additional criticality analyses that modeled the insertion of a fresh fuel assembly between the new fuel storage racks: one in which the assembly was outside of but touching a rack and one in which the assembly was centered between the racks. For both cases, the applicant demonstrated that k_{eff} was slightly greater than that of the normal dry storage condition that it also analyzed. The k_{eff} of the more limiting case (the case with the centered assembly) including bias and uncertainty was well below the regulatory limits for the abnormal conditions of flooding by full-density water and water at

optimum-moderation conditions (0.95 and 0.98, respectively). The applicant also proposed to include the analysis in APR1400-Z-A-NR-14011 per an attached markup.

The staff notes that no additional accident scenarios need be considered concurrently with the misplaced assembly per the double-contingency principle discussed in the NRC memorandum from L. Kopp to T. Collins, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants," dated August 19, 1998 (ML11088A013).

The staff finds the response to RAI 179-8190, Question 09.01.01-21 acceptable because the applicant demonstrated that the placement of a fresh fuel assembly in a space outside of the new fuel storage racks would not present a criticality safety concern. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of APR1400-Z-A-NR-14011, so RAI 179-8190, Question 09.01.01-21 is resolved and closed.

The staff reviewed the drawings of the actual and modeled spent fuel storage racks in APR1400-Z-A-NR-14011 and notes that these drawings clearly show the rack dimensions, configurations in the SFP, and placement of neutron absorber panels. In addition, the staff reviewed the design inputs for regions I and II of the spent fuel storage racks in Tables 3.1-1 and 3.1-2 of APR1400-Z-A-NR-14011, respectively. Of particular note are the rack cell pitch (27.5 cm for region I and 22.5 cm for region II) and neutron absorber boron-10 (^{10}B) areal density, the adequacy of which is determined by the criticality analyses. As stated in DCD Tier 2, Section 9.1.1, the criticality analyses credit only 75 percent of the design ^{10}B areal density to provide safety margin.

In addition, Revision 0 of APR1400-Z-A-NR-14011 stated that the modeled neutron absorber plates in the spent fuel storage racks are assumed to have the maximum thickness allowed by tolerances. The staff noted that this may be non-conservative due to the lost neutron moderating effects of the water displaced by thicker plates. On August 20, 2015, staff issued RAI 167-8191 (ML15233A611), Question 09.01.01-4, asking the applicant to correctly characterize the absorber plate thickness modeling assumption and revise the assumption as appropriate to avoid non-conservatism.

On April 22, 2016, the applicant provided a response to RAI 167-8191, Question 09.01.01-4 (ML16113A445) that explained that the design values for the neutron absorber plate thickness, width, and length in APR1400-Z-A-NR-14011, Revision 0, Tables 3.1-1 and 3.1-2 are not consistent with actual design values and committed to revise the tables. In addition, the applicant committed to revise the neutron absorber plate assumption in the criticality analysis to use the nominal dimensions and capture the effect of the thickness and width tolerances as uncertainty in k_{eff}. The applicant did not consider length in the uncertainty evaluation because the nominal neutron absorber length is greater than the assumed length in the criticality analysis. The applicant attached a markup of APR1400-Z-A-NR-14011 in its response, which incorporated the revised assumptions, presented revised uncertainty results, and applied the revised uncertainty to the existing spent fuel storage rack criticality analyses. The staff notes that, due to the design value error, the applicant's criticality analyses in APR1400-Z-A-NR-14011 already used the nominal values for neutron absorber width and thickness. Therefore, the applicant did not have to recalculate base k_{eff} values for the spent fuel storage racks. The applicant also included a markup of the burnup loading curve in TS 3.7.16.

The staff finds the applicant's approach of incorporating tolerances in the neutron absorber plate thickness and width into the uncertainty analysis acceptable because it corrects the applicant's

previous non-conservative assumption. The applicant does not need to consider length as a tolerance because the existing length assumption is conservative. In addition, the staff finds the tolerances the applicant used and the resulting analysis revisions acceptable. For these reasons, the staff determines that the response to RAI 167-8191, Question 09.01.01-4 is acceptable. In addition, the staff confirmed the revisions in the response are incorporated into APR1400-Z-A-NR-14011, Revision 1. However, a revision to the burnup loading curve in TS 3.7.16 is required, so RAI 167-8191, Question 09.01.01-4 is being tracked as a **Confirmatory Item**.

The staff notes that the information provided in the DCD and APR1400-Z-A-NR-14011 related to the new and spent fuel storage rack designs, characteristics, and dimensions is similar to that for currently operating plants. Furthermore, contingent upon closure of the confirmatory item identified above, the staff finds that the applicant adequately incorporated the rack design information into the new and spent fuel storage rack criticality analyses.

9.1.1.4.3 Storage Rack Materials

Generic Aspects of the New and Spent Fuel Storage Racks

The new and spent fuel racks are fabricated from Type 304 and Type 630 stainless steel. Both stainless steel types have extensive operational history in SFP and reactor environments. The applicant utilized computer codes that appropriately model the neutronic behavior of Type 304 stainless steel, and, as further discussed in Section 9.1.1.4.4 of this report, the staff finds the use of these codes acceptable. The Type 630 stainless steel support pedestals have no impact on the criticality evaluation because the pedestals are located below the active fuel region of the new and spent fuel racks.

The staff reviewed the applicant’s proposed American Society of Mechanical Engineers (ASME) material specifications (including the standard manufacturing tolerances) and determined that the criticality evaluation adequately captures uncertainty of an as-built design.

The fuel assembly tubes of the new fuel rack have supports at the top, bottom, and middle of the tubes. The large spacing between each support point facilitates the need for straight fuel assembly tubes to comply with the geometric spacing in technical report APR1400-Z-A-NR-14011. The applicant has chosen to integrate the form tolerance of the fuel assembly tubes (which includes straightness) into the cell pitch tolerance. The use of the cell pitch tolerance to account for fabrication tolerances is acceptable because localized bow in the fuel tube can be accurately and conservatively modeled as a decrease in the cell pitch. The region I and region II spent fuel racks do not need to account for straightness of the fuel tubes because the region I spent fuel racks utilize multiple spacer bars that ensure consistent spacing between fuel tubes, and the region II racks utilize a common wall between fuel assemblies. The staff concludes that the new and spent fuel storage rack tolerances in technical report APR1400-Z-A-NR-14011 are consistent with the manufacturing and fabrication tolerances expected during construction.

The staff reviewed the quality assurance requirements associated with the fabrication of the new and spent fuel racks. The applicant commits to conforming to the ASME NQA-1, “Quality Assurance Requirements for Nuclear Facility Applications,” quality assurance standard during fabrication, including the requirements of Subpart 2.1, Cleanness Class C. The staff previously endorsed ASME NQA-1 in RG 1.28, “Quality Assurance Program Criteria (Design and Construction).” The staff concludes that ASME NQA-1 provides sufficient quality assurance

controls for the new and spent fuel racks, and ASME NQA-1, Subpart 2.1 contains sufficient requirements to prevent contamination of the Metamic™ and stainless steel materials.

Because the new fuel racks control criticality by geometric spacing and do not use any material other than stainless steel, the staff concludes that the materials selected for the new fuel racks are acceptable. The material selection and fabrication controls are sufficient to prevent degradation of the new fuel racks in all normal, off-normal, and accident conditions.

The spent fuel racks are similar to the new fuel racks but have two important and unique design aspects: the spent fuel racks incorporate the Metamic™ neutron absorber and are submerged in the spent fuel pool. As discussed in SER Section 9.1.2, the Metamic™ and the chemistry of the spent fuel pool do not have a deleterious effect on the stainless steel. Contact between the Metamic™ and stainless steel materials will not degrade the stainless steel material because the stainless steel is more "noble" than the aluminum matrix of Metamic™. Corrosion of stainless steel is prevented by controlling the chemistry of the spent fuel pool water, as described in SER Section 9.1.3. The staff finds the use of stainless steel in the spent fuel racks acceptable. The material selection and fabrication controls are sufficient to prevent degradation of the stainless steel in the spent fuel racks in all normal, off-normal, and accident conditions.

For the spent fuel rack design, the neutron absorbing material is secured to the side of the fuel tubes by encapsulating the neutron absorber in stainless steel sheaths and intermittently welding the sheaths to the sides of the fuel assembly tubes. This design allows water and hydrogen (formed by the oxidation of aluminum in the neutron absorber) to flow out of the sheath. The migration of hydrogen into the spent fuel pool water prevents the formation of a gas bubble within the sheath, which can lead to "pinning" of a fuel assembly. This design feature is acceptable because it is consistent with lessons learned from the use of Boral in spent fuel pool racks and has been found sufficient to prevent (and mitigate) "pinning" of fuel assemblies.

Neutron Absorber Material

As discussed below, the staff reviewed the Metamic™ neutron absorbing material to determine if the fabrication, qualification, monitoring, and modeling of the material is adequate. The staff also reviewed the applicant's use of lessons learned from Boral and Boraflex degradation in the design of the spent fuel racks.

Neutron Absorber Material – Fabrication & Licensing Basis

The applicant utilizes the Metamic™ neutron absorbing material for criticality control. Metamic™ is an aluminum and boron carbide (B_4C) metal-matrix-composite with over 10 years of operating experience in SFPs in the United States. This staff accepts the use of Metamic™ provided that: 1) the critical characteristics (the characteristics associated with how the material is used in the licensing basis) are defined and that qualification testing is conducted to validate the critical characteristics and to ensure that the critical characteristics will be maintained during normal, off-normal, and accident conditions, 2) fabrication limitations associated with the critical characteristics are defined, and 3) the material is monitored to ensure that the critical characteristics are maintained during lifetime of the component.

Holtec (the manufacturer of Metamic™) has already defined the critical characteristics of Metamic™, has performed qualification testing of the material, and has defined fabrication

limitations associated with the critical characteristics. The critical functions for Metamic™ in the APR1400 DCD are neutron absorption and corrosion resistance. Qualification testing for Metamic™ has already been conducted and is described in Holtec Report HI-2043215, "Sourcebook for Metamic Performance Assessment" (Proprietary). Report HI-2043215 has been submitted on several dockets (ML051400333 and ML11364A043). The staff has previously reviewed Report HI-2043215 and found that the qualification report adequately defines and describes the uniformity of ^{10}B in Metamic™ and demonstrates that Metamic™ does not degrade in borated or demineralized water (ML053070593 and ML12181A019). The qualification testing of Metamic™ bounds the Metamic™ material described in technical report APR1400-Z-A-NR-14011. The Metamic™ material described in technical report APR1400-Z-A-NR-14011 contains less B_4C than has been previously approved by the staff (ML13056A514). The staff concludes that the use of Metamic™ described by the applicant is acceptable based upon the applicability and precedence of previous reviews.

In DCD Tier 2, Section 9.1.2.4, "Inspection and Testing Requirements," the applicant states that the principal manufacturing parameters for the neutron absorber are (1) B_4C wt% in the mixture, (2) panel thickness, (3) material density, and (4) ^{10}B areal density. The staff agrees that the manufacturing parameters described by the applicant are the primary variables from which the critical functions of Metamic™ are derived. The applicant also commits to manufacturing Metamic™ in accordance with the Holtec quality assurance program (QAP). In previous interactions with 10 CFR Part 50 licensees, the staff has reviewed the Holtec QAP and concluded that the program ensures that the neutron absorber is manufactured as a high-quality, high-assurance product that is fit for use in a nuclear power plant and that the QAP is compliant with 10 CFR Part 50 Appendix B.

Based upon the provided information, the staff concludes that the controls on manufacturing Metamic™ and the applicant's commitment to use the Holtec QAP provide reasonable assurance that the as-fabricated Metamic™ material will meet the licensing basis described in the DCD Tier 2 and the technical basis described in the material qualification program.

The applicant provided the fabrication sequence for the fuel racks in DCD Tier 2, Section 9.1. Additional details of the fabrication of the fuel racks are docketed in the applicant's supplemental letter dated November 13, 2015 (ML15317A521). The staff reviewed the description of the fabrication sequence to determine if the processes could damage the neutron absorbing material or could introduce a new deterioration mechanism.

On January 11, 2016, the staff issued RAI 364-8421, Question 09.01.01-30, regarding the impact of heat (from welding) on the critical characteristics of the Metamic™ material. In its response to RAI 364-8421, Question 09.01.01-30 dated March 9, 2016 (ML16069A344), the applicant cited Electric Power Research Institute (EPRI) report 1003137, "Qualification of Metamic for Spent Fuel Storage Applications," as evidence that Metamic™ can be exposed to temperatures up to 900 degrees Fahrenheit (°F) without impacting its functional performance. EPRI report 1003137 was previously submitted to the staff and was found acceptable (ML060900250). The applicant also provided data from a welding mockup intended to demonstrate that the Metamic™ would remain below 900°F during the fabrication process.

On April 22, 2016, the staff issued RAI 469-8578 (ML16113A217), Question 09.01.01-38, in which the staff pointed out several flaws in the mockup design significant enough for the staff to conclude that the results from the applicant's mockup testing did not provide a basis for staff approval. However, the staff did conclude that the approach provided by the applicant (using a

mockup to assess the welding temperatures and requiring adherence to welding process parameters used for the mockup) was acceptable because the acceptance criteria of the weld mockup appropriately bound the welding process to ensure that the neutron absorber remains bounded by the material qualification and material characterization testing.

To address the RAI, the applicant added COL 9.1(1) to DCD Tier 2, which requires a COL applicant to qualify a welding procedure for the neutron absorber sheath in accordance with the aforementioned weld mockup approach. The staff accepts the use of a COL information item in response to the RAIs because the COL information item adequately describes the “welding envelope” that will ensure the welding processes will not impact the functional capability of the Metamic™ material. The staff endorses the use of a COL information item to resolve this RAI because describing welding parameters in the DCD would not be consistent with lessons learned from construction of 10 CFR Part 52 plants.

Based on the above evaluation, the staff concludes that the fabrication sequence for the new and spent fuel racks is sufficiently controlled to minimize the potential for damaging the neutron absorber material. Furthermore, the staff concludes that the applicant’s controls on the manufacturing of the Metamic™ material and the fabrication of the spent fuel rack provide reasonable assurance that the neutron absorbing material will meet the credited safety functions.

Neutron Absorber Material – Monitoring Program

Operational experience from Boral and Boraflex has shown that a neutron absorber monitoring program is necessary to ensure that the spent fuel racks continue to meet GDC 62. A coupon monitoring program must provide the ability to assess if the neutron absorbing element (^{10}B) is being lost and if the neutron absorber is experiencing dimensional changes.

The staff reviewed the coupon examination schedule and found it to be consistent with previously accepted coupon monitoring programs. The quantity of coupons is sufficient for the 40-year licensing period of the APR1400, and spare coupons are provided in the unlikely event of accidental damage. The applicant states that the neutron absorber coupons will be provided in the as-fabricated condition from the same production run as the full-size plates. Welding near the neutron absorber would not have an effect on corrosion resistance or neutron absorption of the material. The Metamic™ material qualification included exposing Metamic™ to a 900°F environment for 48 hours and examining the cooled material for changes in material properties. The qualification test demonstrated that the 48 hours in a 900°F environment resulted in no change in areal density, product weight, or dimensions. Additionally, the typical manufacturing process for aluminum-boron carbide composites includes sintering the material at temperatures higher than 1000°F. For these reasons, the staff concludes that the coupons used for the monitoring program are an accurate analog of the larger plates in the spent fuel rack.

The applicant describes the coupon monitoring program in DCD Tier 2, including (1) the parameters to be inspected, (2) the acceptance criteria for the inspections, and (3) the actions to be taken if the inspected parameters do not meet the acceptance criteria. The coupon inspections allow a COL applicant to detect a reduction in neutron attenuation (due to loss of ^{10}B or the existence of an air bubble, which could decrease neutron moderation) or corrosion. The staff finds that the coupon inspection parameters are sufficient to ensure that the credited design functions are continuously monitored during the lifetime of the plant.

The staff reviewed the acceptance criteria for the coupon monitoring program to determine if the minimum and maximum acceptable values would result in continued compliance with the licensing basis. The staff examined the thickness of the stainless steel components, the tolerances on those components, and the permitted changes to the neutron absorber in the coupon monitoring program and calculated that: 1) a fuel assembly would not become "pinned" between two adjacent sheaths, and 2) the designed gap between the fuel assembly and the sheath walls provides significant margin that is much larger than the thickness change permitted by the monitoring program. In addition, the staff notes that if the ^{10}B areal density of the neutron absorber were reduced to the minimum value allowed by the coupon monitoring program, the neutron absorber would still have sufficient ^{10}B density because the applicant only credited 75 percent of the ^{10}B within the material. The staff finds the margin sufficiently large to compensate for uniformity uncertainties and the ^{10}B loss associated with the coupon monitoring program. In addition, the staff concludes that examinations for visual appearance, weight, and specific gravity are sufficient to initiate an engineering evaluation if evidence of degradation is found. Photography of the coupons allows for changes in appearance of the material to be tracked throughout the lifetime of the spent fuel rack.

The staff concludes that the neutron absorber monitoring program is consistent with programs at operating nuclear power plants and is sufficient to detect, track, and trend changes to the Metamic™ material that could indicate an active degradation mechanism. Therefore, the staff finds the applicant's monitoring program to be acceptable.

Storage Rack Materials - Conclusions

The staff has reviewed the applicant's selection of materials for the new and spent fuel racks of the APR1400 nuclear power plant and concludes that the information contained in the DCD meets the acceptance criteria of the SRP. The staff concludes that the material selection is consistent with new and spent fuel racks that meet GDC 62 and 10 CFR 50.68.

9.1.1.4.4 Computational Methods and Data

The applicant used the CSAS5 and TRITON modules in SCALE Version 6.1.2 with the ENDF/B-VII 238-group cross section library to perform its criticality and depletion calculations. The CSAS5 module uses the KENO-V.a Monte Carlo solution method to determine k_{eff} in the fuel storage racks. The TRITON module provides a two-dimensional transport theory-based lattice depletion analysis methodology that couples depletion calculations from the ORIGEN-ARP sequence and the two-dimensional discrete ordinates code NEWT to determine the fuel assembly isotopic number densities as a function of initial enrichment, burnup, cooling time, and other reactor operating parameters. For the region II spent fuel storage racks, the CSAS5 sequence uses the isotopic content determined from the TRITON calculation.

With funding from the NRC, Oak Ridge National Laboratory (ORNL) developed the SCALE code package. The staff finds that the use of SCALE to demonstrate compliance with the regulatory criteria outlined in SRP Section 9.1.1 is within the code's intended applications and is similar to the confirmatory analysis methods used by the staff as well as analysis methods for other licensing applications, including fuel storage criticality analyses. In addition, the staff finds the cross section library and other input data for the SCALE analyses appropriate and acceptable.

9.1.1.4.5 Computational Method Validation

The purpose of validating the computational methods is to determine the bias and bias uncertainty for the codes used in the safety analysis to conservatively adjust the calculated k_{eff}. The applicant described its validation of the CSAS5 module of SCALE 6.1.2 for use in APR1400 analyses in DCD Tier 2, Section 9.1.1, and APR1400-Z-A-NR-14011, and the validation is documented in detail in WCAP-17889.

The applicant stated that the validation methodology follows the guidance provided in NUREG/CR-6698. The benchmark experiments used for the validation are from the International Handbook of Evaluated Criticality Safety Benchmark Experiments (ICSBEP Handbook); NUREG/CR-6361, “Criticality Benchmark Guide for LWR Fuel in Transportation and Storage Packages”; and HTC critical experiments described in NUREG/CR-6979, “Evaluation of the French Haut Taux de Combustion (HTC) Critical Experiment Data.” Most of the experiments are from the ICSBEP Handbook, which the staff finds contains some of the most complete experimental data available that is applicable to the APR1400. The staff also notes that the experiments in NUREG/CR-6361 are intended for use in benchmarking for LWR fuel applications. The HTC experiments used mixed oxide (MOX) fuel with a composition designed to mimic burned PWR fuel with an initial enrichment of 4.5 wt% U-235 and are therefore applicable for burnup credit applications. Thus, the staff finds the sources of experiments appropriate for the APR1400 code validation.

Technical report WCAP-17889 describes the groupings of experiments the applicant chose for the validation: fresh fuel with no absorbers, fresh fuel with absorbers, and fresh fuel and HTC experiments with absorbers. These sets reflect the conditions in the new fuel storage racks, the region I spent fuel storage racks, and the region II racks, respectively. The staff reviewed the experiments and found them to be similar and applicable to the criticality analyses for the APR1400 design. For instance, the cases from the ICSBEP Handbook and NUREG/CR-6361 include fresh uranium dioxide (UO_2) fuel of rectangular pitch enriched to 2.35-4.738 wt% and incorporate soluble boron or boron poison plates in some cases, and the HTC experiments contain simulated burned fuel.

During an audit of the calculation note supporting WCAP-17889 (see staff audit report at ML17230A260), the staff discovered that seven experiments without absorbers were categorized in the “with absorbers” categories, which could impact the bias and bias uncertainty values for the spent fuel pool. Through audit discussions, the staff learned that six of those seven experiments were included in the “with absorbers” categories because they incorporate concrete as a reflecting material. The staff recognizes the value of including these six experiments in the “with absorbers” (SFP) categories to account for the impact of concrete, which is present in some of the SFP models. The remaining case is still categorized incorrectly, but the staff confirmed the impact on the bias and bias uncertainty from that single case would be negligible by examining the calculated k_{eff} values and uncertainties for the validation suite. Ultimately, the audit of the calculation note upheld the bias and bias uncertainty values in WCAP-17889, and the staff has reasonable assurance that the applicant’s doubling of the code bias and bias uncertainty covers any impacts from experiment categorization.

Based on the experiments chosen for the validation, the staff finds that the area of applicability (AOA) of the validation in both WCAP-17889 and Table 3.4-3 of APR1400-Z-A-NR-14011 has been adequately determined.

WCAP-17889 details the statistical analyses performed to calculate a best-estimate bias and bias uncertainty for each of the three groupings of experiments. It also includes trend analyses of calculated k_{eff} against several parameters in the AOA. If the trend analysis indicates a dependency of k_{eff} on a trending parameter, the more limiting of the best-estimate and the trended bias and bias uncertainty is applied to the criticality analysis. The staff finds this approach conservative.

However, the staff noted that the applicant did not consider plutonium content or plutonium fission fraction in its trending parameters, and therefore, the applicant's determination of code bias and bias uncertainty may be non-conservative with regards to plutonium effects. On August 20, 2015, the staff issued RAI 167-8191, Question 09.01.01-12, requesting the applicant to perform a trending analysis against plutonium content and/or computed plutonium fission fraction and to revise the code validation report should the analysis indicate that more conservative bias and bias uncertainty adjustments would result.

On December 17, 2015, the applicant provided a response to RAI 167-8191, Question 09.01.01-12 (ML15351A342). The applicant explained that additional plutonium-containing MOX benchmarks were outside of the AOA guidelines in Table 2.3 of NUREG/CR-6698 considering expected values for the APR1400, so it did not use them. In addition, the applicant noted that other conservatisms in the analysis outweigh potential impacts of not considering additional MOX experiments.

Although inclusion of additional MOX experiments would allow the applicant to trend against plutonium content, the staff notes that the additional experiments would be outside the allowed experiment range for fuel isotopic composition for the APR1400 per the guidance in NUREG/CR-6698. The staff also notes that the applicant doubled the code bias uncertainty in the criticality analyses, which provides reasonable assurance that the applicant is applying a conservative bias uncertainty value. Therefore, the staff finds the response to RAI 167-8191, Question 09.01.01-12 acceptable, so that question is resolved and closed.

In lieu of formally validating the depletion code sequence, the applicant used the guidance in the Kopp memo, as discussed in Section 9.1.1.4.6 of this report. This approach, described further in Interim Staff Guidance (ISG) DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools," is consistent with what the staff documented in several recently issued SERs for SFP criticality analyses and is therefore acceptable.

The staff concludes that the applicant's code validation methodology is consistent with the guidance in NUREG/CR-6698, and the resulting code bias and bias uncertainty values are appropriate.

9.1.1.4.6 Bias and Uncertainty Analysis

Proper handling of bias and uncertainty is essential to ensure conservative criticality analysis results. The applicant performed several sensitivity analyses on the reference models for the new and spent fuel storage racks to determine bias and uncertainty in the calculated k_{eff} due to variations in parameters. In general, the applicant varied one parameter in the reference model at a time and performed a criticality calculation for each variation. The applicant compared the results to the reference case to obtain a bias or uncertainty value for each parameter. The applicant then added the individual biases and statistically combined the uncertainties to form final bias and uncertainty values for the respective rack type's criticality analyses. If the

applicant calculated a bias that reduced reactivity, it conservatively assumed zero bias. The staff finds this overall approach acceptable.

The bias and uncertainty components applied to the new fuel storage rack calculations include the computational method bias and bias uncertainty, the statistical uncertainty of the Monte Carlo calculation, and uncertainty due to mechanical tolerances or design parameter variations. When the staff examined the mechanical tolerances for the new fuel storage racks in Revision 0 of APR1400-Z-A-NR-14011, it was not clear why the tolerances were not consistent with those for the region I and II spent fuel storage racks. For example, the new fuel tolerances did not consider uncertainty in uranium enrichment and both positive and negative tolerances in dimensions such as fuel rod pitch, fuel clad diameter, and rack cell thickness, which are items considered for the spent fuel racks. Therefore, on September 1, 2015, staff issued RAI 179-8190, Question 09.01.01-25, requesting the applicant to either justify the omitted tolerances or update the sensitivity analysis for the new fuel storage racks to include these tolerances and apply the revised results to the new fuel storage rack criticality analysis.

On May 23, 2016, the applicant responded to RAI 179-8190, Question 09.01.01-25 (ML16144A814), with a markup of the new fuel storage rack uncertainty evaluation that incorporates the tolerances that were previously missing. Because consideration of the additional tolerances increased the overall uncertainty value, the applicant also incorporated the revised uncertainty into the criticality analysis results. The staff finds the response acceptable because the applicant evaluated the requested tolerances and applied the resulting new uncertainty value to the criticality analysis for the new fuel storage racks. The staff confirmed that the updated tolerances and uncertainties are included in APR1400-Z-A-NR-14011, Revision 1. Therefore, RAI 179-8190, Question 09.01.01-25 is resolved and closed.

In addition, the staff observed that the sensitivity analyses for mechanical tolerances in the new fuel storage racks did not consider the neutronic effects of the pit wall concrete and the condition of optimum moderation by low-density water. These situations may produce more limiting k_{eff} values, which could impact the final uncertainty in the criticality calculations and hence the margin to the required limits on new fuel storage rack k_{eff}. Therefore, on September 1, 2015, staff issued RAI 179-8190, Question 09.01.01-22, requesting the applicant to provide additional sensitivity calculations on an analysis model that addresses the neutronic effects of potentially more reactive storage pit concrete compositions. In the same RAI, the staff also issued Question 09.01.01-23, asking the applicant to account for the conditions of optimum moderation by low-density water and moderation by full-density water and to revise the criticality analysis as may be warranted by the additional sensitivity results.

On May 23, 2016, the applicant provided a response to RAI 179-8190, Question 09.01.01-22 (ML16144A814). The applicant presented the results of a sensitivity study that calculated k_{eff} in the new fuel storage racks for ten additional types of concrete. The applicant stated that the maximum differences in k_{eff} resulting from different concrete compositions were on the order of one tenth of the total uncertainty, so the effects of concrete type or composition on the criticality calculation are negligible. The staff confirmed that the differences are approximately one tenth of the total uncertainty for the new fuel storage racks, which is negligible compared to the applicant's margin to the regulatory criticality limits. For this reason, the staff finds the response to RAI 179-8190, Question 09.01.01-22 acceptable, so the question is resolved and closed.

The applicant's May 23, 2016, response to RAI 179-8190, Question 09.01.01-23 (ML16144A814), included a markup of APR1400-Z-A-NR-14011 in which the applicant performed sensitivity analyses on a finite-array model including concrete for the water-moderated conditions and showed that the uncertainty in k_{eff} due to the mechanical tolerances slightly increased for the optimum moderation condition and slightly decreased for the full-density condition compared to the original uncertainty analysis. The applicant committed to use the new, higher uncertainty values in the new fuel storage rack criticality analyses.

The staff finds the response to RAI 179-8190, Question 09.01.01-23, acceptable because the applicant performed the additional sensitivity calculations accounting for the effects of concrete and optimum and full-density moderation by water and committed to use the most limiting uncertainty value in its criticality analyses. The staff confirmed that Revision 1 of APR1400-Z-A-NR-14011 contains the revised uncertainty analyses and related revisions. Therefore, RAI 179-8190, Question 09.01.01-23 is resolved and closed.

For the region I spent fuel storage rack calculations, the applicant considered the same biases and uncertainties as the new fuel storage racks plus uncertainty due to eccentric fuel assembly positioning in the racks and bias due to pool cooling water temperature. The applicant also acceptably revised the uncertainty analyses for the region I and II racks to include neutron absorber plate width and thickness as mechanical tolerances as a result of RAI 167-8191, Question 09.01.01-4, as discussed in Section 9.1.1.4.2 of this report.

The region II spent fuel storage rack (burnup credit) calculations consider the same types of biases and uncertainties as the region I racks, which the staff finds acceptable for the region II racks, as well as bias due to the minor actinides and fission products credited in the analyses, depletion uncertainty, bias due to the axial power distribution, and burnup record uncertainty.

The applicant credited burnup for 28 isotopes, grouped into nine major actinides and 19 minor actinides and fission products, as listed in Table 3.2-1 of APR1400-Z-A-NR-14011. Section 3.5.3.8 of APR1400-Z-A-NR-14011 references the Kopp Memo (Kopp, 1998) for the quantification of depletion uncertainty, and Section 3.5.3.4 of the report references NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Criticality (k_{eff}) Predictions," for the quantification of the bias due to minor actinides and fission products.

Because both the Kopp Memo and NUREG/CR-7109 treat bias and bias uncertainty as a percentage of the corresponding reactivity reduction calculated from the depletion and criticality analysis codes, the user of these methods must first determine the base values of k_{eff} with and without depletion and fission product and actinide buildup in separate calculations to determine the reactivity reduction. However, neither the DCD nor APR1400-Z-A-NR-14011-P, Revision 0, provided a clear description on how the applicant determined the reactivity reduction. Therefore, on July 20, 2015, staff issued RAI 90-7939 (ML15201A569), Question 09.01.01-1, requesting the applicant to provide a clear description of how it used the approaches in the spent fuel rack criticality safety analysis and to demonstrate that the assumptions used and the results produced are conservative. Specifically, staff requested the applicant to:

1. Explain how the reactivity reduction was determined for the fuel depletion, including all assumptions used.

2. Explain how the base value of the burnup credit was determined for the 28 isotopes, including a description of the method; and if a method other than those presented in NUREG/CR-6811 ("Strategies for Application of Isotopic Uncertainties in Burnup Credit") was used, provide a clear technical basis for the validity and reliability of the method.

3. Explain how the HTC data were used to benchmark the computer code(s).

On May 23, 2016, the applicant provided a response to RAI 90-7939, Question 09.01.01-1 (ML16144A759). To calculate the reactivity reduction due to depletion, the applicant took the difference between separate calculations of k_{eff} for fresh fuel and fuel of the desired burnup. The applicant then took 5 percent of the difference, including statistical uncertainties, as the depletion uncertainty per the guidance in the Kopp memo. APR1400-Z-A-NR-14011, Tables 3.5-5 and 3.5-6 list the base k_{eff} values and calculation uncertainty values, respectively, and Table 3.5-13 provides the resulting depletion uncertainty values. The staff finds this approach consistent with the guidance in the Kopp memo and DSS-ISG-2010-01.

In addition, the RAI response clarified that the applicant is following the guidance in NUREG/CR-7109 for burnup credit, which states that a conservative estimate for the biases due to the minor actinides and fission products is 1.5 percent of their worth. APR1400-Z-A-NR-14011, Table 3.5-9 presents the worth values, which the applicant calculated as the difference in k_{eff} with and without consideration of minor actinides and fission products.

The staff notes that NUREG/CR-7109 recommends that the bias due to minor actinides and fission products can conservatively be taken as 1.5 percent of their worth only when the worth does not exceed 0.1 Δk. According to APR1400-Z-A-NR-14011, Δk values for all but one combination of initial enrichment and burnup are less than 0.1, and the excess worth for that case is negligible. Although the staff finds this data point non-conservative, the staff notes the excess worth is indeed small. In addition, the applicant selected a conservative bounding Δk value for all burnups and enrichments for the final bias due to minor actinides and fission products, and many of the calculated Δk values in Table 3.5-9 of APR1400-Z-A-NR-14011 are considerably less than the bounding value. Therefore, the staff finds that the applicant applied an appropriate bias due to minor actinides and fission products.

In the third part of the RAI response, the applicant referred to WCAP-17889, discussed in Section 9.1.1.4.5 of this report, for details on how it used the HTC data. The applicant also committed to update DCD Tier 2, Section 9.1.1, and APR1400-Z-A-NR-14011, according to the proposed markups that provide additional detail on the criticality methodology, including burnup credit.

The staff finds the response to RAI 90-7939, Question 09.01.01-1 acceptable because it provided a comprehensive description of, and confirmed the conservatism of, the applicant's burnup credit methodology and assumptions. The staff confirmed the additional methodology details are incorporated in Revision 1 of the DCD and Revision 1 of APR1400-Z-A-NR-14011. Therefore, RAI 90-7939, Question 09.01.01-1 is resolved and closed.

To take burnup credit, an applicant must characterize the spent fuel with a conservative axial burnup profile. At the beginning of life, PWR fuel is exposed to a cosine-shaped axial flux. Therefore, the fuel near the center of the assemblies depletes more quickly than fuel on the ends. The cosine-shaped axial flux will flatten with continued operation as the fuel near the

center of the assemblies depletes and fission products build up. Neutron leakage suppresses burnup near the ends of the fuel assemblies. As a result, assuming uniform axial burnup is generally conservative for low burnups but becomes non-conservative for higher burnups.

Section 3.5.3.9, “Bias due to Axial Power Distribution,” of APR1400-Z-A-NR-14011 describes how the applicant accounted for bias due to the axial burnup profile. The applicant’s region II criticality analysis modeled non-blanketed fuel with uniform axial burnup and added a bias adjustment to account for the “end effect,” which is the difference between the k_{eff} calculated with explicit representation of axial burnup profiles and that calculated with the base model’s uniform profile. Table 3.5-20 of APR1400-Z-A-NR-14011 presents this difference. The staff notes that modeling non-blanketed fuel with uniform burnup is conservative for the base model and that treating the end effect as a bias adjustment is acceptable if the end-effect bias calculation is conservative for the spent fuel from this reactor design.

To calculate the end-effect bias, APR1400-Z-A-NR-14011 states that the applicant selected bounding axial burnup profiles by surveying a set of 304 profiles that cover all possible types of axial burnup distributions. However, APR1400-Z-A-NR-14011, Revision 0 did not present the set of burnup profiles or describe how the applicant generated the profiles, nor did the report clearly describe how the applicant found the bounding profiles. Furthermore, the applicant’s brief description of how it calculated the reactivity bias for the selected bounding profiles lacks important details. Therefore, on August 20, 2015, staff issued RAI 167-8191, Question 09.01.01-9, requesting the applicant to describe in detail how it generated the set of axial burnup profiles and how it determined the most reactive bounding profiles, including how the profile selection process and bias calculation accounted for the reactivity effects of local fuel depletion history parameters such as rodded burnup.

In its December 10, 2015, response to RAI 167-8191, Question 09.01.01-9 (ML15344A144), the applicant explained that it assumed hot full power, all rods out (ARO), and steady-state depletion conditions in generating the axial burnup distributions. To determine the bounding axial burnup profile, the applicant considered all possible axial burnup profiles for the initial cycle through the equilibrium cycle and selected the burnup profile with the most under-depletion at the top of the fuel region. The bounding profile does not account for rodded burnup because of the ARO assumption.

Selecting the axial burnup profile with the most under-depletion near the top of the fuel captures the most extreme end effect and is therefore acceptable. The staff obtained clarification in a teleconference (ML16063A510) that the three-dimensional nodal code ROCS was used to generate the profiles for end-of-cycle conditions, which is consistent with the axial burnup profile generation process used in the nuclear design described in Section 4.3 of this report. The staff notes that hot full power and steady-state depletion are appropriate assumptions because, in practice, a licensee will operate the reactor in such a manner the majority of the time. In addition, as described in Section 9.1.1.4.7 of this report, the response to RAI 483-8602, Question 09.01.01-41 (ML16162A093) showed that ARO is an acceptable assumption. For these reasons, the staff considers the issue raised in RAI 4838191, Question 09.01.01-9, resolved.

For the burnup record uncertainty, the applicant cited NUREG/CR-6998, “Review of Information for Spent Nuclear Fuel Burnup Confirmation,” which states that utility reactor burnup records appear to be accurate to within 5 percent. Therefore, the applicant assumed the uncertainty due to burnup records as the difference in k_{eff} between fuel at the target burnup and fuel

at 5 percent less than the target burnup, including statistical uncertainties. The staff finds this assumption acceptable, especially since NUREG/CR-6998 further states that from 1985 to 2004, several independent comparisons at different utilities showed that the measured burnup values deviated less than 4.2 percent from the predicted values.

The staff concludes that the applicant's new and spent fuel storage rack analyses conservatively account for all relevant sources of bias and uncertainty. Furthermore, the staff independently confirmed that the applicant combined the aforementioned biases and uncertainties correctly and applied them to the nominal k_{eff} values for the new and spent fuel storage racks. Overall, the staff finds the applicant's treatment of bias and uncertainty acceptable.

9.1.1.4.7 Reactor Fuel Depletion Parameters

Section 3.5.1.1 of APR1400-Z-A-NR-14011 describes the fuel depletion parameters the applicant used in the burnup credit analyses, including a list of the bounding reactor operating parameters in Table 3.5-1. These include maximum fuel temperature, maximum fuel density, maximum moderator temperature, maximum cycle average soluble boron concentration, and maximum power level. The use of maximum values for fuel temperature, moderator temperature, and soluble boron concentration contribute to spectral hardening and increased fissile plutonium production; similarly, maximum fuel density maximizes the amount of fissile material. This is acceptable to the staff because the reactor parameters used for depletion calculations should maximize the reactivity of a depleted fuel assembly. In addition, the staff concludes that the applicant chose appropriate numerical values for each of the bounding parameters.

However, per NUREG/CR-6665, "Review and Prioritization of Technical Issues Related to Burnup Credit for LWR Fuel," a minimum, not maximum, fuel power level would be bounding since a lower power level corresponds to higher fuel reactivity. Fuel reactivity increases more when fuel power decreases late in life.

The applicant's depletion sensitivity analysis for fuel specific power considers only a "nominal" power level versus an incrementally higher "maximum" power level. Similarly, the applicant's sensitivity analysis for fuel temperature considers only incremental variations of maximum fuel temperature. It was not clear to the staff that the applicant considered the correlation between fuel power and fuel temperature appropriately. To evaluate whether fuel power or fuel temperature is the dominant parameter, it is important to compare the respective sensitivities on a consistent basis and over appropriate ranges of parameter values. Per DSS-ISG-2010-01, the staff notes that the applicant should conservatively treat any conflicting correlation between reactivity-maximizing and minimizing parameters by setting the subordinate parameter to its nominal or expected value instead of to a minimizing value as it may otherwise do in a best-estimate approach to parameter correlation.

The staff also noted that the applicant did not account for the effect of thermal conductivity degradation (TCD) as a function of burnup in its fuel temperature calculations, as discussed in Section 4.2 of this report. It was therefore unclear how the listed values of expected and maximum fuel operating temperatures account for TCD.

Therefore, on August 20, 2015, staff issued RAI 167-8191, Question 09.01.01-8, requesting the applicant to provide revised analyses that either (1) deplete the fuel at conservative values of high fuel temperature and low fuel power, thereby conservatively neglecting how the two

parameters are correlated, or (2) deplete the fuel at a clearly conservative value of the dominant parameter and at a justified nominal or expected value of the subordinate parameter. If the applicant should choose the second approach, it should revise the supporting sensitivity analyses to provide a consistent basis for assessing parameter dominance, address appropriately lower ranges of fuel power (e.g., representing axial end effects), and clearly show whether high fuel temperature or low fuel power is dominant for the expected ranges of operating parameters. For either approach, the staff also requested an explanation of how the applicant's expected and maximum fuel temperature values account for TCD.

On December 10, 2015, the applicant provided a response to RAI 167-8191, Question 09.01.01-8 (ML15344A144). The applicant performed sensitivity analyses to determine k_{eff} as a function of enrichment and burnup at four different power levels. The applicant demonstrated that no trend is evident between reactivity and power level, and the reactivity differences due to different power levels are quite small—in all cases, a fraction of a percent. In addition, the majority of cases show that the bounding power level in APR1400-Z-A-NR-14011 results in the highest k_{eff}. Therefore, the staff finds that operating power is not a dominant parameter, and the bounding value listed in APR1400-Z-A-NR-14011 is acceptable.

As discussed in the August 11, 2017, response to RAI 5-7954 (ML17223B382), related to Section 4.2 of this report, the applicant has applied a TCD-related penalty to its fuel temperature calculations. The response included markups of the DCD and APR1400-Z-A-NR-14011 showing that the fuel temperature assumed for the depletion calculations bounds the maximum fuel temperature at 100 percent power including the TCD penalty. The staff is tracking RAI 5-7954 as a **Confirmatory Item** pending the updates to DCD Tier 2, Section 9.1.1, and APR1400-Z-A-NR-14011.

The staff concludes the response to RAI 167-8191, Question 09.01.01-8, is acceptable because the applicant demonstrated that the assumption of maximum power in the depletion parameters is adequate. In addition, the response to RAI 5-7954 showed that the fuel temperature assumed for the depletion calculations bounds the effects of TCD. Therefore, RAI 167-8191, Question 09.01.01-8 is resolved and closed.

In further review of the bounding reactor parameters for the depletion calculations, the staff noted that the applicant did not appear to consider the effects of rodded operation in APR1400-Z-A-NR-14011. The APR1400 core design described in DCD Tier 2, Section 4.3, "Nuclear Design," includes the use of inserted control rods at power, particularly part-strength rods. The staff noted that the effects of absorption and moderator displacement by inserted control rods may substantially increase the reactivity of spent fuel by enhancing the production of fissile plutonium. The neglect of rodded fuel depletion history may be non-conservative. Therefore, staff issued RAI 167-8191, Question 09.01.01-7 on August 20, 2015, and follow-up RAI 483-8602 (ML16137A128), Question 09.01.01-41 on May 16, 2016.

The applicant's December 10, 2015, response to RAI 167-8191, Question 09.01.01-7 (ML15344A144) clarified that it performed depletion calculations assuming ARO since the effects of rodded operation are expected to be small and can be covered by the bounding reactor parameters assumed in the depletion calculation. The applicant's June 10, 2016, response to RAI 483-8602, Question 09.01.01-41 (ML16162A093) provided the results of a depletion study based on operating data from an Optimized Pressure Reactor 1000 (OPR1000), which is of similar design to the APR1400, as additional justification. The staff determined that

the rod insertion time assumed in the depletion study is conservative based on data from the operating OPR1000, and the staff also determined that other calculation assumptions, including operating power level, materials, and insertion lengths, are conservative. The applicant examined control rod insertion during three burnup ranges for three initial enrichments and demonstrated that the change in reactivity due to rod insertion is less than one percent for all cases. The results are also consistent with the staff's expectations that insertion at higher burnups has greater effects.

The staff finds the response to RAI 483-8602, Question 09.01.01-41 acceptable because the applicant showed, given conservative assumptions, that any reactivity effects of rodded operation are small. The staff therefore has reasonable assurance that conservatism in the bounding reactor parameters is sufficient to cover reactivity effects of rodded operation, so RAI 483-8602, Question 09.01.01-41, is resolved and closed.

Contingent upon closure of the confirmatory item above, the staff finds the applicant used conservative depletion parameters that will maximize the reactivity of depleted fuel.

9.1.1.4.8 Normal Conditions

10 CFR 50.68(b) does not require criticality analyses of the new fuel storage racks in their normal dry condition. In accordance with 10 CFR 50.68(b)(2) and (b)(3), the criticality analyses performed for the new fuel storage racks consider the abnormal condition of flooding and are discussed in Section 9.1.1.4.9 of this report.

The applicant describes its region I normal-conditions models in Section 3.4 of APR1400-Z-A-NR-14011. The applicant does not credit soluble boron for the normal-conditions models. The model for the normal region I storage cells consists of a single cell with all reflective boundary conditions to simulate an infinite array of storage cells. The model for damaged fuel storage cells depicted in Figure 3.4-3 consists of a 6x8 array of five damaged fuel storage cells and 43 normal fuel storage cells with reflective boundary conditions on all sides. These arrangements are conservative considering the design of the region I racks. In addition, the applicant assumes the limiting water temperature and density in terms of k_{eff}.

The staff noted that the applicant did not characterize the allowed contents of the damaged fuel cells or the type and extent of fuel assembly damage. It appeared the modeling assumption was for fresh fuel enriched to 5 wt%, which may not be bounding for actual damaged fuel. Therefore, on August 20, 2015, staff issued RAI167-8191, Question 09.01.01-5, requesting the applicant to provide a description of the allowed contents and conditions of fuel in the damaged fuel storage cells and, as necessary, an updated analysis with stated assumptions with regard to the modeling of allowed damaged fuel contents.

The applicant's April 22, 2016, response to RAI 167-8191, Question 09.01.01-5 (ML16113A445) discussed damaged fuel scenarios including cladding failure, removal of fuel rods from the fuel assembly, and fuel rod reconfiguration and provided case studies for the latter two scenarios. The applicant committed to update APR1400-Z-A-NR-14011 to clarify that it assumed fresh fuel enriched to 5.0 wt% in the original damaged fuel cell criticality analysis and had already accounted for cladding failure by assuming the gap between the fuel pellet and cladding to be flooded by water. In addition, total cladding failure could cause loss of fuel pellets, which the applicant stated was bounded by the loss of fuel rod scenario.

To analyze the removal of a single fuel rod, the applicant simulated all intact, non-flooded fuel except for the rod removed from the assembly in the central damaged fuel location. The applicant showed that k_{eff} with a single rod removed is no more than 90 percent millirho (pcm) higher than k_{eff} assuming no fuel damage and is bounded by the k_{eff} for damaged fuel in APR1400-Z-A-NR-14011.

The applicant provided an estimate rather than performing calculations for the loss of multiple fuel rods since the number of possible configurations is very large. The applicant referenced NUREG/CR-6835, "Effects of Fuel Failure on Criticality Safety and Radiation Dose for Spent Fuel Casks," and a 2012 ORNL paper by William Marshall and John Wagner, "Impact of Fuel Failure on Criticality Safety of Used Nuclear Fuel," to conclude that the increment in k_{eff} due to loss of multiple fuel rods is up to 2.42 percent Δk. The staff examined these references and notes that cases examined therein use a Westinghouse 17x17 fuel assembly, which is similar enough to PLUS7 fuel for the purposes of an estimate, and the SCALE code package to perform the calculations. The staff therefore finds the references applicable. The applicant assumed a conservative increment relative to the 2.42 percent Δk and added it to k_{eff} without damaged fuel including bias and uncertainty to obtain the estimated k_{eff} due to loss of multiple fuel rods, which is higher than the k_{eff} for damaged fuel in APR1400-Z-A-NR-14011 but still well below the regulatory limit of 1.0 without crediting soluble boron.

Finally, to investigate the effects of fuel rod reconfiguration, the applicant ran a criticality analysis assuming all five damaged fuel assemblies contained fuel with the maximum uniform rod pitch. The calculation result was higher than the k_{eff} for damaged fuel in APR1400-Z-A-NR-14011 but still well below the regulatory limit of 1.0 without crediting soluble boron.

The staff finds that the applicant considered a comprehensive range of damaged fuel scenarios in its RAI response. The applicant's assumptions were conservative, especially the assumption of the most reactive fuel possible—fresh 5.0 wt%. In addition, the results in APR1400-Z-A-NR-14011 bound the loss of single fuel rod scenario, and the loss of multiple rods and fuel rod reconfiguration scenarios showed significant margin to the requirement of $k_{eff} < 1.0$ without soluble boron. Therefore, the staff finds the response to RAI 167-8191, Question 09.01.01-5 acceptable. The staff confirmed that Revision 1 of APR1400-Z-A-NR-14011 contains the revisions proposed in the RAI response. Therefore, RAI 167-8191, Question 09.01.01-5 is resolved and closed.

The staff notes that k_{eff} for the region I racks for both normal and damaged fuel cells, as discussed in APR1400-Z-A-NR-14011, Section 3.4.4, "Results of Criticality Analysis of Spent Fuel Pool Region I," are much less than the regulatory requirement of 1.0 without crediting soluble boron. In addition, the staff performed independent confirmatory calculations using the CSAS6 sequence of SCALE 6.1.2 and the ENDF/B-VII continuous-energy cross-section library and obtained results very close to that of the applicant's without bias and uncertainty. For these reasons, the staff concludes there is reasonable assurance that the region I spent fuel storage racks will remain subcritical under normal conditions.

Figures 3.5-2 and 3.5-3 of APR1400-Z-A-NR-14011 show the normal-conditions model for region II of the spent fuel storage racks. The models show the presence of neutron absorber plates on all four walls of diagonal rack cells and indicate periodic boundary conditions on all sides. This effectively creates an infinite array of the 2x2 checkerboard-type arrangement. Again, the applicant does not credit soluble boron for the normal-conditions models and assumes

a water temperature and density that results in the largest k_{eff}. The staff concludes that the region II normal-conditions model conservatively simulates the actual rack design and conditions.

The applicant also performed a sensitivity analysis on the region I racks to examine the effect of gap size between racks. The applicant demonstrated, as shown in Table 3.4-8 of APR1400-Z-A-NR-14011, that k_{eff} decreased with increasing gap size. Because the spent fuel storage rack normal-conditions models assume a smaller gap between rack cells than the actual gap size, the staff finds the modeled gaps to be conservative.

Region II of the spent fuel storage racks credits burnup, so the applicant presented a burnup loading curve in Figure 3.5-7 of APR1400-Z-A-NR-14011 to demonstrate its analysis results without soluble boron. The applicant developed the curve using k_{eff} values in Table 3.5-24 of APR1400-Z-A-NR-14011, "k_{eff} with Bias and Uncertainty for Spent Fuel Pool Region II," which includes values above 1.0. It was not clear what the maximum k_{eff} values are that correspond to the points on the burnup loading curve; therefore, the staff was unable to verify compliance of the region II racks with 10 CFR 50.68(b)(4). Accordingly, on September 1, 2015, staff issued RAI 179-8190, Question 09.01.01-16, requesting the calculated maximum k_{eff} values to verify they are below 1.0 at a 95 percent probability, 95 percent confidence level.

On April 22, 2016, the applicant provided a supplementary response to RAI 179-8190 (ML16113A467), Question 09.01.01-16. The applicant clarified that it generated the original burnup loading curve with a target k_{eff} of 1.0 with additional margin; however, the k_{eff} of a fuel assembly with an initial enrichment of 4.5 wt% and burnup of 38.5 GWd/MTU was slightly over 1.0. Therefore, the applicant regenerated the loading curve for a target k_{eff} of 0.998. The applicant provided a table that shows the calculated k_{eff} values for different initial enrichments on the loading curve as well as a markup of the new loading curve. The maximum k_{eff} on the loading curve was just over the target k_{eff} of 0.998. The staff finds the response to RAI 179-8190, Question 09.01.01-16 acceptable because the applicant regenerated its burnup loading curve to ensure compliance with 10 CFR 50.68(b)(4) and clearly demonstrated compliance in its table of calculated k_{eff} values. The staff confirmed that the RAI response markups were included in APR1400-Z-A-NR-14011, Revision 1. However, a revision to the burnup loading curve in TS 3.7.16 is required, so RAI 179-8190, Question 09.01.01-16 is being tracked as a **Confirmatory Item** pending that revision.

The staff also performed independent confirmatory calculations for fresh 5 wt% fuel in the region II racks using the same methodology as discussed previously and obtained results that agree closely with the applicant's without bias and uncertainty. Based on this and the results in the response to RAI 179-8190, Question 09.01.01-16, the staff has reasonable assurance that the region II racks will remain subcritical under normal conditions.

The staff noted that the applicant did not provide or describe a complete set of normal conditions for the new and spent fuel storage and handling systems despite citing DSS-ISG-2010-01, which states that the normal conditions of fuel storage and handling include not only static storage but also anticipated fuel handling activities. Therefore, on August 20, 2015, staff issued RAI 167-8191, Question 09.01.01-2, requesting the applicant to identify a comprehensive set of normal conditions for the dry and wet handling of new and spent fuel, to clarify where administrative control procedures are relied upon to limit such conditions, and to provide conservative analyses that show compliance with GDC 62 and 10 CFR 50.68(b) for the most reactive normal conditions of fuel handling operations.

On April 22, 2016, the applicant provided a response to RAI 167-8191, Question 09.01.01-2 (ML16113A445). The applicant stated that, like the new fuel storage racks, the new fuel inspection area is dry and does not require a criticality analysis. The staff agrees, noting that k_{eff} in the new fuel inspection area under normal conditions would be very low. Though the applicant did not explicitly address handling of new fuel in and around the new fuel storage racks, the staff notes that the criticality calculations the applicant performed in response to RAI 179-8190, Question 09.01.01-21, discussed in Section 9.1.1.4.2 of this report, show that a fuel assembly dropped in between the full new fuel storage racks does not present a criticality concern. This case bounds normal handling of new fuel because the most reactive configuration conceivable for new fuel is the new fuel storage racks completely full.

For wet handling of new and used fuel, the applicant specifically addressed the following areas: the new fuel elevator, the SFP, and the fuel transfer system. The staff notes that the wet fuel handling descriptions in DCD Tier 2, Section 9.1.4 do not indicate any more reactive normal handling areas. The staff notes that a criticality safety evaluation is not necessary for the new fuel elevator normal conditions since it only holds one fuel assembly. For the SFP area, the applicant stated that the most conservative normal condition is full storage racks with fuel assemblies in all approved storage locations, which it already analyzed in APR1400-Z-A-NR-14011. Finally, the applicant stated that the fuel transfer system consists of a two-cavity fuel carrier and provided a criticality analysis assuming two fresh fuel assemblies of maximum reactivity loaded in the fuel carrier. As shown in the response, the applicant calculated k_{eff} to be under 0.95 without crediting soluble boron and including bias and uncertainty. The staff finds the response acceptable because the applicant used appropriate modeling assumptions and demonstrated that the two-cavity fuel carrier meets the requirement that k_{eff} not exceed 0.95 when flooded with borated water and 1.0 when flooded with pure water.

Contingent upon the closure of the aforementioned confirmatory item, the staff finds that the applicant considered a comprehensive set of normal conditions given expected operating conditions and modeled the normal conditions appropriately. This includes variations in design parameters and dimensional tolerances and considerations related to burnup credit discussed in Section 9.1.1.4.6 of this report.

9.1.1.4.9 Abnormal Conditions

The postulated accidents considered in APR1400-Z-A-NR-14011 for the new fuel storage rack are moderation by full-density water and optimum moderation by low-density hydrogenous fluid. These scenarios could arise if a fire were to occur near the new fuel storage racks. As discussed in Sections 9.1.1.4.1 and 9.1.1.4.2 of this report, the staff finds that the calculation model for the new fuel storage racks conservatively reflects the fuel and rack design. To identify the optimum moderation condition and to calculate k_{eff} for full-density water, the applicant performed criticality calculations for water densities ranging from 0.01 g/cm^3 to 1.0 g/cm^3. The staff finds that this range covers all probable water densities for the postulated accident conditions. Figure 2.4-1 of APR1400-Z-A-NR-14011 shows the finite-array abnormal-conditions model for the new fuel storage racks. The staff finds that the model is consistent with the actual new fuel storage pit design.

Including bias and uncertainty, k_{eff} for the new fuel storage racks is well below the regulatory limits of 0.95 and 0.98 for the full-density water and optimum moderation conditions, respectively. The staff also performed independent confirmatory calculations using the previously mentioned methodology. The staff's results differ from the applicant's by up to a few

hundred pcm for some densities, which is most likely due to the staff's use of continuous energy cross sections instead of multigroup cross sections. Nonetheless, the staff observed the same general trend in k_{eff} versus density, including the density at which optimum moderation occurred. In addition, the applicant's results are more conservative than the staff's except for the two highest-density cases. For the full-density case, the applicant's margin to the regulatory limit is much greater than the difference between the applicant and staff results.

The applicant also considered additional abnormal-conditions models in which a fresh fuel assembly was assumed to be inserted between the two new fuel storage racks in response to RAI 179-8190, Question 09.01.01-21. As discussed in Section 9.1.1.4.2 of this report, the staff finds the response acceptable.

The postulated abnormal conditions for the spent fuel storage racks in APR1400-Z-A-NR-14011 include a dropped fresh fuel assembly, a fresh fuel assembly misloaded into an incorrect storage rack location, and a boron dilution accident. For the first two accidents, the applicant assumes the TS 3.7.15 minimum soluble boron concentration of 2,150 parts per million (ppm) and also finds the minimum concentration required to remain below the regulatory limit on k_{eff} of 0.95.

Section 4.1 of APR1400-Z-A-NR-14011 describes the dropped fresh fuel assembly scenario. The applicant assumed that a fresh fuel assembly is dropped vertically between the concrete SFP wall and an outermost storage cell in region I of the SFP such that the assembly almost touches the outermost rack cell. The applicant modeled this scenario as a 1x17 array with reflective boundary conditions on all sides except for the concrete pool wall side, which has a vacuum boundary condition. Overall, the staff finds the calculation model conservative because it effectively models a fresh fuel assembly dropped next to the region I racks filled to capacity with fresh fuel, and the assumed enrichment of the fuel assemblies is the maximum possible. The vacuum boundary condition on the concrete wall side is appropriate to the staff because the concrete thickness is considerably greater than a neutron mean free path, making it unlikely for neutrons to return to the pool water if they reach the far side of the modeled concrete.

The analysis results for the dropped fuel assembly show that k_{eff} assuming the limiting condition for operation (LCO) minimum soluble boron concentration is well below 0.95, including bias and uncertainty. The applicant also calculated the minimum concentration necessary to meet the regulatory requirement to be significantly under the LCO minimum soluble boron concentration of 2,150 ppm. Therefore, the staff has reasonable assurance that the LCO minimum soluble boron concentration is sufficient to maintain subcriticality in the spent fuel storage racks if a fresh fuel assembly is dropped outside of the racks.

The fresh fuel misloading accident described in Section 4.2 of APR1400-Z-A-NR-14011 assumes that a fresh fuel assembly of maximum reactivity is loaded into a region II spent fuel cell surrounded by spent fuel. The applicant modeled the scenario as a 2x2 array with three burned fuel assemblies and one misloaded assembly and assumed periodic boundary conditions on the sides, which the staff finds conservative because it effectively creates an infinite array of the 2x2 cell arrangement. The staff notes that the assumed initial enrichment and burnup combination of the spent fuel is conservative because the normal-conditions model k_{eff} for that combination was among the highest calculated for all combinations, and the burnup loading curve would require a higher burnup for that enrichment.

The k_{eff} for the misloaded fuel assembly accident assuming the LCO minimum soluble boron concentration is well below the regulatory limit of 0.95, including bias and uncertainty. The applicant also found the minimum concentration necessary to meet the regulatory requirement to be greater than what was required for the dropped fuel assembly accident but still significantly under the LCO minimum soluble boron concentration of 2,150 ppm. Therefore, the staff has reasonable assurance that the LCO minimum soluble boron concentration is sufficient to maintain subcriticality in the spent fuel storage racks if a fresh fuel assembly is misloaded into the region II racks.

Section 4.3 of APR1400-Z-A-NR-14011 describes the boron dilution accident. The applicant analyzed the region I and region II racks separately to determine the minimum concentration of soluble boron necessary for each region. The region I and II models consist of 2x2 arrays of fuel cells with reflective and periodic boundary conditions on the sides, respectively, which are conservative because they simulate infinite arrays of the 2x2 cell arrangements. For the region I racks, the applicant assumed fresh fuel of maximum reactivity. For the region II racks, the applicant assumed an initial enrichment and burnup combination not allowed by the burnup loading curve, which is conservative since the assumed fuel is more reactive than what is allowed.

APR1400-Z-A-NR-14011 shows that k_{eff} at the LCO minimum soluble boron concentration in the region I and region II racks was well under the regulatory limit of 0.95. A complete boron dilution accident for the region I racks results in k_{eff} of under 0.95, including bias and uncertainty. The region II racks are more limiting, as the applicant showed that the minimum soluble boron concentration to ensure k_{eff} of 0.95 is over 400 ppm. The applicant determined that dilution from the LCO minimum concentration to the minimum required to ensure k_{eff} of 0.95 would require a volume of pure water about 50 percent greater than the nominal SFP volume to be added to the SFP, which would be detected either by high level alarms or operators on rounds in the SFP area. The staff agrees that such a large addition of water without detection is not credible and, therefore, the boron dilution analysis is acceptable.

Overall, the staff concludes that the accident analyses presented in APR1400-Z-A-NR-14011 are acceptable in terms of models, assumptions, and approximations. However, similar to the lack of normal-conditions models for fuel handling operations discussed in Section 9.1.1.4.8 of this report, the applicant did not describe abnormal conditions of fuel handling. This concern was included in RAI 167-8191, Question 09.01.01-2.

On April 22, 2016, the applicant provided a response to RAI 167-8191, Question 09.01.01-2 (ML16113A445). For dry handling of new fuel, the applicant referred to the dropped fuel assembly analysis performed in response to RAI 179-8190, Question 09.01.01-21, discussed in Section 9.1.1.4.2 of this report. For wet handling of new and used fuel, the applicant specifically addressed the new fuel elevator and the fuel transfer system and listed the accident analyses performed in APR1400-Z-A-NR-14011 for the SFP. The staff finds that the dropped and misloaded fuel assembly accidents analyzed in APR1400-Z-A-NR-14011 cover abnormal conditions for fuel handling operations in the SFP. The applicant stated that the most conservative abnormal condition for the new fuel elevator is one fuel assembly in the new fuel elevator with another assembly located adjacent to it, and that for the fuel transfer system is two fuel assemblies in the fuel carrier with another fuel assembly located adjacent to the fuel transfer system. The staff notes that these conditions are the most conservative because the double-contingency principle, as defined in the Kopp memo (Kopp, 1998), states that two

unlikely independent and concurrent postulated accidents are beyond the scope of the required analysis.

The applicant included criticality analyses for the above new fuel elevator and fuel transfer system abnormal conditions in its response. The models are conservative since they maximize fuel reactivity and assume less than the TS minimum soluble boron concentration of 2,150 ppm. For the new fuel elevator and fuel transfer system, the applicant calculated k_{eff} to be well under 0.95 including bias and uncertainty. The staff finds the response acceptable because the applicant used appropriate modeling assumptions and showed that the new fuel elevator and fuel transfer system meet the requirement that k_{eff} remain under 0.95 when flooded with borated water.

In addition to the accidents discussed above, other credible accidents in the fuel storage racks include fuel drops onto or into the racks, safe shutdown earthquake (SSE) and resulting fuel impact loading, uplift loads on rack cells from fuel handling equipment, and tipping of fuel assemblies or the spent fuel storage racks. Such accidents are analyzed in technical report APR1400-H-N-NR-14012, “Mechanical Analysis for New and Spent Fuel Storage Racks.”

For a seismic event, APR1400-H-N-NR-14012 indicates that the maximum displacement of the new and spent fuel storage racks is less than the spacing between adjacent storage racks and between storage racks and the pit or pool walls, so the racks do not impact adjacent racks or the walls above the baseplate. In addition, the spent fuel pool criticality analysis models for normal conditions specify a smaller gap between racks than the minimum gap that would result from a seismic event and therefore bounds the criticality analysis for a seismic event. APR1400-H-N-NR-14012 also shows that mechanical accidents, including drops onto or into the racks and uplift loads from stuck fuel assemblies, will not cause rack deformation that would affect the neutron absorbing material. The potential effects of such accidents on criticality are bounded by the criticality analyses in APR1400-Z-A-NR-14011. The staff’s evaluation of APR1400-H-N-NR-14012 is in Section 9.1.2 of this report.

Overall, the staff finds that the applicant considered a complete range of abnormal conditions and that the assumptions and approximations in the applicant’s models are appropriate and conservative. The staff also finds that the applicant’s analysis results indicate that the fuel will remain subcritical under the analyzed credible abnormal conditions.

9.1.1.4.10 Conditions and Limitations

The staff’s review and approval of the APR1400 new and spent fuel storage rack criticality analyses is based on the fuel designs, rack designs, rack configurations, and models presented in APR1400-Z-A-NR-14011. Any changes to the analysis inputs and assumptions, such as neutron absorber material or storage rack spacing, would be considered changes to the approved methodology and would require additional analysis, review, and approval.

9.1.1.5 Combined License Information Items

There are no COL information items associated with Section 9.1.1 of the APR1400 DCD.

9.1.1.6 Conclusion

The staff reviewed the criticality analyses for new and spent fuel storage and handling described in DCD Tier 2, Section 9.1.1 and the technical report APR1400-Z-A-NR-14011 to evaluate

whether new and spent fuel will remain subcritical in all credible storage conditions and during fuel handling. The staff ensured that the applicant's design information, analysis models, assumptions, and analytical techniques are conservative and adequate to conclude compliance with the regulatory requirements at a 95 percent probability and 95 percent confidence level. The staff also evaluated compliance of the applicant's analysis results with the regulatory requirements. Based on the review above, and contingent on the closure of the aforementioned confirmatory items, the staff concludes that the design of the fresh and spent fuel storage facilities and supporting systems is in conformance with the Commission's regulations in GDC 62 and in 10 CFR 50.68.

9.1.2 New and Spent Fuel Storage

9.1.2.1 New and Spent Fuel Storage (Part 1 – Structural)

9.1.2.1.1 Introduction

As described in the design certification document (DCD) Tier 2, Section 9.1.2, "New and Spent Fuel Storage," the new and spent fuel rack assemblies are classified as nonsafety related but are designed as seismic Category I within the auxiliary building (AB), which is a seismic Category I structure. The new fuel storage racks (NFSRs) and the spent fuel storage racks (SFSRs) are located in the new fuel storage pit in the fuel handling area and the spent fuel pool (SFP) in the fuel handling area of the AB, respectively. The NFSRs provide onsite dry storage for nuclear fuel assemblies. The SFSRs provide onsite storage capability for a core offload during the design life of the plant. This section of the Advanced Power Reactor (APR) 1400 DCD provides the following information on new and spent fuel storage:

- physical description
- applicable design codes, standards, and specifications
- seismic and impact loads
- loads and load combinations
- design and analysis procedures
- structural acceptance criteria
- materials, quality control programs, and special construction techniques

9.1.2.1.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Section 2.7.4.1, "New Fuel Storage," and Section 2.7.4.2, "Spent Fuel Storage."

DCD Tier 2: The applicant has described a DCD Tier 2 system in Section 9.1.2 that includes information on the physical layout, design, construction, and inspection of the new and spent fuel storage racks.

ITAAC: The inspections, tests, analyses, and acceptance criteria (ITAAC) associated with DCD Tier 2, Section 9.1.2, are in DCD Tier 1, Sections 2.7.4.1.2 and 2.7.4.2.2, "Inspection, Tests, Analyses, and Acceptance Criteria."

Technical Specifications: The technical specifications associated with DCD Tier 2, Section 9.1.2, are in DCD Tier 2, Chapter 16, "Technical Specifications," Section 4.3, "Fuel Storage."

Topical Reports: There are no topical reports for this area of review.

Technical Reports: The technical report (TR) associated with DCD Tier 2, Section 9.1.2, is APR1400-H-N-NR-14012-P, Revision 3, "Mechanical Analysis for New and Spent Fuel Storage Racks," issued August 2017.

Cross-Cutting Requirements (Three Mile Island, Unresolved Safety Issue/Generic Safety Issue, Operating Experience): There are no cross-cutting requirements for this area of review.

APR1400 Interface Issues Identified in the DCD: DCD Tier 2, Table 1.8-2, "Combined License Information Items," addresses APR1400 interface issues.

Site Interface Issues Identified in the DCD: DCD Tier 2, Table 1.8-2, addresses site interface issues.

Conceptual Design Information: There is no conceptual design information for this area of review.

9.1.2.1.3 Regulatory Basis

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (SRP), Section 3.8.4, "Other Seismic Category I Structures," Appendix D, "Guidance on Spent Fuel Pool Racks," Revision 4, issued September 2013, gives the relevant requirements of the NRC's regulations and associated acceptance criteria for this area of review, summarized as follows:

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the ability of the design of the new and spent fuel racks to withstand the most severe natural phenomena, such as winds, tornadoes, floods, and earthquakes, and the appropriate combination of all loads.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to the new and spent fuel racks being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to whether shared structures, systems, and components important to safety, such as the new and spent fuel racks, are capable of performing their safety functions without being significantly impaired.

4. GDC 61, "Fuel storage and handling and radioactivity control," as it relates to the design of the new and SFP racks having provisions for safe fuel storage and handling of radioactive materials.

5. GDC 63, “Monitoring fuel and waste storage,” as it relates to monitoring the new and SFP racks to detect conditions that could result in the loss of decay heat removal capabilities, to detect excessive radiation levels, and to initiate appropriate safety actions.

6. 10 CFR 20.1101(b), as it relates to provisions to achieve public and occupational doses that are as low as is reasonably achievable (ALARA).

7. 10 CFR 20.1406, as it relates to the minimization of contamination within the new and spent fuel racks.

8. 10 CFR 50.68, “Criticality Accident Requirements,” as it relates to the criticality requirements of the new and spent fuel racks.

9. 10 CFR 52.47(b)(1), which requires that a design certification (DC) 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 are met, a plant that incorporates the DC is built and will operate in accordance with the DC; the provisions of the Atomic Energy Act of 1954, as amended; and the regulations of the U.S. Nuclear Regulatory Commission (NRC).

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

1. SRP Section 3.8.4, Revision 4, issued September 2013.

2. SRP Section 3.8.5, “Foundations,” Revision 4, issued September 2013.

3. Regulatory Guide (RG) 1.29, “Seismic Design Classification,” Revision 4, issued March 2007.

4. RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, issued March 2007.

SRP Section 9.1.2 lists the review interfaces with other SRP sections.

9.1.2.1.4 Technical Evaluation

The NRC staff reviewed Section 9.1.2 of the APR1400 DCD against the agency’s regulatory guidance to ensure that the DCD represents the complete scope of information relating to this review topic. SRP Section 3.8.4, Appendix D, identifies seven specific acceptance criteria for fuel racks that are considered acceptable to meet the relevant requirements of the NRC’s regulations, as listed in SRP Section 3.8.4.II, “Acceptance Criteria,” and also included in Section 9.1.2(C) of this safety evaluation report. This section evaluates DCD Tier 2, Section 9.1.2, with regard to each of these seven SRP acceptance criteria.

Appendix D of SRP Section 3.8.4 provides guidelines for the staff to use in reviewing the technical areas related to the design of new and spent fuel racks, based on the requirements of GDC 2, 4, 5, 61, and 63; 10 CFR Part 20.1101(b); 10 CFR 50.68; and 10 CFR 52.47(b)(1). Using the guidance described in Appendix D to SRP Section 3.8.4, the staff reviewed DCD Tier 2, Section 9.1.2, and the associated Technical Report, APR1400-H-N-NR-14012-P,

Revision 3. The review described in this section focused on the following seven considerations for the design of new and spent fuel storage racks.

(1) Description of the new and spent fuel racks,

(2) Applicable codes, standards, and specifications,

(3) Seismic and impact loads,

(4) Loads and load combinations,

(5) Design and analysis procedures,

(6) Structural acceptance criteria, and

(7) Materials, quality control, and special construction techniques.

The staff also reviewed applicable COL information items.

The staff reviewed the design of the new and spent fuel storage racks and the finite element models used to represent the design in the analyses of the fuel storage racks. The rack models are used in the seismic analysis and load drop analysis. The staff reviewed the assumptions made in these analyses and ensured that the stresses induced in the racks remain below the allowable stresses.

9.1.2.1.4.1 Description of New and Spent Fuel Storage

DCD Tier 2, Sections 9.1.2.2.1, "New Fuel Storage," and 9.1.2.2.2, "Spent Fuel Storage," along with the associated TR, APR1400-H-N-NR-14012-P, Revision 3, which is incorporated by reference, describe the physical characteristics of the new and spent fuel racks for the APR1400 plant.

The NFSRs are constructed of stainless steel, and are located in the new fuel storage pit. There are two identical racks, each with a 7 x 8 array of storage cells. The NFSRs are bolted to embedment plates at the bottom of the pit to preclude tipping. The total of 112 storage locations is more than enough to store a refueling batch. The center-to center spacing between adjacent fuel assemblies is designed to be 14 inches to maintain sub-criticality. The applicant's new fuel storage system is designed to meet ANSI/ANS 57.3-1983, "Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants."

The dry fuel storage pit is an unlined reinforced concrete cavity which is covered by stainless steel plates. The bottom of the pit has a drain system which is connected to the Auxiliary Building sump. The cover plates and drain system protect the new fuel assemblies from debris, prevent rapid flooding of the new fuel pit, and provides a method of removing water from the pit. DCD Tier 2, FSAR Figures 9.1.4-8 and 9.1.5-6 show the location of the new fuel storage area and its relation to the spent fuel pool (SFP), the new fuel receipt area, and other structures in the Auxiliary Building. The HVAC system in the Auxiliary Building controls the ambient environment for the new fuel storage system.

The SFSRs are constructed of stainless steel, and are located in the SFP. The SPF is divided into two regions, region I and region II. Region I contains four 8 x 8 array racks and two

6 x 8 array racks; region II contains nineteen 8 x 8 array racks and four 8 x 7 array racks. The SFSRs are freestanding, with pedestals resting on embedment plates, which distribute the weight of the loaded racks to the reinforced concrete floor of the SFP. The center-to center spacing between adjacent fuel assemblies is designed to be 10.83 and 8.86 inches for Regions I and II respectively to maintain sub-criticality

The SFP is constructed to ACI 349-1997, “Code Requirements for Nuclear Safety-Related Concrete Structures” as described in FSAR Table 3.2-1. The SFP liner and connected piping are fabricated from Type 304 austenitic stainless steel using material specifications ASTM A-240 and ASME/ASTM (S)A-312. ASTM grade material is used for the SFP liner and the welds of the liner are encapsulated by C-shaped embedments. The C-shaped embedments are designed to collect and direct leakage from the SFP, if any was to occur though the weld joints.

Fabrication of both the new and spent fuel racks is in accordance with the requirements of Subsection NF of Section III, “Rules for Construction of Nuclear Facility Components,” of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code).

The staff reviewed the description of the new fuel and spent fuel storage racks included in DCD Tier 2, Section 9.1.2, and the associated TR, APR1400-H-N-NR-14012-P, which is incorporated by reference in Table 1.6-2, “List of Technical Reports.” The staff determined that a detailed description and the design criteria for the SFP and the pool stainless steel liner were not included in DCD 3.8.4; therefore, the staff could not review how the loads from the storage racks were incorporated in the design. Therefore, in RAI 287-8272, Question 09.01.02-09, the staff asked the applicant to adequately describe the design criteria of the SFP and the pool liner. In its response dated December 15, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15365A547), the applicant stated that it designed the SFP and the pool liner in accordance with American Concrete Institute (ACI) 349 and ASME Code Section III, Division 2, respectively. The applicant also provided markup copies of DCD Tier 2, Sections 3.8.4.1.1, “Auxiliary Building,” and 3.8.4.4.2.7, “Stainless Steel Liner Design,” which describe the physical characteristics and the design criteria of the SFP and the pool liner, respectively.

The staff’s structural safety evaluation of the SFP including the pool liner is provided separately in Section 3.8.3.4.6 of the SER. The staff reviewed the applicant’s response and considered the information provided to be acceptable because the design approach is consistent with design criteria in ACI 349 and Section III, Division 2, of the ASME Code. Accordingly, RAI 287-8272, Question 09.01.02-09, is resolved. The applicant updated DCD Tier 2, Sections 3.8.4.1.1 and 3.8.4.4.2.7, accordingly.

In DCD Tier 1, Revision 0, Section 2.7.4, “New and Spent Fuel Handling System,” Sections 2.7.4.1, “New Fuel Storage,” and 2.7.4.2, “Spent Fuel Storage,” the applicant described the design of the new and spent fuel storage racks. The applicant stated that the new and spent fuel racks are “non-safety related, but seismic Category I for integrity of the spent fuel assemblies.” SRP 3.8.4, Appendix D, states, “Regulatory Guide 1.29, “Seismic Design Classification” classifies spent fuel pool racks as seismic Category I structures. However, the SRP also states spent fuel pool racks should be treated as safety-related components for determining Quality Assurance requirements (10 CFR Part 50, Appendix B) and periodic condition monitoring requirements (10 CFR 50.65 “Maintenance Rule”).”

Therefore, in RAI 287-8272, Question 09.01.02-47, the staff asked the applicant to provide a technical justification for treating the racks as nonsafety-related components and the basis for determining the quality assurance requirements and periodic condition monitoring requirements for the racks. The applicant's response dated September 6, 2016 (ML16250A862) states that the new and spent fuel storage racks are seismic Category I structures that are treated as safety-related components in accordance with the quality assurance criteria of 10 CFR Part 50, Appendix B. The applicant's response also included a combined license (COL) Item (COL 9.1(2)) directing the COL applicant to prepare a periodic inspection program of the spent fuel rack integrity to ensure that the design-basis material and geometric assumptions remain valid during the operating life of the plant. Additionally, the applicant incorporated the quality control and quality assurance procedures in Section 2.3.3, "Quality Control and Quality Assurance," of the TR, APR1400-H-N-NR-14012-P, Revision 3.

The staff reviewed the applicant's response and considered it to be acceptable because itis consistent with SRP 3.8.4, Appendix D, with respect to the staff's expectations for quality assurance and periodic inspection for the spent fuel storage racks. Accordingly, RAI 287-8272, Question 09.01.02-47, is resolved. The applicant updated DCD Tier 1, Revision 1, Sections 2.7.4.1.1, "Design Description," and 2.7.4.2.1, "Design Description," and DCD Tier 2, Revision 1, Sections 9.1.2.2.2, 9.1.6, "Combined License Information," and Table 1.8-2, "Combined License Information Items," accordingly.

The staff concludes that the information prescribed in DCD Tier 2, Section 9.1.2, and the associated TR, APR1400-H-N-NR-14012-P, Revision 3, provide sufficient detail to define the primary structural aspects and elements relied upon for the new and spent fuel racks to perform their functions. The staff finds the description in DCD Tier 2, Section 9.1.2, and TR APR1400-H-N-NR-14012-P, Revision 3, to be acceptable on the basis that the description of the new and spent fuel racks is consistent with the acceptance criteria in 10 CFR Part 50, Appendix B; 10 CFR 50.65; 10 CFR Part 50, GDC 1 and 2; and SRP 3.8.4, Appendix D.

9.1.2.1.4.2 Applicable Codes, Standards, and Specifications

APR1400-H-N-NR-14012-P, Revision 3, Section 6, "References," identifies the following industry codes and regulatory guides that are applicable to the design, fabrication, construction, materials, testing, and inspections of the new and spent fuel storage racks for the APR1400 plant:

- ASME Code, Section III, Division 1, 2007 Edition through 2008 Addenda
- ASME Code, Section II, "Materials," 2007 Edition through 2008 Addenda
- RG 1.29
- RG 1.61

The staff reviewed the applicable codes and standards given in TR APR1400-H-N-NR-14012-P, Revision 3, Section 6, and found the use of these codes, standards, and specifications in the design and construction of the APR1400 new and spent fuel storage racks to be in accordance with the guidance given in SRP Section 3.8.4, Appendix D. On this basis, the staff concludes that the list of applicable codes provided in the TR, APR1400-H-N-NR-14012-P, Revision 3, Section 6, is acceptable.

9.1.2.1.4.3 Seismic and Impact Loads

DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design," and applicable sections of the TR, APR1400-H-N-NR-14012-P, Revision 3 describe the seismic analysis and design of the fuel storage racks. The spent fuel racks are designed as freestanding structures resting on embedment plates in the SFP floor, in the AB. The racks are permanently submerged in water. There are 6 racks in region I and 23 racks in region II, with gaps between the adjacent racks and the surrounding fuel pool walls. These racks are likely to slide and tilt during a seismic event and could potentially impact one another or the fuel pool walls. The racks' support pedestals may lift up and impact the SFP floor. There are also gaps between the individual fuel assemblies and the walls of the cells in which they are stored. The applicant performed a detailed three-dimensional (3-D), nonlinear, time-history analysis of the rack assembly to assess the seismic behavior of the racks. In addition to potential impacts during a seismic event, the applicant also analyzed the impact of an accidental drop of a fuel assembly on the racks. This section describes the staff's evaluation of the analysis and design of the racks for seismic and impact loads.

The staff reviewed the methodologies used by the applicant to determine the input to the seismic analysis of the NFSRs and SFSRs. The staff specifically reviewed the development of the in-structure response spectra (ISRS) and time histories, using the criteria described in SRP Section 3.7.1, "Seismic Design Parameters." In Section 3.1.1, "Acceleration Time Histories Generation," of Revision 0 of the TR, the applicant stated, "An accurate evaluation of nonlinear response requires a 3-D time-history analysis to establish the proper response during a seismic loading. Therefore, the initial step in a 3-D time-history analysis is to develop time-history loadings in the three orthogonal directions that comply with the guidelines of the NRC SRP 3.7.1."

The acceptance criteria for the nonlinear seismic analysis are determined according to SRP Section 3.7.1, which states, "For nonlinear structural analysis problems, multiple sets of ground motion time histories should be used to represent the design ground motion. Each set of ground motion time histories can be selected from real recorded or artificial time histories. The amplitude of these ground motions may be scaled but the phasing of Fourier components should be maintained. The adequacy of this set of ground motions, including duration estimates, is reviewed on a case-by-case basis." SRP Section 3.7.1, Option 2, delineates the requirements for multiple sets of time histories. It states, "For nonlinear structural analyses, the number of time histories should be greater than four and the technical basis for the appropriate number of time histories are reviewed on a case-by-case basis. The staff's review also includes the adequacy of the characteristics of the multiple time histories."

Based on the review of DCD Tier 2, Section 9.1.2, and the referenced TR, APR1400-H-N-NR-14012-P, Revision 0, it was not clear to the staff whether the applicant met the regulatory requirements for the design of the new and spent fuel racks with respect to the use of multiple time histories. In RAI 287-8272, Question 09.01.02-15, the staff asked the applicant to clarify and confirm that it used at least the five sets (greater than the required four) of time histories for the nonlinear structural analyses of the new and spent fuel storage racks and to provide a technical justification for selecting the number of time history sets used in the nonlinear seismic analyses.

In its response to RAI 287-8272, Question 09.01.02-15, dated August 31, 2017 (ML17243A348), the applicant stated that it developed five sets of artificial acceleration time

histories for three orthogonal directions (North-South (N-S), East-West (E-W), and vertical) specific to the NFSRs and SFSRs. The fully synthetic acceleration time histories were developed to match the safe shutdown earthquake (SSE) ISRS (i.e., no time history seed was used). For the NFSRs, the AB ISRS at elevation 41.9 meters (m) (137 feet (ft) 6 inches (in.)) were used. For the SFSRs, response spectra were selected to envelope the ISRS at the elevation of the SFP base (34.7 m, 114 ft 0 in.) and the pool wall (40.2 m, 132 ft 0 in.). The top of the SFSRs is at approximately 39.6 m (130 ft) with the bottom at about 35 m (115 ft). The applicant further stated that the five artificial time histories have a duration of 25 seconds and meet the guidelines set forth in SRP Section 3.7.1. Additionally, consistent with RG 1.61, the 4-percent damped SSE response spectra were used to generate the synthetic time histories for the APR1400 fuel storage racks.

The staff reviewed the applicant's response and considers it to be acceptable because the methodology for analyzing the seismic analysis of its new and spent fuel storage racks is consistent with the regulatory guidance in SRP Section 3.8.4, Appendix D, and Section 3.7.1. The seismic analyses for the NFSRs and SFSRs consider five sets of artificial seismic time histories. The suitability of the time histories was verified in accordance with SRP Section 3.7.1, Option 2, criteria for multiple sets of time histories. The applicant also provided markup copies of the proposed changes to applicable sections of the TR. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P (ML17242A310), and confirmed that it was revised, consistent with the response to RAI 287-8272, Question 09.01.02-15. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-15, to be resolved.

Section 3.6, "Dynamic Simulations," of the TR, Revision 0, describes the nonlinear dynamic simulations of the new and spent fuel racks to determine the structural integrity of the racks. The applicant stated, "The storage rack configurations at the full loading are considered in the dynamic simulations." This sentence implies that assuming every rack with the full loading in the seismic or impact analyses results in a conservative design. It is not apparent to the staff that assuming the full loading for every rack is conservative. For example, consider the following scenario: Assume a fully loaded rack subjected to an earthquake does not slide; now, consider two racks with one rack empty and the other rack fully loaded. During the same earthquake, the lighter rack slides because its friction force at the base is now less than if it were fully loaded. The fully loaded one by itself would not slide; however, it may slide because of the impact from the lighter rack; thus, the whole system (the lighter rack and the fully loaded rack) slides. Based on the above example, in RAI 287-8272, Question 09.01.02-16, the staff asked the applicant to provide a technical rationale and the results of any study performed to demonstrate that the assumption that all fully loaded racks will always result in a conservative design. Otherwise, the applicant was asked to consider appropriate loading patterns in the analyses. The loading patterns considered should include the case of all racks completely empty to demonstrate that the racks and the liner of the SFP would not be damaged from the impact.

In its response to RAI 287-8272, Question 09.01.02-16, dated August 31, 2017 (ML17243A348), the applicant in Table 3-5 provided a list of simulations performed for the new and spent fuel racks when subject to seismic loadings. In its dynamic simulation of the racks, the applicant considered the configurations of the SFSR at full, 25-percent full, 50-percent full, and empty mixed loadings and the NFSR fully loaded. The applicant performed the nonlinear dynamic analyses for dynamic simulations of the NFSRs and the SFSRs using the ANSYS finite element program and compared the results of the simulations to the stress and kinematic

criteria. The applicant also performed sensitivity runs for the NFSRs and the SFSRs to demonstrate that the fuel rack response is reasonably bounded.

The staff reviewed the applicant's response and considers it to be acceptable because the applicant demonstrated that the dynamic analysis of the fully loaded racks results in a conservative design. The applicant provided a markup table that shows that the freestanding SFSRs do slide and that different fuel loading arrangements were considered. Table 3-5, "List of Simulations," showed that most runs analyzed for fully loaded racks, but one sensitivity involved all racks being empty and another had one quarter-full rack and two half-full racks loaded uniformly. The results in Table 3-6 showed that the displacements of the empty fuel racks were significantly less than those of the fully loaded racks. The applicant also provided markup copies of the proposed changes to applicable sections of the TR. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-16. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-16, to be resolved.

Section 3.1.2.2, "Details for Rack and Fuel Assembly," of the TR, Revision 0, describes the detail dynamic analysis modeling of the racks. The applicant stated, "A vertical movement of fuel assembly is assumed to be the same as the vertical movement of the storage rack." The applicant's assumption implies that that there is no fuel rattling in the vertical direction because the vertical displacement of the fuel is the same as the vertical displacement of the rack. However, there is a potential for the fuel assembly to separate from the baseplate during vertical ground motion, depending on the vertical frequencies, phasing, and relative maximum vertical input acceleration of the fuel assembly and the storage rack. In RAI 287-8272, Question 09.01.02-17, the staff asked the applicant to provide a technical justification for concluding that the vertical movement of the fuel assembly and the storage rack is the same.

In its response to RAI 287-8272, Question 09.01.02-17, dated August 31, 2017 (ML17243A348), the applicant provided the fundamental vertical frequencies of the new and spent fuel racks and the fuel assembly, which all exceed the zero period acceleration frequency of the applicable in-structure response spectra. The applicant provided plots of the spectra, showing that the zero period acceleration in all cases is less than 1g. Therefore, the weight of the fuel assembly is not overcome by the vertical seismic acceleration, eliminating the possibility of uplift. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-17, to be resolved.

Section 3.4.3, "Structural Damping," of the TR, Revision 0, describes the types of structural damping used in the dynamic analysis modeling of the racks. The applicant stated, "Rayleigh damping is used to specify mass (M) and stiffness (K) proportional damping (C)." The applicant further stated that the constant multiplier to the mass and stiffness matrix is calculated in the range of the lowest and highest frequencies of interest in the dynamic analysis. In RAI 287-8272, Question 09.01.02-18, the staff asked the applicant to provide (1) the numerical value of the range of the lowest and the highest frequency considered, (2) natural frequencies of new and spent fuel storage racks identifying the primary horizontal, vertical, and rocking frequencies of vibration, and (3) the technical basis for determining that the range of the lowest and highest frequencies specified in the analysis will provide conservative results.

In its response to RAI 287-8272, Question 09.01.02-18, dated August 31, 2017 (ML17243A348), the applicant stated that the fundamental frequencies of the NFSR and the SFSR are above 20 and 30 Hertz (Hz), respectively. The applicant further stated that "the

design basis damping value for the NFSRs and the SFSRs is 4% for a SSE event in accordance with the regulatory guide (RG) 1.61 for welded steel. The frequency range from 2 Hz to 85 Hz is applied to NFSR, while 2 Hz to 65 Hz is applied to SFSR considering installation in the water. The frequencies selected bound the natural frequencies of interest (e.g., for the NFSRs and SFSRs, frequencies of the fuel assemblies and rack structure). The damping model underpredicts damping (i.e., is conservative) at intermediate frequencies where the highest input accelerations occur."

The staff reviewed the applicant's response and considers the information to be acceptable because (1) the frequencies selected bound the natural frequencies of interest for the NFSRs, and the SFSRs, (2) the damping model underpredicts (i.e., is conservative) at intermediate frequencies where the highest input accelerations occur, and (3) the applicant provided markup copies of the TR that fully describe the natural frequencies and the structural damping used in its dynamic analysis of the storage racks. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-18. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-18, to be resolved.

9.1.2.1.4.3.1 Modeling of Fuel Assem*bly*

Section 3.1.2.2 of the TR, Revision 0, describes the mathematical model of the rack and fuel assembly and the computer program used for the nonlinear seismic analysis. The staff reviewed the information provided and determined that the information on the rack and fuel assembly mathematical model and the computer program used for the nonlinear seismic analysis is insufficient. In RAI 287-8272, Question 09.01.02-30, the staff asked the applicant to provide the technical basis for the three-node model of the fuel assembly; assumptions and computational details of the contact stiffness between the fuel and the rack's cell wall, as well as the details of benchmarking, validation, and verification of the ANSYS commuter program used in the seismic analysis of the fuel rack assembly.

In its response to RAI 287-8272, Question 09.01.02-30, dated August 31, 2017 (ML17244A512), the applicant stated that the NFSR and fuel assembly model is of a single rack and includes 3-D elastic beam elements (ANSYS BEAM4) and lumped mass elements (ANSYS MASS21) with properties derived from the dynamic characteristics of the detailed 3-D shell model of the NFSR.

Effective structural properties for the dynamic model are determined from the natural frequencies and mode shapes of the detailed model. Vertical portions of the NFSR cells and fuel assemblies are each represented by five nodes. Nodes are located at the rack baseplate, ¼ H, ½ H, ¾ H, and H (where H is the rack height measured above the baseplate). Each rack node has six degrees of freedom (three translations and three rotations) and a lumped mass associated with it. The nodes for the rack and the fuel assembly are connected by contact elements (ANSYS CONTAC52) in the horizontal direction. There is a single contact element in the vertical direction between the fuel assembly bottom node and the base plate node. The applicant also noted that the SFSR model is similar to the NFSR model and is composed of elastic beam elements and lumped mass elements with properties derived from the dynamic characteristics of the detailed 3-D shell model of the SFSR.

All the fuel assemblies in each storage rack module are modeled as one beam of which the mass equals the sum of the masses of all the fuel assemblies in a rack module. Because the

fuel assemblies in a rack module are modeled together, all fuel assemblies move simultaneously in one direction. This assumption results in larger impact forces on the rack module than the actual case and results in conservative loads on the storage rack. Because the fuel assembly is modeled with five nodes, the calculated impact loads on the nodes will be larger than the actual value because the fuel assembly has 11 spacer grids. The maximum fuel assembly grid horizontal impact load is determined by dividing the maximum impact load at each node by the number of grids associated with that node. Lumped masses of the rack and fuel assemblies are distributed among the five nodes for SFSR cells and fuel assemblies. Each node of the fuel assembly beam is connected to the corresponding node of the rack beam using a contact element to represent the impact between the fuel assembly and the rack cell wall. The normal direction stiffness of this element is calculated assuming a series spring connection of the stiffness of the fuel assembly spacer grid and the local stiffness of the cell in the horizontal direction. To be conservative, the cell wall local stiffness is neglected. The fuel assembly/rack cell contact element has a local stiffness (Ki) to account for the impact phenomena of the fuel assembly-to-cell wall. The grid stiffness for a fuel assembly beam is multiplied by the number of fuel assemblies assumed to be in the rack. The stiffness of the fuel assembly grid is applied by dividing the total grid stiffness at each node by the number of grids associated with the node.

In its response on the benchmarking of the ANSYS computer code used in its analysis of the fuel storage racks, the applicant stated that it performed a benchmarking study to demonstrate that the ANSYS computer program, Version 15.07, is an acceptable computer code for the seismic analysis of the SFSR and NFSR. While SRP Section 3.8.1, "Concrete Containment," Section II.4.F, "Computer Programs," states that meeting any one of the following methods is sufficient to validate computer programs used for design analysis, the benchmarking study addressed all three:

(1) The computer program is recognized in the public domain and has had sufficient history of use to justify its applicability and validity without further demonstration.

(2) The computer program's solutions to a series of test problems have been demonstrated to be substantially identical to those obtained from classical solutions or from accepted experimental tests or to analytical results published in the technical literature. The test problems should be demonstrated to be similar to or within the range of applicability of the classical problems analyzed to justify acceptance of the program.

(3) The computer program's solutions to a series of test problems have been demonstrated to be substantially identical to those obtained by a similar and independently written and recognized program in the public domain. The test problems should be demonstrated to be similar to or within the range of applicability of the problems analyzed by the public domain computer program.

The applicant further stated that the nuclear energy industry has used the ANSYS computer program for nearly 40 years. The ANSYS software is developed within an ISO 9001 quality program that meets the requirements of both ASME NQA-1 and 10 CFR Part 50, Appendix B. The NRC staff has previously accepted the ANSYS software for performing seismic structural analyses of SFSRs on a case by case basis. The applicant ran five test cases with ANSYS Version 15.07 to compare ANSYS results to analytical results published in the technical literature. These test cases exercised the ANSYS elements (MASS21, COMBIN14,

CONTAC52, BEAM4, and MATRIX27) and features (direct integration time history, mass, spring, friction, impact, and hydrodynamic coupling) used for the APR1400 fuel rack seismic analysis. The five test cases involved coulomb friction, a two degree of freedom system with inertial coupling, mass impact on a beam, mass impact on a flexible surface, and the Fritz methodology for modeling hydrodynamic mass.

The applicant concluded that the results of these five test problems were reasonable when compared to the published analytical results. To further validate the use of ANSYS for the APR1400 fuel rack seismic analysis, the applicant analyzed a single SFSR with both the ANSYS and LS-DYNA computer programs for five different sets of acceleration time histories. ANSYS is an implicit finite element code used for structural analysis with the capability to perform both static and dynamic simulations, while LS-DYNA is an explicit finite element code used for transient analysis. The two computer codes were in reasonable agreement (i.e., the result for maximum forces for design), considering the highly nonlinear nature of the response of the freestanding racks subject to a seismic base excitation.

The staff reviewed the applicant's response and considers the information to be acceptable because (1) the applicant used a more refined five-node model instead of the three-node model of the fuel assembly to adequately represent the dynamic characteristics of the fuel assembly, (2) the applicant provided detailed information that describes how the stiffness of the beam that represents all the fuel assemblies in a rack is calculated to capture the dynamic characteristics of the free-standing racks under seismic loading, and (3) the applicant provided markup copies of the TR that fully describe the details of the rack and fuel assembly, the stiffness of the model, and the benchmarking of the ANSYS computer code. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-30. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-30, to be resolved.

9.1.2.1.4.3.2 *Rack-to-Rack Impact*

Section 3.7.1.3, "Impact Loads," of the TR, Revision 0, describes the case of rack-to-rack impact. The applicant stated that the prominent baseplate of the fuel storage rack for the APR1400 design is installed almost in contact with the adjacent baseplate and that the analysis results show that the impact occurs not between the pool wall and the upper part of the rack, but rather between the baseplates of the racks. The applicant did not provide details of the spring rates considered for the rack-to-rack impacts. In RAI 287-8272, Question 09.01.02-31, the staff requested that the applicant provide the technical basis for calculating the impact spring constant for the rack-to-rack and rack baseplate-to-rack baseplate impact analysis to maximize the impact force and to address how it considered the sensitivity of the impact force to the impact spring constant in its analysis and design of the storage racks.

The applicant's response to RAI 287-8272, Question 09.01.02-31, dated August 31, 2017 (ML17244A512), states that the upper parts of the racks do not come into contact. Therefore, the only rack-to-rack contact is between the baseplates of the racks. To minimize the impact of the rack-to-rack force, the SFSRs are installed as closely as possible with the protruding baseplate intended to be in contact with the adjacent baseplates. The applicant provided equations that showed how the impact spring constant between baseplates is calculated, in order to predict the impact force. The applicant further stated that three sensitivity analyses were performed on the spring constants in the model:

- The rack-to-floor stiffness was evaluated at ±20 percent of the nominal value.
- The rack-to-rack stiffness was evaluated at ±20 percent of the nominal value.
- The fuel-to-rack stiffness was evaluated at ±20 percent of the nominal value.

The applicant concluded that the effect of the sensitivities was a change in predicted loads within the variation found for different time histories and was less than the variation for different coefficients of frictions.

The staff reviewed the applicant's response and concluded that the information it provided is acceptable because it adequately addresses the rack-to-rack and rack baseplate-to-baseplate impact analysis. In addition, the applicant provided markup copies of the TR that fully describe the spring constant for the rack baseplate-to-baseplate and the rack-to-rack impact. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-31. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-31, to be resolved.

9.1.2.1.4.3.3 Fuel-to-Cell Wall Impact

Section 3.7.1.3 of the TR, Revision 0, describes the case of fuel-to-cell wall impact. Between the fuel assemblies and the walls of the guide tubes are gaps, and because of those gaps, additional loads can be generated by the impact of fuel assemblies during a postulated seismic excitation. Additional loads resulting from this impact effect may be determined by estimating the kinetic energy of the fuel assembly. The maximum velocity of the fuel assembly may be estimated to be the spectral velocity associated with the natural frequency of the submerged fuel assembly. Thus, the loads generated should be considered for local as well as overall effects on the walls of the rack, the supporting framework. It should be demonstrated that the consequent loads on the fuel assembly do not lead to damage of the fuel. In RAI 287-8272, Question 09.01.02-13, the staff asked the applicant to provide a detailed description how the additional loads caused by the impact of fuel assemblies during a postulated seismic excitation are computed and how these loads are considered in the analysis and design of the walls of the rack and supporting framework, as well as a demonstration of the structural integrity of the fuel.

In its response to RAI 287-8272, Question 09.01.02-13, dated August 31, 2017 (ML17243A348), the applicant stated that the maximum impact loads of the fuel assembly-to-cell wall are determined by dividing the maximum total fuel assembly beam to cell wall load by the number of fuel assemblies in the rack under evaluation (e.g., divide by 64 for a full rack, 32 for a half-full rack). For purposes of determining the effect on the fuel assembly grids, the impact load on each of the fuel support grids at each time step is determined by dividing the maximum calculated impact load per cell at each of the five nodes by the number of spacer grids associated with each of the nodes. For each run, the impact loads in the East-West (E-W) and North-South (N-S) directions are combined using the square-root-of-the sum-of-the squares (SRSS) method.

The lateral impact load on the spent fuel assembly is evaluated for two acceptance criteria: fuel spacer grid buckling and fuel cladding yield stress. The structural integrity of fuel assembly cladding is evaluated for the maximum lateral acceleration load, obtained by combining by SRSS the maximum impact loads in the E-W and N-S directions at any time step. The fuel assembly spacer grid is evaluated for the maximum grid impact load, obtained by combining by SRSS the impact loads in the E-W and N-S directions at each time step. The lateral impact

loads on a single fuel spacer grid are compared against the critical buckling load of the fuel spacer grid. The maximum lateral acceleration acting on the fuel mass is used to calculate a load uniformly distributed over a single fuel rod modeled as a beam simply supported by the spacer grids. The applicant provided equations for calculating the uniformly distributed load on the fuel rod and the maximum bending stress in the fuel cladding. The applicant compared the bending stress to the yield stress for the fuel rod cladding. The applicant concludes that the structural integrity of the stored fuel assemblies under the SSE event is maintained since safety factors 1.57 and 8.3 for fuel spacer grid and fuel rod cladding, respectively are greater than 1.0.

The staff reviewed the applicant's response and concluded that the detailed information provided by the applicant adequately describes the impact of the additional loads resulting from the fuel assemblies when subject to seismic loadings and the fuel spacer grid and fuel rod cladding has adequate design margin for the design basis SSE loads. The applicant also provided markup copies of the technical report that fully describe the impact load for the fuel assembly-to-cell wall, the structural evaluation of the fuel space grid, and the stress evaluation of the fuel cladding. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-13. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-13, to be resolved.

9.1.2.1.4.3.4 Evaluation of Bearing Pressure on Pool Slab Due to Pedestal Impact Load

Section 3.1.2.1, "General Considerations," and Section 3.7.1.2, "Support Pedestal Loads of Rack," of the TR, Revision 0, describe the pedestal-to-bearing pad interface in the dynamic model of the rack for the impact loads. In Table 3-9, "Maximum Loads on Single Pedestal," the staff noted that, for the SFSR, the force on the pedestal in the N-S direction is generally much less (about 50 percent) than that in the E-W direction. The staff did not find sufficient details and description of the underlying analyses in the report and was not able to confirm a large variation in forces in the two horizontal directions. In RAI 287-8272, Question 09.01.02-14, the staff asked the applicant to provide a technical justification for the large difference in pedestal forces in the two horizontal directions. In its response to RAI 287-8272, Question 09.01.02-14, dated August 31, 2017 (ML17243A348), the applicant showed that the seismic loading in the N-S direction is approximately fifty-percent of the seismic loading in the E-W direction. This is consistent with the difference in structural responses between the N-S and E-W directions. The applicant provided Table 3-7, "Maximum Pedestal Loads of Each Simulation," which shows the maximum horizontal and vertical loads generated on the support pedestal when subject to seismic loading; those loads are used to perform the structural integrity evaluation of the support pedestal and the rack. The dynamic simulations of the racks give results for the vertical and two horizontal forces (i.e., E-W and N-S directions) throughout the transient. From those values, the maximum axial force in the vertical direction and the maximum shear forces of the two horizontal directions per pedestal are determined. The resultant shear force for each run is conservatively calculated by combining the maximum horizontal loads on any single pedestal using the SRSS method. The maximum bending moment at the bottom baseplate-to-pedestal interface is computed by multiplying the maximum shear force and the distance from the bottom baseplate to the contact point surface underneath the NFSRs and SFSRs.

In Section 3.1.2.1 of the TR, Revision 0, the applicant included the pedestal-to-bearing pad interface in the dynamic model of the rack for the impact loads. However, the staff noted that the acceptance criteria for the bearing pad were not provided. In RAI 287-8272, Question 09.01.02-32, the staff asked the applicant to provide a sketch showing the bearing pad

dimensions; a layout of the bearing pad with respect to the rack pedestal and the pool floor; and the acceptance criteria for the bearing pads, including the maximum calculated and allowable bearing stress. In its response to RAI 287-8272, Question 09.01.02-32, issued August 31, 2017 (ML17244A512), the applicant stated that the SFSR modules are free standing with pedestals resting on embedment plates that distribute the dead weight of the loaded racks to the reinforced concrete structure of the floor and that the SFSRs do not rest on the liner or use bearing pads. The applicant provided figures that show the layouts and dimensions for the embedment, including the spent fuel rack modules.

The staff reviewed the applicant's response and concluded that the detailed information provided by the applicant adequately describes the variance in the pedestal forces in the two horizontal directions and the layouts and dimensions for the embedments. The applicant also provided markup copies of the TR that fully describe the support pedestal loads of the racks and the SFSRs. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Questions 09.01.02-14 and 09.01.02-32. Accordingly, the staff considers RAI 287-8272, Questions 09.01.02-14 and 09.01.02-32, to be resolved.

9.1.2.1.4.3.5 Mechanical Accidents Evaluation

Chapter 4, "Mechanical Accidents Analysis," of the TR, Revision 0, describes the performance of the fuel racks under postulated mechanical accident conditions using the energy balance method. The evaluation considers three postulated fuel assembly drop scenarios (shallow drop, deep drop away from the support pedestal, and deep drop above the support pedestal). The applicant provided additional details of the analysis, including the methods used to perform the calculations and the formulas used to evaluate the postulated fuel assembly drop scenarios. In Section 4.1 "Description of Mechanical Accident," the applicant assumed that a dropping mass (fuel assembly along with the handling tool) drops down from a height of 0.61 meters (m) (2 ft). The applicant did not provide a technical basis for this assumption. In RAI 287-8272, Question 09.01.02-10, the staff asked the applicant to provide (1) sketches and sufficient details of the fuel handling system to facilitate the review of the fuel drop parameters, (2) the justification for the assumption, (3) a description of both the fuel handling operation that determines the drop height of 0.61 m (2 ft) and the operational controls on spent fuel handling that will ensure that the analyzed 0.61-m (2-ft) drop height will not be exceeded, and (4) a COL information item that includes the development of plant procedures and control of the fuel handling activities over the SFP. In its response to RAI 287-8272, Question 09.01.02-10, dated January 7, 2016 (ML16007A389), the applicant stated that the spent fuel handling machine is designed to permit the bridge or trolley movement only when the auxiliary hoist hook with the spent fuel assembly is at the predetermined operational up-limit. The applicant also provided sketches that show the handling of the fuel assembly with the machine's handling tool at an elevation of less than 40.2 m (132 ft). The applicant concluded that, since the top elevation of the SFSR is 39.6 m (130 ft), the fuel assembly cannot be lifted more than 0.61 m (2 ft) from the top of the SFSR. The applicant also included a COL item (COL 9.1(4)) in Section 9.1.2.2.3, specifying the COL applicant to provide plant procedures and administrative control of fuel handling activities over the SFP, to ensure the assumed 0.61 meter drop height is not exceeded.

The staff reviewed the applicant's response and finds the information to be acceptable because it provided a technical basis for assuming a 0.61-m (2-ft) drop for the mass of the fuel assembly and the handling tool. The analysis demonstrates that a shallow fuel drop onto a fuel assembly

tube sidewall would result in approximately 8.66 inches of damage to the fuel assembly tubes measured from the top of the structure. The top of the neutron absorbing material is approximately 24 inches below the top of the spent fuel rack. The staff concludes that dropping a fuel assembly onto the sidewall of a fuel assembly tube would not damage the Metamic neutron absorbing material. Moreover, the applicant included a COL item (COL Item 9.1(4)), which requires the COL applicant to provide plant procedures and administrative control of fuel handling activities over the SFP. The staff confirmed that DCD Tier 2, Revision 1, dated March 10, 2017, was revised as specified in the response to RAI 287-8272, Question 09.01.02-10. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-10, to be resolved.

Section 4.3, "Analysis Method," of the TR, Revision 0, describes the analysis method for computing the different mechanical accident scenarios. The applicant stated, "This calculation covers the new fuel storage racks in NFP [new fuel pit] and the spent fuel storage racks of region I and region II in SFP. Region I racks are structurally stronger than region II racks. To conservatively estimate the damage of the racks due to the postulated drop accidents, the calculation is performed for region II racks. Since the new fuel storage rack is firmly attached to the embedment plates of NFP using a stud bolt and is supported by additional intermediate plate, and has no 'poison zone,' the drop accident evaluation is performed only for the case of drop (away from pedestal) on baseplate of the new fuel rack."

In RAI 287-8272, Question 09.01.02-33, the staff asked the applicant to provide a technical basis for concluding that the SFSRs in region I are structurally stronger than the region II racks. In its response to RAI 287-8272, Question 09.01.02-33, dated August 31, 2017 (ML17244A512), the applicant stated that some of the region II periphery cells, which are formed by welding a panel plate to three adjacent box cells, are structurally weaker. Therefore, a shallow drop over a region II rack periphery panel plate governs. For deep drops over a pedestal, impact velocities are the same for both regions. For deep drops away from a pedestal, the impact velocities for region I and region II SFSRs are calculated based on the inner dimension of the damaged fuel canister cells and that of other cells, respectively. Drop height causes different drag conditions for region I and region II SFSRs. The impact velocity for the region I SFSRs is greater than those of region II and is used in the drop analysis. A drop into an NFSR is through air, rather than water; consequently, it has a higher impact velocity.

The staff reviewed the applicant's response and finds the information to be acceptable because the structurally weaker region II racks are analyzed for the maximum SFSR impact velocities. The applicant also provided markup copies of the technical report that describe how the impact velocities of the SFSRs in regions I and II are calculated. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-33. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-33, to be resolved.

In Section 4.1(2), "Straight Deep Drops," of the TR, Revision 0, the applicant considered the drop of a fuel assembly into a cell away from the support pedestal for one of the "Straight Deep Drops" scenarios. The falling assembly enters a storage cell and impacts the rack baseplate. It is not clear from the description whether the rack baseplate evaluation caused by the fuel impact assumed that other fuel assemblies are in place when a fuel assembly drops through an empty cell. A full load of fuel assemblies may introduce progressive deformation of the baseplate after a fuel assembly impacts the rack baseplate. The maximum downward deformation of the baseplate may be significant enough to initiate a progressive deformation. In

RAI 287-8272, Question 09.01.02-23, the staff asked the applicant to provide (1) the technical basis and justification for not considering all other fuel assemblies in place when a fuel assembly drops through an empty cell and (2) specific location(s) of the drop on the rack base plate that were considered to maximize the deformation of the rack baseplate.

In the applicant's response to RAI 287-8272, Question 09.01.02-23, dated August 31, 2017 (ML17244A512), it stated that, for assessing the impact of a drop on the baseplate, away from the support pedestal, two locations are considered (a central cell and a peripheral cell at the midpoint of a side) that maximize the distance to the points of support. A fuel assembly along with the handling tool is dropped from a fuel bottom height of 0.61 m (2 ft) above the racks. The falling assembly is assumed to enter an unoccupied storage cell away from a pedestal and impact the rack baseplate. This scenario is also evaluated for the NFSR, and the analysis for this scenario is the same as for the SFSR, except the speed at impact is higher because the drop does not have the viscous drag associated with falling through water. The applicant assumed that the rack is fully loaded with fuel assemblies for the straight deep drop scenario.

The applicant further stated that all the drops were analyzed by developing a finite element model in ANSYS LS-DYNA. The impactor (e.g., the fuel assembly and its handling tool, a dropped transport container handling tool) is conservatively modeled as a rigid solid with no energy absorption capacity except for the straight deep drop over a pedestal. The detailed configurations of the impact target (i.e., the rack) are modeled in all analyzed events. The deep drop analysis model considers the effects of all the stored fuel assemblies in the rack by modifying the density of the baseplate to simulate the loading effects of the other fuel assemblies. In most cases, the model of the rack did not include any the structure underneath the rack, but, for the deep drop over a pedestal, the effect of the impact on concrete underneath the pedestal baseplate was evaluated. The applicant provided figures that show the detailed finite element models, the impact locations of the drop on the baseplate, and the results for the straight deep drop scenario, including the plastic strain and the maximum stress on the baseplate. ANSYS LS-DYNA Elements, SHELL163 (explicit thin structural shell), and SOLID164 (explicit 3-D structural solid), were used to mesh the cell walls, baseplate, and rack feet.

The staff reviewed the applicant's response and finds the information to be acceptable because the rack is fully loaded in the drop analysis and the drop locations are appropriate to evaluate the maximum baseplate deflection. The applicant used a detailed 3-D finite element model to demonstrate that the impact of the straight deep drop of a fuel assembly on specific locations on the baseplate does not cause any significant deformation to the baseplate. The applicant also provided markup copies of the TR that fully describe the impact of the straight deep drop scenario. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-23. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-23, to be resolved.

9.1.2.1.4.4 Loads and Load Combinations

Section 3.2, "Stress Limit Criteria," of the TR, Revision 0, describes the loads and load combinations used for the analysis and design of the fuel storage racks. Table 3-1, "Load Combinations for Rack Analysis," provides the load combinations corresponding to the applicable service level limits. The applicable loads and their combinations are excerpted from SRP Section 3.8.4, Appendix D. Dead load, live load, thermal loads, seismic load, stuck fuel

assembly load, and load caused by an accidental fuel assembly drop of the heaviest load from the maximum possible height are the various components of the loads that were considered.

The staff reviewed the loads and load combinations used by the applicant for the analysis and design of the racks. In Section 3.7.3.4(3), "Secondary Stress by Temperature Effects," the applicant stated, "The thermal stress is classified as secondary stress on the ASME Code Section III, Division 1. Therefore, it is independently evaluated without combining with primary stress of other load condition." The staff notes that the thermal stress may not be combined with the primary stress; however, the thermal expansion will reduce the gaps between the fuel assembly and the cell, as well as between racks. The gap reduction increases the possibility for impact between the fuel assembly and the cell, as well as between racks. In RAI 287-8272, Question 09.01.02-11, the staff asked the applicant to quantify thermally the imposed loads at the base of the pedestal and discuss how it has considered these thermal load effects in the analysis and design of the new and spent fuel storage racks.

In its response to RAI 287-8272, Question 09.01.02-11, dated August 31, 2017 (ML17243A348), the applicant stated it considered the temperature gradients across the rack structure caused by differential heating effects between one or more filled cells and one or more adjacent empty cells. The worst thermal stress in a fuel rack is obtained when a storage cell has a fuel assembly generating heat at the maximum postulated rate and the surrounding storage cells contain no fuel. The thermal stresses that occur in this scenario are secondary stresses as defined by ASME Code Section III, Division 1. It is independently evaluated without combining with the primary stress due to other load conditions. The applicant presented a calculation showing that the predicted maximum thermal stress is less than the allowable limit.

The applicant also provided another possible source of temperature-induced stress. It is the expansion of adjacent SFSRs with increased temperature, resulting in a contact load between the baseplates of the adjacent racks or differential expansion of a fuel assembly and the cell surrounding it. The applicant determined that, given the fuel assembly dimensions, the total differential expansion is negligible compared to the available gap.

The staff reviewed the applicant's response and concluded that the evaluation of the effects of thermal loads on the spent fuel storage racks is acceptable because the thermally induced stress and deflections are within acceptable limits. In addition, the staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-11. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-11, to be resolved.

9.1.2.1.4.5 Design and Analysis Procedures

Chapter 3, "Structural and Seismic Analysis," of the TR, Revision 0, describes the various aspects of the procedures for the design and analysis of the fuel storage racks. Chapter 4 describes the performance of the fuel storage racks under postulated mechanical accident conditions. Safety evaluation report Section 9.1.2.1.4.3.5, "Mechanical Accident Evaluation," includes the staff's evaluation of the racks under mechanical accident conditions.

The fuel storage racks are designed for the storage and structural protection of new and spent fuel assemblies. The TR classifies the storage racks as seismic Category I structures. The storage racks are made of stainless steel and are designed by analysis to meet the requirements of ASME Code Section III, Division 1, Subsection NF, for Class 3 linear-type

supports. The classification of the fuel storage racks as seismic Category I, and the approach to design the racks by analysis based on ASME Code Section III, Division 1, Subsection NF, Class 3 component supports are consistent with RG 1.29 and with the guidance in Appendix D to SRP Section 3.8.4. On this basis, the staff concludes that the classification and design by analysis approach for the fuel storage racks in the TR are acceptable.

Table 3-1 provides the postulated load combinations and the corresponding service limits for the fuel storage rack design. In addition to the three service limits (level A, level B, and level D), the racks are designed to maintain functional capability for accidental fuel drop events. The postulated load combinations and the corresponding service limits are consistent with the guidance in Appendix D to SRP Section 3.8.4 and are therefore acceptable. The following paragraphs discuss the staff's evaluation of the design and analytical procedures for the various levels of service limits.

9.1.2.1.4.5.1 Service Level A Limits

Section 3.2.2.1, "Normal Conditions (Level A)," discusses the service level A limits. Service level A limits apply to load combinations, including dead load, live load, and differential temperature-induced loads based on the most critical transient or steady-state conditions under normal operation or shutdown conditions. The applicant provided the acceptance criteria for normal and upset conditions, service level A and service level B in Sections 3.2.2.1 and 3.2.2.2, "Upset Conditions (Level B)," respectively. However, the applicant did not describe or provide the evaluation results for the normal and upset conditions. In RAI 287-8272, Question 09.01.02-34, the staff asked the applicant to describe its evaluation for the normal and upset conditions.

In its response to RAI 287-8272, Question 09.01.02-34, dated August 31, 2017 (ML17244A512), the applicant stated that, for its seismic analysis and design of the APR1400 seismic Category I structures, systems, and components, the operating basis earthquake (OBE) ground motion is defined as one-third the SSE ground motion design response spectra. Therefore, in accordance with 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," an OBE design analysis is not required. The primary stress evaluation for the normal condition is performed for dead weight, which includes only the racks and the fuel assembly weight. The applicant also provided a table that shows the maximum stress factors on rack for service levels A and D.

The staff reviewed the applicant's response and considered it to be acceptable because the new and spent fuel storage racks are designed to meet the applicable acceptance criteria in Appendix D, in SRP 3.8.4, which addresses the appropriate load combinations and allowable stress and deformation limits. The applicant also provided markup copies of the TR and applicable sections of DCD Tier 2, which describe in detail the evaluation of the racks for service level A and D conditions. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-34. However, the proposed changes to applicable sections of DCD Tier 2 have not been implemented. Thus, RAI 287-8272, Question 09.01.02-34, is being tracked as **Confirmatory Item 9.1-1** pending the update to DCD Tier 2, Section 9.1.2.1, "Design Basis," and Table 3.8-9C, "Spent Fuel Storage Rack—Design Loading Combination Table."

9.1.2.1.4.5.2 Service Level B Limits

Service level B limits apply to dead load, thermal loads, and the upward force on the racks caused by a postulated stuck fuel assembly. Section 4.3.5, "Methodology for Stuck Fuel Accident," of the TR, Revision 0, evaluates the stuck fuel assembly. The racks were analyzed using the strength of the materials formula for a bounding vertical pull force of 5,000 pound-force (lbf). The staff reviewed the applicant's analysis and the results and found them acceptable because the calculated stresses meet the service level B allowable limits. However, the staff noted that, in Section 4.3.5, the applicant did not use the allowable stress of level A but instead increased the service level A allowable in shear to service level B allowable. In RAI 287-8272, Question 09.01.02-35, the staff asked the applicant to clarify the apparent inconsistency in the implementation of service level B allowable stress.

In its response to RAI 287-8272, Question 09.01.02-35, dated August 31, 2017 (ML17244A512), the applicant stated that the stuck fuel assembly is evaluated to level B service limits to ensure the integrity of the rack is unaffected. The results showed that the fuel racks are adequate to withstand the uplift force 5,000 lbf caused by a stuck fuel assembly because the neutron absorbing poison plate is not damaged and the structural integrity of the rack is maintained. The applicant also provided a table that showed the results of the evaluation for the cell wall tensile stress, the cell-to-cell weld shear stress, and the base metal shear stress for the stuck fuel assembly accident scenario. The results showed that the calculated stress cell wall, the cell-to-cell weld, and the base metal region are significantly less than the allowable stresses for the level B service condition.

The staff reviewed the applicant's response and considered it to be acceptable because (1) the applicant demonstrated that the forces caused by the uplift of a stuck fuel assembly do not cause damage that affects the margin to criticality or structural integrity, (2) the acceptance criteria for the stuck fuel assembly meet the regulatory guidance in Appendix D to SRP 3.8.4, and (3) the applicant provided markup copies of the TR that fully describe the acceptance criteria and results of the stuck fuel assembly. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-35. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-35, to be resolved.

9.1.2.1.4.5.3 Service Level D Limits

Service level D limits apply to the evaluation of racks for dead load, live load, differential temperature-induced loads based on postulated abnormal design conditions, and SSE-induced loads. Section 3.2.2, "Stress Limit Criteria," of the TR, Revision 0, describes the analysis and design of the racks for level D loads. The following paragraphs describe the staff's evaluation of the analysis and design of the racks for level D loads.

9.1.2.1.4.5.3.1 Dynamic Model

The seismic response of the freestanding fuel storage rack modules is highly nonlinear and involves a complex combination of motions (sliding, rocking, twisting, and turning) resulting in impacts and friction effects. The applicant used the ANSYS Version 10 computer program for the analysis and design of the racks for level D load combinations.

The staff reviewed the basic features of the dynamic model used for simulating the behavior of the racks under seismic excitation. The staff's review determined that additional information

was needed to confirm that the simulations are adequate for predicting the dynamic response of the racks. In RAI 287-8272, Question 09.01.02-20, the staff asked the applicant to provide additional information, including the technical basis and justification of the mathematical model and its parameters (e.g., spring elements, hydrodynamic mass, time history integration time step), that were considered for the nonlinear seismic evaluation of the new and spent fuel racks so that the staff can perform its safety evaluation of the seismic analysis.

In its response to RAI 287-8272, Question 09.01.02-20, dated August 31, 2017 (ML17244A512), the applicant provided a detailed description of the rack and fuel assembly model, the movement of the fuel assembly during a seismic event, the stiffness of the model, the sensitivity analysis performed for the spring constants in the model and the time-history integration time step, the fluid coupling effect of the SFSR, and the impact of the rack-to-rack and rack-to-pool wall in the event of a seismic load. The applicant stated that the NFSR and the SFSR models are composed of 3-D elastic beam elements and lumped mass elements with properties derived from the dynamic characteristics of the detailed 3-D shell model of the NFSR and the SFSR. All the fuel assemblies in each storage rack module are modeled as one beam, of which the mass equals the sum of the masses of all the fuel assemblies in a rack module. Because the fuel assemblies in a rack module are modeled together, all fuel assemblies move simultaneously in one direction. The applicant concluded that this assumption results in larger impact forces on the rack module than the actual case and results in conservative loads on the storage rack.

The applicant further stated that, during a seismic event, the rack is affected by the irregular movement of every single fuel assembly. For a conservative evaluation, all the fuel assemblies within the rack rattle in unison (modeled as a single beam) throughout the seismic event, which exaggerates the impact against the cell wall. For the SFSR model, the applicant used the 3-D elastic beam elements and the contact elements to analyze the spring stiffness of the model, including fuel assembly-to-rack cell wall, pedestal-to-embedment plate, rack-to-rack, and rack-to-pool wall. The applicant performed a sensitivity analysis for the time-history integration time step and provided a figure that showed the displacement plots for of one of the racks. The comparison of the rack top displacements at the time step sensitivity runs showed small changes in calculated results comparable to the run-to-run variation with different time histories.

The staff reviewed the applicant’s response and concluded that the information provided by the applicant is acceptable because it (1) adequately described the modeling of the rack and the fuel assembly and the movement of the fuel assembly during a seismic event, (2) performed a sensitivity analysis and described the sensitivity of the numerical results to the integration time step used in the nonlinear seismic analyses of the racks, and (3) provided markup copies of the TR that fully describe the design details of the racks. The staff reviewed Revision 3 of the TR, APR1400 H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-20. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-20, to be resolved.

Section 3.1.2.3, “Hydrodynamic Mass,” of the TR, Revision 0, details the hydrodynamic masses of the rack-to-rack, and rack-to-fuel assembly of the SFSRs. The staff notes that the applicant did not describe the hydrodynamic mass under the baseplate of each rack. It is the staff’s belief that the applicant should quantify the effect of effective mass from submergence in water. In RAI 287-8272, Question 09.01.02-21, the staff asked the applicant to (1) clarify whether the hydrodynamic mass under the rack baseplate of each rack has been considered in all nonlinear seismic analyses and (2) provide the methodology for calculating this hydrodynamic mass.

In its response to RAI 287-8272, Question 09.01.02-21, dated August 31, 2017 (ML17244A512), the applicant stated that the hydrodynamic mass under the rack baseplate of each rack is considered in the dynamic analysis of the SFSR model to account for fluid coupling. The hydrodynamic mass is included in the SFSR model with the ANSYS MATRIX27 element and added mass, which represents an arbitrary element whose geometry is undefined but whose kinematic response can be specified by mass coefficients. The applicant provided a mathematical formula for calculating the hydrodynamic mass under the baseplate of each rack.

The staff reviewed the applicant's response and concluded that the information provided by the applicant is acceptable because it considered the hydrodynamic mass under the rack baseplate of each rack in its nonlinear seismic analyses of the racks. Moreover, the applicant provided markup copies of the TR that fully describe the computation of the hydrodynamic mass under the baseplate of each rack. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-21. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-21, to be resolved.

9.1.2.1.4.5.3.2 Analysis Procedure

In Chapter 3 of the TR, Revision 0, the applicant described the methodology for the seismic analysis of the new and spent fuel racks. The applicant used Version 10 of the ANSYS computer program for its seismic analysis and design of the fuel storage racks. A nonlinear time history of the racks used the input acceleration time history at the pool level. The numerical solution was obtained by direct integration of the nonlinear equations of motion. Nonlinear seismic analyses were performed for three values of the coefficient of friction: 0.2, 0.5, and 0.8.

The staff reviewed the seismic analysis procedure and determined that it needed additional information to confirm that the calculated seismic responses are adequate and conservative. In RAI 287-8272, Questions 09.01.02-12, the staff asked the applicant to provide the key aspects of the seismic analysis procedure, including the number of input acceleration time histories used and the validation of the input acceleration time histories used for the seismic evaluation of the new and spent fuel racks.

In the applicant response to RAI 287-8272, Question 09.01.02-12, dated August 31, 2017 (ML17243A348), the applicant stated that it developed five sets of artificial acceleration time histories for three orthogonal directions (N-S, E-W, and vertical) specific to the NFSRs and SFSRs. The fully synthetic acceleration time histories were developed to match the SSE ISRS (i.e., no time history seed was used). For the NFSRs, the AB ISRS at elevation 41.9 m (137 ft 6 in.) were used. For the SFSRs, the response spectra were selected to envelope the ISRS at the elevation of the spent fuel pool base (34.7 m, 114 ft 0 in.) and the pool wall (40.2 m, 132 ft 0 in.). The applicant verified the five time histories in accordance with the acceptance criteria in SRP Section 3.7.1, Option 2.

Based on the above, the staff considered the applicant's response to be acceptable because (1) the use of the five time artificial histories is considered satisfactory for the nonlinear structural analysis of the fuel storage rack response to seismic conditions, (2) the five time histories meet the acceptance criteria set forth in SRP Section 3.7.1, and (3) the applicant provided markup copies of the TR that fully describe the validation of the input acceleration time histories used in its seismic evaluation of the new and spent fuel racks. The staff reviewed

Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-12. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-12, to be resolved.

9.1.2.1.4.5.3.3 Dynamic Simulation

In Section 3.7.1.1, "Displacement of Racks," of the TR, Revision 0, the applicant described the dynamic simulation and solution methodology used in calculating the seismic response of the racks. The staff reviewed the dynamic simulation and solution methodology and determined that it needed additional information to confirm that the dynamic simulations are adequate for predicting the dynamic response of the racks. In RAI 287-8272, Question 09.01.02-36, the staff asked the applicant to provide additional information on the seismic model of racks and how the effect of the rack-to-rack gap is considered in the dynamic simulation of the whole pool multirack model. In the applicant's response to RAI 287-8272, Question 09.01.02-36, dated August 31, 2017 (ML17243A348), the applicant provided figures that showed the layout and plan view of the NFSRs and the SFSRs, including the rack gaps at and above the baseplate level. The applicant stated that the gaps between fuel assemblies and rack cell walls/baseplate, adjacent rack baseplates, and pedestals and embedment plates are modeled with contact elements. Contact (i.e., gap) elements are used in the representation of rack sliding and impact. A directional stiffness is assigned to the contact element. The pool floor is assumed to be a rigid body initially in contact with the rack pedestals. The contact elements are used to represent the potential impact of a rack pedestal on the pool floor. The coefficient of friction between the rack pedestals and pool floor is incorporated into a contact (gap) element. The contact elements are used to calculate horizontal loads caused by friction (between the rack pedestal and embedment plate) and impacts (fuel-to-cell wall, rack-to-rack, and pedestal-to-embedment plate).

The SFSRs are specified to be installed with pedestals and baseplates as close as possible. Therefore, during a seismic event, they will initially move apart, although they could slide together again during the transient. Because of the random nature of the seismic acceleration, the racks will move in different directions by different amounts, and this can be affected by the time step and the coefficient of friction (COF) used in the analysis. The applicant further stated that the use of five independent time histories with sensitivities for the COF and the rack loading provides a reasonable range of possible displacements. Since none of the runs predicted displacements of more than a small fraction of the gap between the outermost racks and the SFP wall, contact of cells between SFSRs and the SFP walls is not expected. The applicant also included a COL item (COL 9.1(5)) asking the COL applicant to provide post-seismic event inspection procedures to measure the gaps between the NFSRs.

The staff reviewed the applicant's response and considered it to be acceptable because (1) the applicant demonstrated that the displacements of the racks during a seismic event are not damaging because they are less than the gaps provided, (2) the applicant provided a COL item (COL 9.1(5)), and (3) the applicant provided markup copies of applicable sections of DCD Tier 2 and the TR that fully describe the gaps between the fuel assemblies and the rack cell walls/baseplate, adjacent rack baseplates, and pedestals and embedment. The staff reviewed DCD Tier 2, Revision 1, dated March 10, 2017, and Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that they were revised as specified in the response to RAI 287-8272, Question 09.01.02-36. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-36, to be resolved.

9.1.2.1.4.5.3.4 Rack Design

In Section 3.7.3, "Rack Structural Evaluation," of the TR, Revision 0, the applicant described the structural design of various elements of the rack structure—stresses in welds between cell-to-baseplate, baseplate-to-pedestal, and cell-to-cell, and local stresses caused by cell wall impact, cell wall buckling, and secondary stress by temperature effects. The time history results from the ANSYS computer program provide the pedestal normal and lateral interface forces in Table 3-9. The staff noted that the applicant did not describe how the pedestal impact forces reported in Table 3-9 were converted to the bending moment and shear force at the bottom baseplate-to-pedestal interface for the rack design. In RAI 287-8272, Question 09.01.02-37, the staff asked the applicant to provide the details as to how the pedestal forces reported in Table 3-9 were converted to the bending moment and shear force at the bottom baseplate-to-pedestal interface for the rack design.

In its response to RAI 287-8272, Question 09.01.02-37, dated August 31, 2017 (ML17244A512), the applicant stated that the maximum horizontal and vertical loads generated on the support pedestal with the application of a seismic load are used to perform the structural integrity evaluation of the support pedestal and the rack. The dynamic simulations of the racks provide the results for the vertical and the two horizontal forces (i.e., E-W and N-S directions) throughout the transient. From those values, the maximum axial force in the vertical direction and the maximum shear forces of the two horizontal directions per pedestal are determined. The resultant shear force for each run is conservatively calculated by combining the maximum horizontal loads on any single pedestal using the SRSS method. The maximum bending moment at the bottom baseplate-to-pedestal interface is computed by multiplying the maximum shear force and the distance from the bottom baseplate to the contact point surface underneath the NFSRs and the SFSRs.

The staff reviewed the applicant's response and considered it to be acceptable because (1) the applicant adequately described how the maximum horizontal and vertical loads and the maximum moment and shear generated on the support pedestal are evaluated, and (2) the applicant provided markup copies of applicable sections of the TR that included additional information on the dynamic simulations of the racks. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-37. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-37, to be resolved.

Weld Stresses and Stress Factors

Section 3.7.3.3, "Cell-to-Cell Weld," of the TR, Revision 0, provides a general description of the forces considered in the evaluation of cell-to-cell welds. However, the staff noted that the applicant did not describe how it calculated the stresses in the weld. In RAI 287-8272, Question 09.01.02-38, the staff asked the applicant to provide a detailed description as to how it determined the stresses in the cell-to-cell welds and to include a free-body diagram explaining how the loads were transferred and used to evaluate the cell-to-cell welds.

In its response to RAI 287-8272, Question 09.01.02-38, dated August 31, 2017 (ML17244A512), the applicant stated that the cell-to-cell connections are a series of connecting welds along the cell height. Stresses in the SFSR cell-to-cell welds develop because of fuel assembly impacts with the cell wall. Weld stress is calculated based on the maximum fuel-to-cell wall impact load and shear stress, which is obtained by using the cell wall shear stress

coefficient under level D conditions from the dynamic analysis results. The applicant further stated that these weld stresses are conservatively considered by assuming that fuel assemblies in adjacent cells are moving out of phase with one another so that impact loads in two adjacent cells are in opposite directions and are applied simultaneously. This load application tends to separate the two cells from each other at the weld. Stress in the cell-to-cell weld is combined using the SRSS method for the shear stress caused by the horizontal load acting on the rack, the shear stress caused by the impact load of the rack fuel-to-cell wall, and the stress caused by the cell wall axial shear load. The applicant also provided Figure 1, "SFSR Weld Stress Diagram," which shows a free-body diagram explaining how the loads were transferred and used to evaluate the cell-to-cell welds.

Based on the information provided by the applicant, the staff considered the applicant's response to be acceptable. The applicant provided (1) details that fully describe how the stresses in the cell-to-cell welds are determined and (2) markup copies of applicable sections of the TR that included additional information related to the stresses in the SFSR cell-to-cell welds. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-38. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-38, to be resolved.

Section 3.7.3.4(3), "Secondary Stress by Temperature Effects," of the TR, Revision 0, states that "a conservative estimate of the weld stresses along the length of an isolated hot cell is obtained by considering a beam strip uniformly heated by 65°F and restrained from growth along one long edge. The Applicant further stated that temperature rise envelops the difference between the maximum local spent fuel pool water temperature (155°F) inside a storage cell and the bulk pool temperature (121°F) based on the thermal-hydraulic analysis of the spent fuel pool." In RAI 287-8272, Question 09.01.02-22, the staff asked the applicant to provide the methodology for calculating the maximum local SFP water temperature inside a storage cell and the bulk pool temperature.

In the response to RAI 287-8272, Question 09.01.02-22, dated August 31, 2017 (ML17244A512), the applicant stated that this analysis assumes an almost full SFP to which freshly discharged fuel with worst-case decay heat is added in adjacent cells and the SFP thermal capacity is only the water above the top of the SFSRs. The applicant described the methodology for calculating the local cell and bulk water temperatures used in the assessment. The applicant provided the mathematical formula for computing the maximum shear stress caused by the temperature gradient for an isolated hot cell weld. The applicant further explained that this thermal stress is classified as secondary stress, and the allowable shear stress criteria for a level D condition is used as the limit of allowable.

The staff reviewed the applicant's response and concluded that the methodology for computing the maximum local SFP water temperature inside a storage cell and the bulk pool temperature is acceptable. The applicant's thermal-hydraulic analysis of the SFP is referenced in the TR. The applicant also provided markup copies of applicable sections of the TR that describe the maximum local SFP water temperature inside a storage cell and the bulk pool temperature based on the thermal-hydraulic analysis of the SFP. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-22. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-22, to be resolved.

Section 3.7.3.3(2), “Baseplate-to-Pedestal Weld,” of the TR, Revision 0, describes the stresses on the baseplate-to-pedestal weld. The applicant indicated that the weld between the baseplate and the support pedestal is checked using finite element analysis to determine that the maximum stress is 124.1 megapascals (Mpa) (17,992 pounds per square inch (psi)) under a level D condition. In RAI 287-8272, Question 09.01.01-39, the staff asked the applicant to provide details of the loads considered in the weld stress analysis.

In the response to RAI 287-8272, Question 09.01.01-39, dated August 31, 2017 (ML17244A512), the applicant indicated the weld stress is derived from the simultaneous application of the maximum tensile force, as obtained from a separate ANSYS analysis, and the maximum pedestal friction forces in the horizontal directions (F_{xs} = 756.2 kN (170,000 lbf) and F_{ys} = 660.1 kN (148,400 lbf)), as determined by dynamic analysis. This is conservative, since these maximum loads may not occur at the same pedestal or at the same time instant. The applicant showed that the calculated maximum stress for the NFSR and SFSR is below the level D allowable stress.

The staff reviewed the applicant’s response and considered the information on the maximum stresses induced in the baseplate-to-pedestal weld to be acceptable. The applicant demonstrated that the maximum stress identified in its seismic evaluation of the stresses in the baseplate-to-pedestal weld is below the level D allowable. The applicant also provided markup copies of the TR that describe the evaluation of the stresses between the baseplate and the support pedestal. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-39. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-39, to be resolved.

Section 3.7.3.3, “Stresses on Welds,” of the TR, Revision 0, describes the weld locations of the NFSRs and the SFSRs subjected to seismic loading. The applicant evaluated stresses in cell-to-baseplate and baseplate-to-pedestal welds but did not calculate the base metal shear stress. The safety factor (ratio of allowable to actual shear stress) for the base metal may be lower than that of the weld. This reduction is noted in the safety factors in Table 3-13, “Stress Evaluation for Fuel Racks.” The staff noted that the safety factor for the cell-to cell weld stress is 5.42 and, for the base metal shear, it is reduced to 3.68. In RAI 287-8272, Question 09.01.02-28, the staff asked the applicant to provide the base metal shear stress and corresponding safety factor for the cell-to-baseplate and baseplate-to-pedestal weld connections.

In its response to RAI 287-8272, Question 09.01.01-28, dated August 31, 2017 (ML17244A512), the applicant in Table 3-12 provided the base metal shear stress and corresponding safety factor for the cell-to-baseplate and baseplate-to-pedestal weld connections. The applicant showed the base metal shear stress safety factor (i.e., the calculated stress versus the allowable stress, and the safety factor) for the rack cell-to-baseplate and the baseplate-to-pedestal weld connections to be 1.19 and 1.51 respectively.

The staff reviewed the applicant’s response and concluded that the computation of the base metal shear stress and the corresponding safety factor for the cell-to-baseplate and baseplate-to-pedestal well connection is acceptable because the applicant’s approach is consistent with industry practices. The applicant provided markup copies of the TR that describe the evaluation of the base metal shear stresses for the cell wall to baseplate weld and the baseplate to support pedestal weld. The staff reviewed Revision 3 of the TR,

APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-28. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-28, to be resolved.

Buckling Evaluation for Cell Walls

The highest potential for the rack cell wall buckling is at the base of the cell along the perimeter of the rack, because under seismic loading, the perimeter cell walls experience the maximum compressive stress from the axial load plus bending. Section 3.2.2.3, "Faulted (Abnormal) Conditions (Level D)," of the TR, Revision 0, specified the allowable compressive stress as two-thirds of the critical buckling stress for the stress limit criteria for the combined axial compression plus bending loads. In subsection 3.7.3.4(2), "Local Stress Evaluation," the applicant calculated the critical buckling stress of 12,731 psi but did not reduce it to two-thirds to obtain allowable compressive stress for the rack cell wall. In RAI 287-8272, Question 09.01.02-40, the staff asked the applicant to provide a technical justification for using the calculated critical buckling stress as the limit under the service level D condition, instead of the two-thirds of the critical buckling stress as stated in the level D stress limit criteria. The applicant was also requested to explain what boundary conditions are assumed on the long edges of the simplified cell wall buckling model, and provide the technical basis for this designation

In its response to RAI 287-8272, Question 09.01.01-40, dated August 31, 2017 (ML17244A512), the applicant provided the results of a detailed analysis of rack cell wall buckling. The applicant used the ANSYS computer program to evaluate the buckling capacity of the SFSR cells at the base of the racks. The applicant provided figures that showed the boundary conditions and the applied load of the finite element model and the buckling analysis results. Based on the analysis, the critical elastic buckling pressure of the fuel rack cell wall is 136.68 MPa (19,823 psi). Two-thirds of the critical buckling stress is taken as the limit under the service level D condition: 91.12 MPa (13,215 psi). This is greater than the maximum calculated local compressive stress in the cell wall due to seismic plus deadweight loading.

The staff reviewed the applicant's response and considered it to be acceptable because the applicant (1) demonstrated that the SFSR cells remain in a stable configuration under the maximum seismic load without any gross yielding of the fuel storage rack cell wall and that buckling of the rack cell wall will not occur, and (2) satisfied the ASME Code requirements for level D conditions. The applicant also provided markup copies of the TR that describe the buckling analysis of the storage cell walls subject to seismic loadings. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-40. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-40, to be resolved.

9.1.2.1.4.5.3.5 Fuel Assembly Integrity

Section 3.7.2, "Fuel Structural Evaluation," of the TR, Revision 0, describes the evaluation of the structural integrity of the stored fuel assemblies under an SSE event. Section 3.7.2.1, "Buckling Evaluation of Fuel Spacer Grid," discusses the buckling evaluation of the fuel spacer grid, and Section 3.7.2.2, "Stress Evaluation of Fuel Cladding" describes the stress evaluation of the fuel cladding.

Table 3-11, "Stress Evaluation for Fuel Assembly," in Revision 0 of the TR provides the allowable limit for fuel grid spacer and fuel rod cladding, including the buckling load and the bending stress. However, the staff noted that the applicant did not describe the bending stress calculation in the fuel rod cladding that is reported in the table. In RAI 287-8272, Question 09.01.02-42, the staff asked the applicant to provide a technical description of the bending stress, the yield strain, and the acceptance criteria used to evaluate the fuel cladding.

In its response to RAI 287-8272, Question 09.01.02-42, dated August 31, 2017 (ML17244A512), the applicant provided markup copies of the TR, and applicable sections of DCD Tier 2, that detail the stress evaluation of the fuel cladding. The applicant stated that the maximum lateral acceleration acting on the fuel mass is used to calculate a load uniformly distributed over a single fuel rod modeled as a beam simply supported by the spacer grids. The applicant provided mathematical equations that show how it calculated the uniformly distributed load on the fuel rod, the maximum bending stress in the fuel cladding, and the strain associated with the maximum bending stress. The applicant then compared the bending stress to the yield stress for the fuel rod cladding.

The staff reviewed the applicant's response and considered it to be acceptable because it demonstrated that the maximum impact load on an individual fuel grid spacer cell, the bending stress, and the strain induced in the fuel rod cladding caused by the maximum lateral acceleration are below the allowable limits. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-42. However, the proposed changes to the applicable sections of DCD Tier 2 have not been implemented. Thus, RAI 287-8272, Question 09.01.02-42, is being tracked as **Confirmatory Item 9.1-2** pending the update to DCD Tier 2, Sections 9.1.2.2.1 and 9.1.2.2.2.

9.1.2.1.4.5.3.6 Punching Shear Evaluation

The staff reviewed Section 3.7.3 of the TR, Revision 0, and noted that the applicant did not provide the punching shear evaluation of the rack baseplate against the rack pedestal impact loads. The staff believes that a credible failure mode for the rack baseplate is a punching shear failure caused by the concentrated load transmitted by a support pedestal under SSE conditions and the impact load on the rack baseplate caused by an accidental drop of a fuel assembly. In RAI 287-8272, Question 09.01.02-43, the staff asked the applicant to demonstrate that the capacity of the rack baseplate against punching shear failure is larger than the calculated rack pedestal impact load.

In its response to RAI 287-8272, Question 09.01.01-43, dated August 31, 2017 (ML17244A512), the applicant provided markup copies of the TR that detail the punching shear analysis of the rack baseplate, including the punching shear caused by the vertical pedestal load and the fuel impact load. The applicant provided equations for calculating the punching shear capacity of the baseplate and the punching shear stress caused by the fuel impact load. The applicant stated that the punching shear capacity of the baseplate exceeds the maximum pedestal load, and the maximum fuel impact load.

The staff reviewed the applicant's response and considered it to be acceptable because it demonstrated that a punching shear failure of the rack baseplate will not occur because the safety factor (allowable value/calculated value) for the punching shear due to vertical pedestal load and the fuel impact load is 2.9 and 19.7 respectively, is significantly higher than the

required safety factor of 1.0. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-43. Accordingly, the staff considers RAI 287-8272, Question 09.01.02-43, to be resolved.

9.1.2.1.4.6 Structural Acceptance Criteria

In Section 3.2.2 of the TR, Revision 0, the applicant stated that the acceptance limits of the rack structures are defined in ASME Code Section III, Subsection NF, as applicable for Class 3 components support. The staff considers the design requirements for the racks to be acceptable because the structural acceptance criteria are consistent with the guidance in SRP Section 3.8.4, Appendix D. The sections below discuss the principal elements of the structural acceptance criteria.

Kinematic Criteria

Section 3.2.1, "Kinematic Criteria," of the TR describes the kinematic criteria for the racks. In Section 3.7.1.1, "Displacements of Rack," the applicant describes the kinematic stability determination and states that the maximum rack displacement is calculated as 104.3 millimeters (mm) (4.1 inches), small compared to the dimensions of the racks. Also, a large margin of safety exists against the rack overturning. The applicant also states that the maximum rocking angle of the racks is 1.2 degrees, compared to the critical rocking angle of 20.6 degrees that may cause overturning. This provides a safety factor of about 17 against overturning, which is greater than the acceptance criteria of 1.5. Based on the above information, the staff finds that the sliding and tilting motions of the racks are less than the kinematic acceptance criteria in SRP Section 3.8.4, Appendix D, and are therefore acceptable.

Code Stress Limits Criteria

The applicant provided the load combinations and acceptance limits in TR Table 3-1. The referenced ASME Code, the load combinations, and the acceptance limits that were used are consistent with Table 1 in SRP Section 3.8.4, Appendix D, and are therefore acceptable.

TR Sections 3.2.2.1, 3.2.2.2, and 3.2.2.3 provide the stress limits for service level conditions A, B, and D, respectively. TR Table 3-4, "Material Properties" (shows the material properties at 93.3 degrees Celsius (C) (200 degrees Fahrenheit (F)) used to develop the stress limits for various service level conditions). The staff reviewed the stress limits used for service level A conditions and found them acceptable because they are consistent with those specified in ASME Code Section III, Subsection NF-3320. The applicant conservatively used service level A stress limits to evaluate service level B loading combinations, and that is acceptable.

The applicant used the increase factors for service level D stress limits following the criteria in ASME Code Section III, Appendix F, Section F-1334, "Criteria for Linear-Type Supports." The applicant also identified the exceptions to the use of the general increase factors following the provisions in the subsections of Section F-1334.

9.1.2.1.4.7 Material, Quality Control, and Special Construction Techniques

The applicant utilizes Type 304 austenitic stainless steel for SFP liners, piping, and other connected components. This material is commonly used in nuclear power plants for the SFP and other safety-related systems. The selection of the Type 304 material is appropriate

provided that the applicant takes precautions to avoid material degradation. Degradation may occur if welding, cleaning, and water chemistry is not controlled adequately.

In response to RAI 380-8443, Question 09.01.02-49 (ML16081A253), the applicant describes process controls which minimize the potential for introducing material degradation mechanisms during fabrication and construction of the SFP liner and associated systems. The applicant will employ process controls to maintain welding interpass temperatures below 350 °F, will restrict the welding heat input to 60 kJ/inch, will require weld filler material to meet or exceed 5FN delta ferrite, and will ensure that the liner plates meet ASME NQA-1, Subpart 2.1, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components for Nuclear Power Plants." The staff finds the response acceptable because the welding and cleanness controls are consistent with RG 1.31 "Control of Ferrite Content in Stainless Steel Weld Metal" and RG 1.44 "Control of the Processing and Use of Stainless Steel." Use of these regulatory guides appropriately limits the potential for sensitization of austenitic stainless steels and prevents contamination of materials to mitigate the initiation of a corrosion cells.

The water chemistry of the SFP is evaluated separately by the staff in SER Section 9.1.3.

The staff concludes that the applicant's welding and cleaning process controls in conjunction with proper water chemistry control (as evaluated in SER Section 9.1.3) are sufficient to prevent degradation of the SFP liner and connected supporting systems.

The principal construction materials for the new and spent fuel racks are SA-240 Type 304L for cells and plates, and SA-564 Grade 630 for support studs. Neutron absorber material (METAMIC) is attached to the spent fuel rack structure, but the material does not perform any structural function and is not considered a structural material. TR Section 3.4.4 contains the material properties for the analysis and stress evaluation. Material properties of the fuel assembly in Table 3-3, "Data of Fuel Assembly," are taken from the PWR PLUS7 fuel assembly, and the rack properties in Table 3-4 are obtained from ASME Code Section II, Part D. The values listed correspond to a design temperature of 93.3 degrees C (200 degrees F). The structural materials used to fabricate the fuel storage racks are in accordance with the provisions of ASME Code Section III, Subsection NF, and are therefore acceptable.

The staff did not find any description of the governing quality control requirements, the manufacturing process, special fabrication techniques, or the sequences used for constructing the fuel storage racks to reduce fabrication distortions and to provide accessibility for inspection. In RAI 287-8272, Question 09.01.02-44, the staff asked the applicant to provide the governing quality control requirements and procedure and any special fabrication and construction techniques used for constructing the fuel storage racks.

In its response **to** RAI 287-8272, Question 09.01.02-44, dated August 31, 2017 (ML17243A348), the applicant included markup copies of the TR and applicable sections of DCD Tier 2 that describe in detail the fabrication procedures for the NFSR and the SFSR, the general requirements, the quality control and quality assurance, the welding requirements, and the cleanliness requirements of the material. The applicant stated that the fabrication of the new and spent fuel racks is in accordance with the requirements of ASME Code Section III, Subsection NF, for component supports, and that the fuel storage racks meet the guidance in NRC RG 1.29 and American National Standards Institute/American Nuclear Society 57.3. The applicant characterized the new and spent fuel racks as seismic Category I structures that are treated as safety-related components for determining quality assurance requirements

(10 CFR Part 50, Appendix B) and periodic condition monitoring requirements (10 CFR 50.65). The applicant stated that the quality control requirements for the fuel storage racks are in accordance with 10 CFR Part 50, Appendix B. The applicant further stated the acceptance criteria for visual examination of all fuel rack welds comply with the ASME Code Section III, NF-5360, and Section V, T-952.

The staff reviewed the applicant's response and consider it to be acceptable because it addresses all of the information requested, and (1) satisfies the requirements in the ASME Code, (2) meets the regulatory guidance in 10 CFR Part 50, Appendix B, and in 10 CFR 50.65, and (3) is consistent with the regulatory guidance in SRP Section 3.8.4, Appendix D. The staff reviewed Revision 3 of the TR, APR1400-H-N-NR-14012-P, issued August 2017 (ML17242A310), and confirmed that it was revised as specified in the response to RAI 287-8272, Question 09.01.02-44. However, the proposed changes to applicable sections of DCD Tier 2 have not been implemented. Thus, RAI 287-8272, Question 09.01.02-44, is being tracked as **Confirmatory Item 9.1-3,** pending the update to DCD Tier 2, Sections 9.1.2.1, "Design Bases"; 9.1.2.2, "Facilities Description"; 9.1.2.3, "Safety Evaluation"; and 9.1.2.4, "Inspection and Testing Requirements."

The new fuel rack is composed of Type 304L stainless steel and Type 630 (17-4) PH stainless steel which have excellent resistance to general atmospheric corrosion. Normal operation of the HVAC system and maintenance of the fuel building is sufficient to prevent the new fuel rack from getting wet. Without a conductive fluid to form a corrosion cell, stress corrosion cracking and other localized corrosion phenomena are precluded. In the event that new fuel pit is flooded or the new fuel rack is wet by mist, stainless steel has good corrosion resistance in acidic and neutral water environments.

The addition of cover plates over the new fuel pit and a draining system on the floor of the new fuel pit provide defense-in-depth. Water and debris intrusion into the pit is prevented, but if water was introduced into the dry fuel pit the draining system provides a built-in method to drain the pit.

The staff concludes that the new fuel storage system is designed to preclude material deterioration during normal, off-normal, and accident conditions.

The spent fuel rack design utilizes two types of stainless steel: Type 304L and Type 630 (17-4 PH). Both materials have good resistance to corrosion in acidic, basic, and neutral water. The potential for corrosion is further reduced by SFP water chemistry controls. Localized sensitization during welding of the stainless steel is prevented by using the "L" grade material; the use of "L" grade material is consistent with the recommendations in Regulatory Guide (RG) 1.44. The weld material will be required to have a delta ferrite level between 8 and 25 FN. The minimum delta ferrite level is consistent with RG 1.31. The maximum delta ferrite of 25 FN is greater than the RG 1.31 limit of 20 FN, but the maximum delta ferrite level in RG 1.31 was chosen to limit the potential for thermal embrittlement. Thermal embrittlement is not a concern in the SFP because the temperature is too low for thermal embrittlement to occur. The applicant commits to solution heat treating any austenitic stainless steel material that is heated above 350 427 °C (800 °F, (except during welding). This requirement eliminates the possibility of bulk sensitization of the base material and is more conservative than 800 °F is consistent with the sensitization temperature specified in Regulatory Guide 1.44.

The SFP racks are protected from harmful chemicals and foreign material by conformance with the requirements of NQA-1, Subpart 2.1, and Cleanness Class C. The applicant commits to inspecting crevices for cleanness which further reduces the potential for crevice corrosion and foreign material intrusion. The process controls provide adequate assurance that the spent fuel racks can be fabricated without introducing the potential for localized degradation.

Contact between Type 304L stainless steel and the aluminum matrix neutron absorbing material is a feature in SFP rack design. Although an electrochemical potential between the two metals exists, corrosion is prevented by reducing ion concentration in the SFP water. The ion concentration is maintained at levels low enough that an electrochemical cell does not develop. Failure of the SFP cleanup system would not degrade the stainless steel structural material because the aluminum matrix neutron absorber is the more anodic material.

Corrosion of the neutron absorbing material would not impact the structural integrity of the spent fuel rack and is evaluated in SER Section 9.1.1.

The staff concludes that the selection of base materials combined with the water chemistry controls and the controls on fabrication is sufficient to ensure that the SFP liner and the SFP racks will be able to perform the credited safety functions described in the DCD Tier 2 FSAR. The staff concludes that the spent fuel storage system is designed to preclude material deterioration during normal, off-normal, and accident conditions.

9.1.2.1.5 Combined License Information Items

DCD Table 9.1.2-1 lists the COL information items related to fuel racks and their descriptions:

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.1(2)	The COL applicant is to prepare a periodic program of spent fuel rack integrity to ensure that the design bases material and geometric assumptions remain valid during the operating life of the plant	9.1.2.2.2, 9.1.6
9.1(3)	The COL applicant is to perform a confirmatory structural dynamic and stress analysis for the new and spent fuel racks, including reconciliation of loads imposed by the new and spent fuel racks on the new fuel pit and the spent fuel pool structures, considering the site-specific condition,	9.1.2.2.3, 9.1.6

	such as a safe shutdown earthquake	
9.1(4)	The COL applicant is to provide plant procedures and administrative control for fuel handling activities over the spent fuel pool	9.1.2.2.3, 9.1.6
9.1(5)	The COL applicant is to provide post-seismic event inspection procedures to measure gaps between the new fuel storage racks	9.1.2.3.1, 9.1.6

The staff found the list of COL information items to be complete because it adequately describes actions necessary for the COL applicant to perform. Therefore, no additional COL information items are needed for the new and spent fuel storage racks.

9.1.2.1.6 Conclusion

Provided all the confirmatory items are addressed in the next DCD revision, the staff concludes that the design of the new and spent fuel storage racks is acceptable and meets the relevant requirements of 10 CFR 20.1101(b); 10 CFR 20.1406; 10 CFR 50.68; and GDC 2, 4, 5, 61, and 63. This conclusion is based on the following eight findings:

(1) The applicant has met the requirements of GDC 2 by designing the new and spent fuel storage racks to withstand the most severe earthquake that has been established for the site with sufficient margin and to withstand the combinations of the effects of normal and accident conditions with the effects of environmental loadings, such as earthquakes and other natural phenomena.

(2) The applicant has met the requirements of GDC 4 by designing the new and spent fuel storage racks to withstand the dynamic effects associated with missiles, pipe whipping, and discharging fluids.

(3) The applicant has met the requirements of GDC 5 by designing the new and spent fuel storage racks to perform their safety functions without being significantly impaired.

(4) The applicant has met the requirements of GDC 61 by designing the new and spent fuel pool racks to ensure adequate safety under normal and postulated accident conditions.

(5) The applicant has met the requirements of GDC 63 by monitoring the new and spent fuel pool racks to detect (1) conditions that could result in the loss of decay heat removal capabilities and (2) excessive radiation levels to initiate appropriate safety actions.

(6) The design of the new and spent fuel storage rack has met the requirements of 10 CFR 20.1101(b), as it relates to provisions to achieve public and occupational doses that are ALARA)

(7) The design of the new and spent fuel storage racks has met the requirements of 10 CFR 20.1406, as it relates to the minimization of contamination within the new and spent fuel racks.

(8) The design of the new and spent fuel storage racks has met the requirements of 10 CFR 50.68, as it relates to the criticality requirements of the new and spent fuel racks.

The criteria used in the analysis, design, and construction of the new and spent fuel storage racks to account for anticipated loadings and postulated conditions that may be imposed during its service lifetime are in conformance with established criteria, codes, standards, and RGs acceptable to the staff. These include compliance with the criteria of ASME Code, Section III, Division 1, and with the NRC guidance in SRP Section 3.8.4, Appendix D, and RGs 1.29 and 1.61.

The use of these criteria, as defined by applicable design codes, standards, and specifications; seismic and impact loads; loads and loading combinations; design and analysis procedures; structural acceptance criteria; and materials, quality control programs, and special construction techniques, provide reasonable assurance that, in the event of a seismic event, the new and spent fuel storage racks will withstand the specified conditions without impairment of their structural integrity or safety function.

9.1.2.2 New and Spent Fuel Storage (Part 2 – Thermal and Hydraulic)

9.1.2.2.1 Introduction

Onsite dry storage of new fuel assemblies required for refueling the reactor is provided by the New Fuel Storage Pit (NFSP). Onsite underwater storage of spent fuel assemblies and optional underwater storage of some of the new fuel assemblies is provided by the Spent Fuel Pool (SFP). The NFSP and SFP provide the necessary design features unique to fuel storage during initial receipt, refueling operations, and accident conditions, including maintaining cooling and limiting offsite exposure in the event of a fuel handling accident (FHA). New and spent fuel is transferred between the Reactor Building and the Auxiliary Building (AB) by the fuel transfer tube or loaded into casks in the cask loading pit. The fuel racks ensure that stored fuel is maintained in a suitable geometry to prevent criticality and provide cooling for all design conditions.

The NFSP and SFP structures, systems, and components (SSCs) related to fuel storage are described in DCD Tier 2, Section 9.1.2. The Auxiliary Building, spent fuel pool cooling system, fuel handling system, and AB ventilation are evaluated separately.

9.1.2.2.2 Summary of Application

DCD Tier 1: The applicant has provided a general description of the new and spent fuel storage systems in DCD Tier 1, Section 2.7.4, “New and Spent Fuel Handling System.”

DCD Tier 2: The applicant has provided a description of new and spent fuel storage in DCD Tier 2, Section 9.1.2. These facilities provide for the storage of new and spent fuel assemblies and include the new fuel storage pit, new fuel storage racks, spent fuel pool, and spent fuel

storage racks. The safety functions are to maintain the fuel assemblies in a safe and subcritical array during all storage conditions.

ITAAC: ITAAC information for fuel storage can be found in DCD Tier 1, Table 2.7.4.1-1, "New Fuel Storage ITAAC," and Table 2.7.4.2-1, "Spent Fuel Storage ITAAC."

Technical Specifications: The Technical Specifications applicable to the storage of spent fuel can be found in DCD Tier 2, Chapter 16, "Technical Specifications": Section 3.7.14, "Spent Fuel Pool Water Level"; Section 3.7.15, "Spent Fuel Pool Boron Concentration and Enrichment"; and Section 3.7.16, "Spent Fuel Assembly Storage."

9.1.2.2.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.1.2, "New and Spent Fuel Storage," Revision 4, March 2007, and are summarized below. Review interfaces with other SRP sections can also be found in NUREG-0800, Section 9.1.2.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the capabilities of the structures housing the system and the system itself to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of safety-related functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to effects of missiles inside and outside containment, effects of pipe whip, jets, environmental conditions from high- and moderate-energy line-breaks, and dynamic effects of flow instabilities and attendant loads (e.g., water hammer) during normal plant operation, as well as upset or accident conditions.

3. GDC 5, "Sharing of structures, systems, and components," insofar as it requires that SSCs important to safety not be shared among nuclear power units unless it can be shown that sharing will not significantly impair their ability to perform their safety functions.

4. GDC 61, "Fuel storage and handling and radioactivity control," as it relates to the requirement that the fuel storage system be designed to assure adequate safety under normal and postulated accident conditions.

5. GDC 63, "Monitoring fuel and waste storage," as it relates to monitoring systems for detecting conditions that could cause the loss of residual heat removal capabilities for spent fuel assemblies, detecting excessive radiation levels, and initiating appropriate safety actions.

6. CFR 20.1101(b), "Radiation protection programs," as it relates to radiation doses kept as low as reasonably achievable (ALARA).

7. CFR 52.47, "Contents of applications; technical information," Item (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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the Atomic Energy Act, and NRC regulations.

9.1.2.2.4 Technical Evaluation

The staff's evaluation of the new and spent fuel storage facilities is based upon the information provided in the applicant's DCD, Revision 1, including Tier 1 and Tier 2.

The NFSP provides onsite dry storage for new fuel assemblies required for refueling the reactor. In accordance with DCD Tier 2, Table 4.1-1, "Core Configuration," the APR1400 reactor contains 241 fuel assemblies. In DCD Tier 2, Section 9.1.1.1, the applicant stated that the NFSP is designed with storage capacity for 112 new fuel assemblies, which represents about 46 percent of the core. This corresponds to one refueling batch plus margin.

The spent fuel handling area consists of three separate water-filled fuel storage and handling areas: the spent fuel cask loading pit, the SFP itself, and the fuel transfer canal. All three of these areas are designed as seismic Category I within the seismic Category I auxiliary building (AB).

DCD Tier 2, Section 9.1.2 states that the SFP itself provides storage for a minimum of 1,792 spent fuel assemblies stored in a single pool. DCD Tier 2, Section 9.1.1 states that this storage capacity is sufficient to store one full core, one maximum refueling batch, five damaged fuel canisters, and a 20-year quantity of discharged fuel based on a refueling cycle of 18 months.

This storage capacity meets the recommendation of SRP Section 9.1.2(iii)(1) which indicates that the minimum SFP storage capacity should equal or exceed the amount of spent fuel from 5 years of operation at full power plus one full - core discharge.

9.1.2.2.4.1 GDC 2, Design bases for protection against natural phenomena

The NFSP and the SFP are located within the auxiliary building (AB), which is a Seismic Category I structure designed to provide protection from the effects of natural phenomena including earthquakes, tornadoes, hurricanes, floods, and external missiles, as well as providing radiation shielding. The NFPS and the SFP are designed to meet Seismic Category I requirements; therefore, they meet Position C.1 in RG 1.13 (that all structures and equipment necessary to safely maintain the conditions necessary for radiation shielding, should be designed to Seismic Category I requirements), and RG 1.29 (all SSCs that must remain functional following a design basis seismic event should be designed to Seismic Category I criteria.)

SRP Section 9.1.2.III.2.C states that nonsafety-related SSCs not designed to seismic Category I standards located in the vicinity of the new and spent fuel storage facilities are reviewed for whether their failure would cause an increase in K_{eff} to more than the maximum allowable. The staff determined that the applicant's DCD does not discuss this scenario. Therefore, in RAI 79-7990, Question 09.01.02-01, the staff requested the applicant to include in the DCD a

discussion of how the APR14000 design prevents the failure of non-seismic category I component from increasing the K_{eff} in the NFSP and the SFP.

In response to RAI 79-7990, Question 09.01.02-01, the applicant stated that the SSCs whose failure, by virtue of physical proximity to safety-related equipment or structures, could prevent a component or structure from fulfilling its required function are classified as Seismic Category II. DCD Tier 2, Table 3.2-1, "Classification of Structures, Systems, and Components," presents the seismic classification for the SSCs related to the new and spent fuel storage facilities. The applicant further stated that the only Seismic Category III SSCs in the vicinity are the fuel handling tools and the rails of the spent fuel handling machine (SFHM). A drop analysis has been performed for the fuel handling tool.

The staff evaluated the applicant's response and determined that, by designing SSCs in the vicinity to the NFSP and the SFP to seismic Category II, the applicant is adequately protecting the NFSP and the SFP from seismically induced structural failure of these SSCs. By classifying the fuel handling tool to seismic Category III standards (not designed to withstand a safe-shutdown earthquake (SSE)), the applicant has not introduced any new accident scenario not previously evaluated, nor does it compromise the safety function of the safety-related SSCs in the vicinity of the NFSP or the SFP. Therefore, the staff finds that the safety-related SSCs located in the NFSP and the SFP are protected from the failure of the fuel handling tool. The staff also evaluated the proposed DCD markups that accompanied the RAI response and found them acceptable. The staff has confirmed the inclusion of these markups into Revision 1 of the DC.

In its response the applicant also stated that the SFHM is designed not to derail in the event of an SSE, due to the strength of the rail mounting design, although the rails of the SFHM are designed as seismic Category III. The staff evaluated the applicant's response and determined that additional information is required. The DCD classifies the SFHM as a seismic Category II system, but the rails of the machine are designed as seismic Category III. By definition, as seismic Category III, these rails cannot be credited to remain functional following an SSE; therefore, these rails cannot be credited to prevent the derailment of the SFHM.

In RAI 480-8608, Question 9.1.2-55, the staff requested the applicant to provide additional information to clearly identifying how the SFHM design prevents it from falling into the SFP following an SSE (assuming failure of the seismic Category III rails), and to update the DCD accordingly. In the applicant's updated response to Question 9.1.2-55, the applicant proposed to design the rails of the SFHM as seismic Category II. Therefore ensuring the SFHM design prevents it from falling into the SFP following an SSE. The applicant's response also proposed changes to Tier 2, Table 3.2-1, "Classification of Structures, Systems, and Components," to clearly indicate that the refueling machine bridge rails and spent fuel handling machine bridge rails are design to seismic Category II standards. The staff confirmed that Revision 1 of the DCD includes these proposed changes.

The evaluation of the adequacy of the design of the SFHM is addressed in Section 9.1.4 of this report.

The SFP is provided with a leak-tight, seismic Category I, stainless steel liner. The staff finds the SFP stainless steel liner seismic classification is in accordance with the recommendations of SRP Section 9.1.2.

Based on the above discussion, the staff concludes that the APR1400 SFP meets the requirements of GDC 2, because it is designed to withstand the effects of natural phenomena without loss of capability to perform its safety function.

9.1.2.2.4.2 GDC 4 Environmental and dynamic effects design bases

In accordance with RG 1.117, protection of designated SSCs from the effects of missiles created by tornados may be accomplished by designing protective barriers to preclude such damage. The NFSP and the SFP are located inside the AB which is designed to sustain missile impact and, therefore, satisfies RG 1.117. The SFP walls are designed as a Seismic Category I structure which provides protection from the effects of internally generated missiles. The applicant also stated that the fuel handling area does not contain any credible source of missiles.

DCD Tier 2, Section 3.5.1 discusses the site missile protection features, which states that the AB is oriented in such a way so that all essential SSCs are excluded from the low-trajectory turbine missile strike zone. This orientation meets the guidance provided in RG 1.115, "Protection Against Low-Trajectory Turbine Missiles."

The staff finds that locating the AB outside the low-trajectory turbine missile strike zone meets the recommendation of RG 1.13, Regulatory Position C.3, which states that the spent fuel storage facility should be designed to protect the spent fuel from low-trajectory turbine missiles, and the storage pool should retain watertight integrity if struck by such missiles.

Based on the missile design features identified above, the staff finds that the APR1400 design of the NFSP and the SFP meet the requirements of GDC 4, in that SSCs important to safety are protected against the effects of missiles from events and conditions outside the nuclear power unit.

9.1.2.2.4.3 GDC 5 Sharing of structures, systems, and components

The APR1400 design is a single unit design; therefore, the staff finds that GDC 5 is not applicable to the NFSP or the SFP design.

9.1.2.2.4.4 GDC 61, Fuel storage and handling and radioactivity control

GDC 61 requires that the fuel storage system be designed for adequate safety under anticipated operating and accident conditions. The fuel storage system must be designed with (1) the capability for appropriate periodic inspection and testing of components important to safety, (2) suitable shielding for radiation protection, (3) appropriate containment, confinement, and filtering capability, (4) residual heat removal that reflects the safety importance of decay heat and other residual heat removal, and (5) the capability to prevent a significant reduction in fuel storage coolant inventory under accident conditions.

The new fuel is not considered radioactive prior to initial core load and therefore does not require radiation shielding, but is protected from external hazards by the new fuel storage pit. In addition, the new fuel does not generate sufficient residual heat to require residual heat removal system. The concrete storage pit houses the new fuel assembly storage racks and auxiliary components. In DCD Tier 2, Section 9.1.1, the applicant stated that the new fuel assemblies can be stored dry in the new fuel storage rack such that they are maintained subcritical. The applicant also states that the new fuel storage racks are classified as Seismic Category I.

The NFSP is covered by steel plates that protect the new fuel stored in the racks. The steel plates are designed not to fall or collapse in the event of an SSE. A representative layout and cross-section sketch of new and spent fuel storage racks are given in DCD Tier 2, Figure 9.1.2-1, "New Fuel Storage Racks," and Figures 9.1.2-2A&B, "Spent Fuel Storage Rack Regions." In accordance with the guidance provided in SRP Section 9.1.2, adequate spacing should be provided to maintain a minimum clearance to prevent criticality during earthquakes or other natural phenomena. In DCD Tier 2, Section 9.1.1.1, the applicant stated that new fuel storage racks are designed with adequate spacing to maintain subcriticality. The adequacy of critically prevention in the new and spent fuel racks is evaluated in Section 9.1.1 of this Report.

SRP 9.1.2.III.2.B states that the new and spent fuel storage racks are designed such that a fuel assembly can be inserted only in a designed location. The design also should prevent placement of fuel assemblies in the adjacent regions external to the racks. The applicant's description of the new storage racks does not discuss these design features. Therefore, in RAI 79-7990 Question 09.01.02-02 the staff requested the applicant to discuss in the DCD the design features that prevent the storage of more than one assembly into each storage location or the storage of fuel assemblies outside of the designated storage racks.

The applicant responded to RAI 79-7990, Question 09.01.02-02, stating that a physical barrier (projecting concrete structure) limits the available space between the racks and the walls, preventing the placement of fuel bundles outside the racks. Additionally, the fuel handling machine incorporates interlocks to limit movement to pre-determined zones.

The staff evaluated the applicant's response and found adequate to limit the available open space surrounding the racks, thus reducing the likelihood of a misplaced assembly. The staff also evaluated the proposed DCD markups that accompanied the RAI response and found them acceptable. The staff has confirmed the inclusion of these markups into Revision 1 of the DC.

Additional discussion of the fuel handling machine and the movement interlocks are presented in Section 9.1.4 of this report.

SRP Section 9.1.2 recommends that low-density storage should be used, at a minimum, for the most recently discharged fuel to enhance the capability to cool it. If low-density storage is not used, the use of high-density storage racks needs to be evaluated on a case-by-case basis. The applicant identified that the spent fuel will be stored in high-density racks. The applicant's DCD provided a criticality and a thermal evaluation of the high density racks. The staff's evaluation of the criticality analysis for the SFP is discussed in Section 9.1.1 of this report. The staff's evaluation of the applicant's thermal analysis report that demonstrates adequate cooling in the SFP is reviewed in Section 9.1.3 of this report.

The staff also identified that the control element assembly (CEA) platform is used to hold the CEA/ in-core instrumentation (ICI) transport container. Since the CEA/ICI transport container has the same dimensions as a fuel assembly, the staff determined that the CEA platform is sized such that it could hold a fuel assembly. The applicant has not provided technical justification or design evaluation needed to credit the CEA/ICI platform as a safe storage location for a fuel assembly. Therefore, in RAI 23-7929 Question12.02-06, the staff requested the applicant to (1) identify all equipment and areas within the refueling cavity that are intended to be used or could be used to store and handle fuel, (2) indicate if the current APR1400 design physically excludes the intermediate fuel storage racks discussed in the September 2013 application, and (3) update DCD Tier 1, Section 2.7.4 to identify all equipment and locations within the plant which will be used to handle or store reactor fuel, including a statement indicating that no other equipment or locations will be used to store or handle fuel beyond the items listed.

The staff's evaluation of the applicant's RAI response is discussed in Section 12.2 of this report. However, this response also included proposed DCD changes to DCD Tier 1, Table 2.7.4.4-1, "Light Load Handling System Equipment Location/Characteristics." The staff evaluated these changes, which include identifying all the locations specifically designed to store fuel assemblies, and found them acceptable.

In DCD Tier 2, Section 9.1.2.2.2, "Spent Fuel Storage," the applicant describes the spent fuel handling area as consisting of three separate water-filled areas; spent fuel cask loading pit, SFP, and the fuel transfer canal. These pools are separated by a hinged gate. The pools and the gates are designed as seismic Category I components and will remain leaktight after an SSE. The bottom of the gates that lead from the SFP to the fuel transfer canal and the spent fuel cask loading pit are above the top of the stored fuel assemblies.

SRP Section 9.1.2.III.2.H.i states that the SFP design should include weirs and gates separating the spent fuel storage areas from handling areas to prevent the accidental draining of the coolant to levels inadequate for fuel cooling or radiation shielding. The bottom of any of the gates should be above the top of the fuel assemblies, and the volume of the adjacent fuel-handling areas should be limited so that leakage into these areas while drained would not reduce the coolant inventory to less than 3 meters (10 feet) above the top of the fuel assemblies. The staff determined that the applicant's description of the SFP does not address all the design criteria identified in SRP Section 9.1.2.III.2.H.i. Therefore, the staff submitted RAI 98-8051, Question 9.1.2-8, requesting the applicant to discuss in the DCD the volume (sizing) of the adjacent fuel handling areas such that the leakage into these areas, while drained, would not reduce the coolant inventory to less than 3 meters (10 feet) above the top of the fuel assemblies.

The applicant's response provides a summary of the volume calculation that demonstrates that, after a gate failure, the SFP water level still remains more than 3 meters (10 feet) above the top of the fuel assemblies.

The staff evaluated the applicant's response and determined that additional information is needed. The staff identified that DCD Tier 2, Figures 3.4-4 and 5 "Location of Watertight Doors and Flood Barrier Plan View Elevation 120'-0" and Elevation 137'-6"" show a swing gate between the CLP and the cask decontamination pit (CDP). While the gate between the SFP

and the CLP is open, the gate between the CLP and the CDP is maintaining the SFP water inventory. The staff does not find clear indication that the applicant has taken into consideration the added volume available due to the cask CDP. Therefore the staff submitted RAI 458-8569, Question 09.01.02-54, requesting the applicant to (a) clarify if the cask decontamination pit volume was taken into consideration in the pool draindown calculation, and (b) to reevaluate the pool draindown calculation, if necessary.

In its response to Question 9.1.2-54, the applicant clarified that the gate located between the cask loading pit and the cask decontamination pit is designed as seismic Category I. In the event of a single gate failure, the available volume of the CDP needs not be considered in the pool draindown calculation.

The staff evaluated the applicant’s RAI response and finds that since the gate between cask loading pit and the cask decontamination pit is designed as seismic Category I. The SRP does not require the applicant to also postulate failure of several gates. The event assumes that one of the gates fail, therefore, the staff found the applicant’s justification and proposed DCD modifications to be acceptable. The staff also confirmed that the applicant included these proposed DCD changes to Revision 1 of the DCD.

The SFP is separated from the adjacent fuel-handling areas by a single swing gate, and designed to allow the draining of the fuel transfer canal and the CLP without impacting SFP water level. Since the APR1400 design only has one gate in each location (unlike other designs that relied on double gates) it is unclear to the staff how the applicant prevents a single operator error from opening the gates while the adjacent fuel-handling areas are drained, particularly when the fuel transfer equipment is undergoing maintenance. Therefore, in RAI 79-7990, Question 9.1.2-5, the staff requested the applicant to discuss how the design prevents and/or mitigates the consequences of an accidental opening of a gate.

The applicant responded to the staff’s RAI by stating that the seismic Category I gates (the gate between the SFP and the fuel transfer canal, and the gate between the SFP and the CLP) can only be open if the adjacent area is already full with water. The applicant states that the hydraulic pressure of the volume of water already in the SFP prevents the opening of these gates into an empty area. The applicant’s response also echoes the evaluation conducted in response to RAI 98-8051, Question 9.1.2-8, which concluded that even in the unlikely event that a gate opens into an empty volume, the SFP would not lower the SFP water level to less than 3 meters (10 feet) above the stored fuel. If the gate would be open while the SFP cleanup system is draining one of the adjacent volumes, the low SFP water level setpoint would terminate the process. The SFP is provided with diverse makeup water sources capable of reflooding the SFP in case of low SFP level.

The staff evaluated the applicant’s response and found that the SFP gates are designed to inherently prevent an operator error from opening the gates. If an error were to occur and the gates open to empty volumes, the system is configured such that it would limit the amount of water that would flow out of the SFP and the system is also provided with diverse methods of reflooding the SFP. The staff evaluation of the SFP makeup sources, their capacity and velocity are evaluated in Section 9.1.3 of this report. Based on this, the staff finds that the applicant has adequately addressed the staff concerns discussed in RAI 79-7990 Question 9.1.2-5. Therefore RAI 79-7990 Question 9.1.2-5 is considered resolved

The APR1400 DCD Tier 2, Section 9.1.2.2.2 states that piping penetrations to the SFP are at least 3.05 m (10 ft) above the top of the fuel assemblies seated in the spent fuel storage racks, which complies with the SRP recommendation 9.1.2.III.H.ii.

DCD Tier 2, Section 9.1.2.3.2 states that the thermal-hydraulic analysis demonstrates that the flow through the spent fuel rack is adequate for decay heat removal from the spent fuel assemblies during anticipated operating conditions. However, the applicant has not provided this report for evaluation. Therefore, in RAI 79-7990, Question RAI 09.01.02-06, the staff requested the applicant to provide the report for staff evaluation.

The staff performed an audit of the applicant's thermal calculation to confirm that the racks are designed with adequate flow area in order to provide sufficient decay heat removal. The analysis should also show adequate natural circulation and prevention of nucleate boiling for all fuel assemblies. The staff review of the adequacy of the safety-related spent fuel pool cooling system is discussed in Section 9.1.3 of this evaluation. While performing the audit of the thermal calculation the staff confirmed that the rack is designed to allow for natural circulation while maintaining the SFP water temperature below nucleate boiling. Based on this, the staff finds RAI 79-7990 Question RAI 09.01.02-06 resolved.

Based on the design features reviewed above, the staff finds that the APR1400 design meets GDC 61.

9.1.2.2.4.5 GDC 63, Monitoring fuel and waste storage

GDC 63 requires appropriate systems in fuel storage and radioactive waste systems and handling areas to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and to initiate appropriate safety actions. GDC 63 requires for dry storage of new fuel, either criticality accident monitors pursuant to 10 CFR 70.24, "Criticality accident requirements," or an acceptable method of preventing an increase in k_{eff} beyond safe limits pursuant to 10 CFR 50.68, "Criticality accident requirements."

The applicant stated that a drainage system is provided to prevent accumulation of water or other moderation media in the NFSP. In accordance with SRP Section 9.1.2, flood prevention in the NFSP is required to avoid submerging the new fuel in an unintentional moderator which may lead to an unintentional criticality. DCD Tier 2, Section 9.1.2.2.1 states that the NFSP is provided with a drain system connected to the AB sump to minimize the effects of flooding. The system is provided with a check valve to prevent backflow through the system into the NFSP. SRP Section 9.1.2.III.2.L states that the drain system should be sized to handle the maximum flow from the rupture of the largest water pipe in the area. The applicant's description of the drain system did not discuss the sizing criteria for the system. Therefore, in RAI 09.01.02-3, the staff requested that the applicant include in the DCD the design description that demonstrates that the NFSP drain system is capable of handling the maximum flow from the rupture of the largest water pipe in the area.

The applicant responded to the staff's RAI stating that the there is no piping in the upper area of the NFSP and that the top of the NFSP is provided with a curb, with a height of approximately 4 inches, which would deny water from going into the pit.

The staff evaluated the applicant's response and determined that additional information was needed since the response did not provided the sizing criteria (drain size and maximum design flow) for the drainage system as requested in the original RAI. The applicant response states that there are no pipes located in the NFSP, but it does not address pipes located nearby whose failure could still spill water into the pit (such as fire protection piping).

Therefore, in RAI 458-8569, the staff requested the applicant to (a) provide the sizing criteria (drain size and maximum design flow) for the drainage of the NFSP and (b) consider any pipes nearby the NFSP (such as fire protection piping) that could fail and spill water that could reach the NFSP, and how the NFSP drainage system together with the curb design would work to prevent fluid in the pit from reaching the bottom of the fuel assemblies.

In its response the applicant discusses that the estimated flow from the fire protection system, and the size of the drain system located in the NFSP. The design of the NFSP drain system ensures that the maximum flood for the area is less than 2 inches. The new fuel storage rack is 8.25 inches above the NFSP floor.

The staff evaluated the applicant's description of the maximum water flow into the NFSP, the drain system capacity, and the elevation of the new fuel storage rack and determined that the NFSP drain system is design with adequate flow capacity to handle the worst expected flood level of the NFSP. The staff finds RAI 458-8569 resolved.

SRP Section 9.1.2.III.2.D states that the spent fuel racks need to be designed to withstand the maximum fuel handling equipment uplift forces without an increase in k_{eff} or damage to the watertight integrity of the spent fuel pool liner. DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design," states that the spent fuel storage racks are designed to withstand the fuel handling machine uplift force.

The APR1400 design includes a liner leakage collection system that monitors, collects, and routes possible liner wall and floor leakage. The system is checked weekly and inspected periodically to ensure that solid buildup (boron or other mineral) has not occurred within the system channels. The channels are sized to allow form inspection and cleanup of buildup. The description of the APR1400 liner leakage system meets the SRP Section 9.1.2 recommendation that detection and collection of SFP liner leaks are incorporated into the design with capability to collect pool liner leaks to prevent uncontrolled releases of radioactive material to the environment and to keep radiation exposure as low as reasonably achievable for personnel.

Based on the design features reviewed above, the staff finds that the APR1400 design meets GDC 63 and provides assurance that loss of residual heat removal capability and high radiation levels will be detected and that the release of radioactive materials to the environment will be prevented.

9.1.2.2.4.6 ALARA

The spent fuel areas within the building provide containment and confinement of the fuel during operations and limit offsite exposure in the event of a FHA. DCD Tier 2, Section 12.3.4.1.5, "ARMS," states that the SFP area is provided with safety related radiation monitors for actuating engineered safety features. These monitors perform additional safety functions that generate containment purge isolation and fuel area emergency ventilation actuating signals. The fuel area normal ventilation system is isolated, and the emergency ventilation system is initiated by the fuel area emergency ventilation actuating signal. This features meet the recommendation of

SRP 9.1.2 and position C7 of Regulatory Guidance 1.13, that high radiation signal should initiate automatic ventilation. The staff's complete evaluation of the ALARA design and decontamination details that the applicant described in DCD Tier 2, Section 12.1 and Section 12.3.1 are discussed in Section 12 of this report.

9.1.2.2.4.7 ITAAC

The staff reviewed DCD Tier 1, Section 2.7.4.1, "New Fuel Storage," which contains the specific ITAAC for the NFSP. Table 2.7.4.1-1, "New Fuel Storage ITAAC," specifies the inspections, tests, analyses, and associated acceptance criteria for the new fuel storage racks. DCD Tier 1, Section 2.7.4.2, "Spent Fuel Storage," contains the specific ITAAC for the SFP. Table 2.7.4.2-1, "Spent Fuel Storage ITAAC," specifies the inspections, tests, analyses, and associated acceptance criteria for the new fuel storage racks.

The staff evaluated the proposed ITAAC for the NFSP and identified that the system design description does not include a discussion of the flood prevention features (drain sizing and back-flow prevention), and Table 2.7.4.1-1 does not verify the proper installation of the back flow prevention features. The staff also identified that DCD Tier 2, Section 9.1.2.2.1 indicated that the minimum edge-to-edge spacing between fuel assemblies in adjacent rows is maintained to keep the fuel assemblies in a subcritical configuration. However, DCD Tier 1, Section 2.7.4.1, "New Fuel Storage," does not discuss the minimum separation requirement and Table 2.7.4.1-1 does not includes a test to verify this on the once installed new fuel racks. DCD Tier 2, Section 9.1.2 also describes the racks as seismic Category I components, bolted to the pit floor to prevent tipping; however, this description is also missing from Tier 1, as well as the test to confirm it.

The staff issued RAI 79-7990, Question 09.01.02-04, requesting the applicant to modify DCD Tier 1, Section 2.7.4.1, in order to add detailed information to the system description section and to create a new specific ITAAC.

The staff also evaluated the design description provided in DCD Tier 1, Section 2.7.4.2.1 indicating no pipe penetrates the pool below 3 meters (10 ft) above the stored fuel and that any pipe that extends below this level is provided with siphon breakers at this level or above. As a result, the staff identified that there is no test in Table 2.7.4.2-1 to verify this requirement. In addition, the staff determined that the system description does not address several features, identified in DCD Tier 2, Section 9.1.2, which are credited for maintaining SFP water level. Therefore, the staff issued RAI 79-7990, Question 09.01.02-07, requesting the applicant to update the ITAAC system description and to include inspection items in Table 2.7.4.2-1 addressing the fact that there are seismic Category I SSCs, the leak tightness of SSCs and the pool dimensions.

The applicant responded to 79-7990, Questions 09.01.02-04 and 09.01.02-07 by proposing to add clarifications to the system description sections and to use a single functional arrangement ITAAC on each section to address all of the staff's concerns. The staff evaluated the applicant's responses and determined that the proposed ITAAC is unacceptable. The applicant's proposed ITAAC is using generic terms such as "sufficient" or "approximately" which are not conducive to the successful application of the ITAAC process.

The staff submitted RAI 458-8569, Question 09.01.02-52 requesting the applicant to:

a. update DCD Tier 1, Section 2.7.4.1 to include a description of the anti-flooding features credited to prevent flooding of the NFSP (pit drainage back-flow protection) and create an ITAAC to confirm the proper construction and installation of these features;

b. update DCD Tier 1, Section 2.7.4.1 to include a description of the anti-tipping feature of the NFS racks (bolted to the floor) and an ITAAC to confirm that the racks are adequately installed (and bolted);

c. create a new ITAAC that verifies that no non-seismic Category I component is located in an area where its failure could impact NFSP racks or stored fuel;

d. create a new ITAAC that verifies that no non-seismic Category I component is located in an area where its failure could impact a SFP safety-related SSC, the racks, or stored fuel.

In its response to the staff RAI, the applicant proposed to expand the design description of the New Fuel Storage in Tier 1, Section 2.7.4.2.1. The expanded description states that non-seismic Category I component located near the area of NFSP will not impact NFSP racks and stored fuel due to its failure during SSE, also, the new fuel storage racks are designed and constructed to prevent tipping. The applicant's response also propose to modify the acceptance criteria of the new fuel storage functional arrangement ITAAC to verify anti-flooding provisions, the anti-tipping provisions of the racks, and that non-seismic Category I component around the pit and racks will not impact NFSP racks and stored fuel due to its failure during SSE.

The staff reviewed the applicant's response to RAI 458-8569, Question 09.01.02-52 and the proposed DCD Tier 1 proposed changes and determined that expanding the design description of the new fuel storage addresses the staff concerns discussed in items a) and b) of the RAI. The proposed changes to the new fuel storage functional arrangement ITAAC addresses the staff concerns of items c) and d) of the RAI. The staff also confirmed that Revision 1 of the DCD incorporates the proposed changes discussed in the RAI response.

The staff also submitted RAI 458-8569, Question 09.01.02-53 requesting the applicant to:

a. update Tier 1 Section 2.7.4.2 to include a detailed description (or a figure) that identifies the elevations of all pipes, gates, drains, openings, and anti-siphon devices in the SFP, and create an ITAAC to verify that the components has been installed as described (at correct location and elevation);

b. update Tier 1 Section 2.7.4.2 to include a detailed description (or a figure) that identifies the pool dimensions and create an ITAAC to verify the as-built pool has been built as designed.

In its response to RAI 458-8569, Question 09.01.02-53, the applicant agreed to make the changes the RAI suggested and propose to update ITAAC in DCD Tier 1 Table 2.7.4.2-1 accordingly.

The staff evaluated the DCD proposed changes and confirmed that the proposed changes address the staff's concerns identified in items (a) and (b) of RAI 458-8569, Question 09.01.02-53. The staff also confirmed that Revision 1 of the DCD incorporates the proposed changes discussed in the RAI response.

Based on the ITAACs identified for the NFSP and the SFP support systems, the staff concludes that the applicant has proposed adequate ITAAC to verify the proper construction and operation of the NFSP and the SFP as required in 10 CFR 52.47(b)(1).

9.1.2.2.4.8 Technical Specifications

The applicant has not identified any TS for the NFSP. The staff reviewed the DCD and concluded that no TS are required for the NFSP.

As for the SFP, the applicant provides two TS as follows:

TS 3.7.14, "Spent Fuel Storage Pool Water Level," requires the applicant to maintain a minimum of 7 m (23 ft) of water above the stored fuel. The staff finds this requirement adequate to assure that the fuel stored in the SFP has sufficient shielding to maintain the dosage on the SFP floor below acceptable levels.

TS 3.7.15, "Spent Fuel Storage Pool Boron Concentration," and TS 3.7.16, "Spent Fuel Assembly Storage," are related to the spent fuel criticality, and the staff evaluation of these TS is documented in Chapter 16 and Section 9.1.1 of this report.

9.1.2.2.4.9 Combined License Information Items

The applicant has not identified combined license information items related to this area of review. The staff has evaluated the DCD Section and determined that no COL Item is needed.

9.1.2.2.5 Conclusions

As described above, the staff concludes that the APR1400 new fuel storage pit and spent fuel handling area designs are in compliance with the requirements of GDC 2, 4, 5, 61, and 63 as specified above and the guidelines of SRP Section 9.1.2, and, therefore, are acceptable.

9.1.3 Spent Fuel Pool Cooling and Cleanup System

9.1.3.1 Introduction

The safety function to be performed by the spent fuel pool cooling system (SFPCS) (in conjunction with the spent fuel pool itself) is to assure that the spent fuel assemblies are cooled and remain covered with water during all storage conditions. Other functions performed by the system but not related to safety include water cleanup for the spent fuel pool, refueling canal, in-containment refueling water storage tank, and other equipment storage pools; means for filling and draining the refueling canal and other storage pools; and surface skimming to provide clear water in the storage pool.

9.1.3.2 Summary of Application

DCD Tier 1: In DCD Tier 1, Section 2.7.4.3, "Spent Fuel Pool Cooling and Cleanup System," the applicant states that the SFPCS is a safety-related system and that the spent fuel pool cleanup system (SFPCL) is non safety-related but, as showed in Figure 2.7.4.3-1, "Spent Fuel Pool Cooling and Cleanup System," a portion of the system provides the safety-related functions of containment isolation.

DCD Tier 2: The applicant has provided DCD Tier 2 system description in Section 9.1.3, "Spent Fuel Pool Cooling and Cleanup System" (SFPCCS), which consists of two separate subsystems: the SFPCS and the SFPCL.

The SFPCS consists of two redundant divisions that are independent of each other. The SFPCS, during normal and accident conditions, is designed to remove the decay heat that is produced by the spent fuel assemblies of the newest batch just offloaded from the core and the accumulated assemblies resulting from previous refueling. The SFPCS is shown in DCD Tier 2, Figure 9.1.3-1, "Spent Fuel Pool Cooling and Cleanup System Flow Diagram."

Each of the two cooling divisions is designed to maintain the pool temperature below 48.9 degrees Celsius (°C) (120 °F) during refueling periods to facilitate operations in the pool area, and a maximum temperature of 60 °C (140 °F) during normal and accident conditions.

Initial Test Program: DCD Tier 2, Section 14.2.12.1.77, "Spent Fuel Pool Cooling and Cleanup System Test," addresses the startup tests for the SFPCCS.

ITAAC: The ITAAC associated DCD Tier 2, Section 9.1.3, are identified in DCD Tier 1, Section 2.7.4.3, "Spent Fuel Pool Cooling and Cleanup System."

Technical Specifications: There are no TSs applicable to the spent fuel pool cooling and purification system; however, related TS information can be found in DCD Tier 2, Chapter 16, Sections 3.7.14, "Spent Fuel Storage Pool Water Level," through 3.7.16, "Spent Fuel Storage"; 4.3, "Fuel Storage"; and Bases 3.7.14, "Spent Fuel Storage Pool Water Level," through Bases 3.7.16, "Spent Fuel Storage." These TSs are reviewed in Section 9.1.2, "New and Spent Fuel Storage," of this report.

9.1.3.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.1.3, "Spent Fuel Pool Cooling and Cleanup System," and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.1.3.

1. GDC 2, "Design bases for protection against natural phenomena," 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. This criterion only applies to components important to safety and, therefore, does not apply to the cleanup portion of the system and need not apply to the cooling system if both the fuel pool makeup water system (and its source) and the auxiliary building (and its ventilation and filtration system) meet this criterion.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to the requirement that structures, systems, and components (SSCs) important to safety be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents and dynamic effects resulting from pipe whip, missiles, and discharging fluids.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to shared systems and components important to safety being capable of performing required safety functions.

4. GDC 61, "Fuel storage and handling and radioactivity control," as it relates to the requirement that the fuel storage system be designed to assure adequate safety under normal and postulated accident conditions. The system shall be designed with the capability to permit appropriate periodic inspection and testing of components important to safety; suitable shielding for radiation protection; appropriate containment, confinement and filtering capability; residual heat removal capability that reflects the importance to safety of decay heat and other residual heat removal; and the capability to prevent a significant reduction in fuel storage coolant inventory under accident conditions.

5. GDC 63, "Monitoring fuel and waste storage," as it relates to monitoring systems provided to detect conditions that could result in the loss of decay heat removal capability, to detect excessive radiation levels, and to initiate appropriate safety actions.

6. 10 CFR 20.1101, "Radiation protection programs," paragraph (b), as it relates to radiation doses being kept ALARA

9.1.3.4 Technical Evaluation

The SFPCCS consists of the SFPCS and the SFPCL. The SFPCCS is designed to remove the decay heat generated by the spent fuel assemblies stored in the SFP, and purify the water of the SFP and the in-containment refueling water storage tank (IRWST). Cooling is accomplished by taking heated water from the pool, pumping it through a heat exchanger, and returning the cooled water to the pool. The SFPCCS is also used to clarify and purify water in the fuel transfer canal and refueling pool during the refueling operation.

The staff reviewed the applicant's SFPCCS information in DCD Tier 1 and the supporting DCD Tier 2 information, in accordance with the applicable GDC and the guidance provided by NUREG-0800, Section 9.1.3.

The SFPCS is designed as two redundant, 100 percent capacity, safety related divisions that are independent of each other. The SFP cooling system, during normal and accident conditions, is designed to remove the decay heat that is produced by the spent fuel assemblies of the newest batch just offloaded from the core and the accumulated assemblies resulting from previous refueling. Each of the two cooling divisions is designed to maintain the SFP water temperature below 60 °C (140 °F) with the SFP heat exchanger through the component cooling water system (CCWS) at the design flow and temperature. The system is designed to maintain an SFP temperature below 60 °C (140 °F) assuming a single active failure.

The SFP receives normal borated makeup water from the boric acid storage tank (BAST) via the boric acid makeup pump (BAMP). The BAST, BAMP, and all associated piping are classified as seismic Category I and safety Class 3. The component cooling water (CCW) makeup pumps take water from the auxiliary feedwater storage tanks (AFWST) and provide seismic Category I makeup water to the pool.

The staff evaluated the DCD information against the regulatory requirements presented in Section 9.1.3.3 above, as discussed in the paragraphs below.

9.1.3.4.1 GDC 2, Design bases for protection against natural phenomena

Compliance with GDC 2 requires that SSCs important to safety be designed to withstand the effects of expected natural phenomena combined with the appropriate effects of normal and accident conditions without loss of capability to perform their safety functions. The acceptance criteria for meeting GDC 2 are based on conformance to Regulatory Guide (RG) 1.13, "Spent Fuel Storage Facility Design Basis," Regulatory Positions C.1, C.2, C.6, and C.8; and RG 1.29, "Seismic Design Classification," Regulatory Position C.1, for safety-related portions of the system, and Regulatory Position C.2 for nonsafety-related portions of the system.

RG 1.13, "Spent Fuel Storage Facility Design Basis," Regulatory Position C.1, "Seismic Design," states that the spent fuel storage facility, including all structures and equipment necessary to maintain minimum water levels necessary for radiation shielding, should be designed to seismic Category I requirements. RG 1.13, Regulatory Position C.2, "Protection Against Extreme Winds," states that the spent fuel storage facility should be designed to (1) keep extreme winds and missiles generated by those winds from causing significant loss of watertight integrity of the fuel storage pool, and (2) keep missiles generated by extreme winds from contacting fuel within the pool. RG 1.13, Regulatory Position C.6, "Drainage Prevention," states that; "Drains, permanently connected mechanical or hydraulic systems, and other features that (by maloperation or failure) could reduce the coolant inventory to unsafe levels should not be installed or included in the design." RG 1.13, Regulatory Position C.8, "Makeup Water," states that a Quality Group C, seismic Category I makeup system should be provided to add coolant to the pool. RG 1.29, Regulatory Position C.1 contains a list of SSCs, including their foundations and supports, which should be designed to withstand the effects of the SSE and remain functional. RG 1.29, Regulatory Position C.2 states that any portion of SSCs that are not required to remain functional after an SSE, but could still reduce the functioning of any plant feature that is required to remain functional to an unacceptable safety level or could result in incapacitating injury to occupants of the control room, should be designed and constructed so that the SSE would not cause such failure.

The SFPCS components are located within the auxiliary building structure. The auxiliary building is classified as seismic Category I and is designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other natural phenomena as described in DCD Tier 2, Sections 3.3, "Wind and Tornado Loadings," to 3.8, "Design of Category I Structures."

The SFPCS components such as piping, pumps, valves, and heat exchangers are safety-related and designed to remain operational following a SSE. DCD Tier 2, Section 9.1.3.1, "Design Bases," states that, to preclude loss of minimum SFP water level that provides proper shielding, all piping that penetrates the pool are located approximately 3 m (10 ft) above the top of the spent fuel assemblies and all piping extending down into the pool have siphon breaker holes at or above this level.

The staff evaluated the applicant's description of the SFPCS and notice that the applicant has not specified the elevation of the intake. In Section 9.1.3.2.1.1, "Spent Fuel Cooling Pumps," the applicant describes the SFPCS cooling pumps and it states that the net positive suction head (NPSH) available from the system exceeds each pump's required NPSH. This is based

on the minimum pool level and the maximum pool temperature of 60 °C (140 °F). However, the applicant has not clarified if the failure of any non-seismic Category I component has the capability of lowering the SFP water level below the minimum water level needed to operate the safety-related SFPCS.

In RAI 77-7991 (ML15196A607), Question 09.01.03-1, the staff requested the applicant to identify the minimum water level needed to provide adequate NPSH to the SFPCS pumps, identify the elevation of all the pipes that connect with the SFP, and to provide an evaluation that demonstrates that the failure of non-seismic components in the SFP (including pipes that penetrate the pool walls or pipes that extend below the minimum water level needed to ensure sufficient NPSH for the SFP cooling pump) will not prevent the SFPCS from performing its safety function.

In letter dated January 26, 2016 (ML16026A554), the applicant responded to the staff RAI 77-7991 providing the requested additional information. The applicant provided the minimum water level needed to provide the SFP cooling system with adequate NPSH and the elevation of all the connections to the SFP. The applicant's response also discussed the system design and configuration that ensure that the safety-related SFPCS operability is ensured following a failure of non-seismic Category I components.

The staff evaluated the applicant's response and determined that additional information was needed. The staff identified that the RAI response included several non-conservative or contradictory statements, therefore the staff issued RAI 473-8582 (ML16123A040) Question 09.01.03-4, requesting the applicant to:

a. Clearly identify the minimum safety water level credited to be retained in the SFP in order to ensure the proper operation of the safety-related SFPCS and update the DCD accordingly,

b. Clearly demonstrate that the minimum safety water level still provides adequate NPSH to operate the SFPCS pumps, and update the DCD accordingly, and

c. Revise the thermal-hydraulic calculations associated with the SFP cooling system using the revised minimum safety water level, and update the DCD accordingly.

The staff previously tracked resolution of RAI 473-8582, Question 09.01.03-4, as Open Item 9.1.3-1.

Additionally, while evaluating the applicant's responses to RAI 77-7991, the staff identified that, in some places, the normal water level has been identified as elevation 154', while in other places it shows as elevation 153'. The TSs identify the normal water level as 23' above the stored fuel, which results in EL. 153'. The staff issued RAI 473-8582, Question 9.1.3-5, requesting the applicant to:

a. Correct the inconsistency in the values of normal water level, and update the DCD accordingly and

b. Revise the thermal-hydraulic calculations associated with the SFP cooling system using the appropriate normal water level, and update the DCD accordingly.

In its response to RAI 473-8582 Question 09.01.03-5 (ML16189A184), the applicant clarified that the normal water level for the spent fuel pool is EL.154 ft. The water level of 23 ft discussed in Technical Specification Subsection 3.7.14 is the water level that shields and minimizes the general area dose when the storage racks are at their maximum capacity and provides shielding during the movement of spent fuel. In response to Item b, the applicant stated that the thermal-hydraulic calculation has been revised in response to RAI 473-8582, Question 09.01.03-4. The applicant proposed DCD changes in order to indicate clearly that these two levels represent different conditions.

The staff reviewed the applicant's RAI response and found that these two water levels represent different conditions, and therefore do not present an inconsistency in the DCD. The staff reviewed the proposed DCD changes and found them acceptable. The staff has confirmed that Revision 1 of the DCD includes the proposed DCD change described in the response to RAI 473-8582 Question 09.01.03-5. NUREG-0800, SRP Section 9.1.2 "New and Spent Fuel Storage," Item III.2.C states that nonsafety-related SSCs not designed to seismic Category I standards located in the vicinity of the new and spent fuel storage facilities are reviewed for whether their failure would cause an increase in k_{eff} to more than the maximum allowable.

The staff evaluated the system description provided in DCD Tier 2, Section 9.1.3, and determined that the applicant did not discuss this design criterion for the SFPCS. Therefore, in RAI 79-7990 (ML15196A610), Question 09.01.02-1, the staff requested the applicant to include in the DCD a discussion of how the APR1400 design prevents the failure of non-seismic Category I component from increasing the k_{eff} in the NFSP and the SFP. The staff evaluation of the resolution of this RAI is discussed in Section 9.1.2 of this report.

Based on the review above, the staff concludes that the SFPCCS design satisfies the requirements of GDC 2 as they relate to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, and hurricanes.

9.1.3.4.2 GDC 4, Environmental and dynamic effects design bases

Compliance with GDC 4 requires that SSCs important to safety be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents, and to be able to accommodate the dynamic effects resulting from pipe whip, missiles, and discharging fluids.

The applicant stated that the SFPCS is located inside the auxiliary building, which is designed to provide protection from externally generated missiles. The pool cooling pumps and heat exchangers are physically separated by the divisional wall in the auxiliary building.

The staff confirmed that DCD Tier 2, Section 3, states that the auxiliary building is designed to sustain external missile impact and that the divisional wall in the auxiliary building provides protection from the effects of internally generated missiles. The staff evaluation of the adequacy of missile barriers is addressed in Chapter 3, "Design of Structures, Components, Equipment, and Systems," of this report.

The staff also finds that locating the auxiliary building outside the turbine trajectory hazard zone meets the recommendation of RG 1.13, Regulatory Position C.2, which states that the spent

fuel storage facility should be designed to (a) keep extreme winds and missiles generated by those winds from causing significant loss of watertight integrity of the fuel storage pool, and (b) keep missiles generated by extreme winds from contacting fuel within the pool. Therefore, the staff concludes that the SFPCCS design meets the requirements of GDC 4.

9.1.3.4.3 GDC 5, Sharing of structures, systems, and components

Compliance with GDC 5 requires that SSCs important to safety not be shared among nuclear power units unless it can be shown that such sharing will not impair their ability to perform their safety functions.

The APR1400 design is a single-unit design, and a COL applicant must comply with GDC 5 for a multiple-unit site; therefore, the staff finds that the SFPCCS design satisfies the requirements of GDC 5 as they relate to whether shared SSCs important to safety are capable of performing their required safety functions.

9.1.3.4.4 GDC 61, Fuel storage and handling and radioactivity control

Compliance with GDC 61 requires that the fuel storage system be designed to assure adequate safety under normal and postulated accident conditions. The system shall be designed with:

- the capability to permit appropriate periodic inspection and testing of components important to safety;
- suitable shielding for radiation protection;
- appropriate containment, confinement, and filtering capability;
- residual heat removal that reflects the importance to safety of decay heat and other residual heat removal; and
- the capability to prevent a significant reduction in fuel storage coolant inventory under accident conditions.

The SFPCS is a safety-related, seismic Category I system designed to provide SFP cooling under normal and accident conditions. The system consists of two redundant, independent, one hundred percent capacity divisions, each capable of maintaining the SFP water below 48.9° C (120° F) during normal operations (including one single active failure) or below 60° C (140° F) assuming a full core offload (including one single active failure). The decay heat is transferred from the SFPCS heat exchangers to the CCW. DCD Tier 2 Section 9.1.1 defines a fueling batch as 112 fuel assemblies. The SFP has a total storage capacity of 1,792 fuel assemblies. Tier 2 Table 9.1.3.-2, “Spent Fuel Pool Cooling System Principal Component Design Parameters,” presents the design parameters for the SFPCS heat exchanger and the pump.

SRP 9.1.3.III.1 states that the reviewer needs to review the SFPCCS functional performance requirements to confirm that it addresses the minimum system heat transfer and system flow requirements for normal plant operation, component operational degradation requirements (i.e., pump leakage, etc.) and that procedures will be followed to detect and correct these conditions should degradation become excessive. The staff evaluated the system description provided in DCD Tier 2, Section 9.1.3, and determined that additional information was needed. The system description does not provide the values of the maximum normal and abnormal (full core offload)

SFP heat loads, nor does it state what is the heat exchanger capacity and minimum system flow are. Therefore, in RAI 77-7991, Question 9.1.3-2, the staff requested the applicant to update DCD Tier 2, Section 9.1.3, to include the values of the maximum normal and abnormal (full core offload) SFP heat loads and the minimum heat exchanger cooling water flow.

In their January 26, 2016, response to RAI 77-7991 the applicant stated that the SFPCS heat exchangers are sized based on the maximum heat load that could occur during refueling operations, which is the most limiting case. The applicant proposed to update the DCD Tier 2, Table 9.1.3-2 to include the system design heat load of 17.7 X 10^6 W (60.6 X 10^6 Btu/hr).

The staff evaluated the applicant's RAI response and determined that including the system design thermal loading and required cooling water flow into Table 9.1.3-2 addresses the staff concerns discussed in RAI 77-7991, Question 9.1.3-2. The staff has confirmed that Revision 1 of the DCD includes the proposed DCD change described in the response to the RAI.

DCD Tier 2, Section 9.1.3 states that the SFPCL is a separated sub-system design to clean and purify the water in the SFP, refueling pool, cask loading pit, fuel transfer canal, and refueling canal without causing any interruption in the refueling operation. The SFPCL subsystem is independent from the safety-related SFPCS, with its own suction and return connections, and is designed such that no failure could impact the SFPCS. The system piping is designed to seismic Category II standards and connects to the SFP above the minimum safety water limit to ensure that a failure of the nonsafety-related SFPCL will not prevent the safety-related SFPCS from performing its intended safety function.

DCD Tier 2, Section 9.1.3, states that the SFPCS (piping, pumps, valves, and heat exchangers) is safety-related, seismic Category I, safety Class 3, and designed in accordance with ASME Section III. Designing the SFPCS to seismic Category I standards is consistent with the staff guidance described in SRP 9.1.3.III.1.B. Therefore the staff finds the system design criteria adequate to ensure the SFPCS will remain available and operational following an SSE.

SRP Section 9.1.3.III.1.C instructs the reviewer to verify that the quantity of fuel to be cooled by the spent fuel cooling system is consistent with the quantity of fuel stored. The staff reviewed the statements made in the DCD in regards to the thermal capability of the SFPCS and confirmed that assuming that the SFP is full at capacity is conservative and is consistent with the guidance provided in SRP 9.1.3. The staff also performed an audit of the applicant's thermal calculations and confirmed that the total number of fuel assemblies assumed in the calculations is consistent with the SFP storage capacity, and the guidance provided in SRP Section 9.1.3.III.1.C.

SRP Section 9.1.3.III.1.D states that the SFPCS should be capable of removing more than 0.3 percent of the reactor rated thermal power and the cooling system should retain at least half of its full heat removal capacity assuming a single active failure. The APR1400 is designed with a reactor rated thermal power of 3,982 MW (13,590 MBtu/hr). Each SFPCS heat exchanger is designed to transfer 17.7 MW (60.6 MBtu/hr), which is higher than the 0.3 percent reactor rated thermal power of 11.95 MW (40.77 MBtu/hr). DCD Tier 2, Table 9.1.3-3, "Failure Modes and Effects Analysis of the Spent Fuel Pool Cooling System," documents an evaluation of the SFPCS that demonstrates that the system can cope with an active failure and still maintain the SFP water temperature below the limit. The staff finds that the SFPCS design meets the design criteria discussed in SRP Section 9.1.3.III.1.D.

The SFP is designed to seismic Category I standards; pipping that connects to the SFP is designed to prevent draining of the SFP to unacceptable levels. There are no connections below 3 m (10 ft) above the stored fuel. These design features are consistent with the recommendations of SRP 9.1.3.III.1.E; therefore, the staff finds them acceptable. Note that the staff's evaluation of the acceptability of the relative elevation of all connections to the SFP is evaluated in Section 9.1.2 of this report.

SRP Section 9.1.3.III.1.F discusses the design features of the SFP water makeup system. In DCD 9.1.3 the applicant stated that the SFPCS is designed to prevent boiling of the SFP water; however, in the unlikely event that the SFPCS is not operating, the SFP contains sufficient water volume such that it would take 3.7 hrs for the SFP water to start boiling. The staff reviewed the applicant's thermal analysis report and confirmed that the report identifies that boiling could start after 2.5 hrs. The staff finds that this apparent inconsistency between the DCD and the thermal analysis needs to be justified or corrected. Therefore, the staff Issued RAI 497-8622 (ML16169A367), Question 09.01.03-6, requesting the applicant to correct this inconsistency between the DCD and the SFP thermal analysis report.

In its response to RAI 497-8622 Question 9.1.3-6 (ML16236A274), the applicant stated that the time to boil of 3.7 hours was derived by a hand calculation completed before the specific design inputs were prepared for the thermal hydraulic (T/H) analysis. The applicant's response also stated that the preparation of the T/H analysis identified non-conservative inputs in the original hand calculation. The applicant stated that the latest hand calculation (which is more conservative than the T/H analysis) resulted in a time to boil of 2 hours. The applicant has proposed DCD changes to reflect the latest calculation results.

The staff evaluated the applicants response and proposed DCD changes and determined that the propose DCD changes would eliminate the inconsistency between the DCD and the T/H analysis. The staff finds that a time to boil of 2 hrs allows the operators sufficient time to establish makeup to the SFP in the unlikely event of a loss of safety related cooling. The staff has confirmed that Revision 1 of the DCD incorporates this DCD change. The staff finds RAI 497-8622 Question 9.1.3-6, resolved.

The staff also identified that the DCD does not identify the maximum calculated SFP boil-off rate. The staff found that the audited thermal-hydraulic analysis determined the maximum boil-off rate for the SFP to be 546.6 L/min (144.4 g/min).

DCD Section 9.1.3.3.2 states that the SFP normally receives borated makeup water from the BAST, which is seismic Category I, safety Class 3, via seismic Category I components. The BAST is able to supply 643.52 L/min (170 gpm), which bounds the maximum boil-off rate. The BAST has capacity to store 250,000 gallons of borated water with a concentration of 4000 ppm. The design is also capable of supplying non-borated makeup water from the AFWST at a rate of 946.35 L/min (250 gpm).

The SFP is also capable of receiving makeup water from other non-seismic water sources. The SFP design includes two makeup lines and two spray lines that are seismic Category I, and allows the connection of a portable equipment (such as fire truck or portable pumps) to provide makeup to the SFP.

In DCD Section 9.1.3.4, "Inspection and Testing Requirements," the applicant states that the SFPCCS is designed to allow for periodic testing and inservice inspection of the systems. The

inservice inspection of pumps, valves, and piping is carried out in compliance with the requirements of ASME Section XI, and inservice testing of active pumps and valves is carried out to provide reasonable assurance of operational readiness, as described in Subsection 3.9.6.

The staff finds that the inspections and maintenance provisions discussed in 9.1.3.4 are in accordance with the recommendations of SRP Section 9.1.3.III.1.G and therefore acceptable. The SFP water chemistry parameters for cleanliness are shown in DCD Table 9.1.3-1, "Spent Fuel Pool Water Chemistry Parameters." This table provides the level to which contaminants are controlled and the sampling frequency. The staff compared this table to the guidance provided in the EPRI PWR Primary Water Chemistry Guidelines and found it to be fully consistent with it and in some cases more stringent.

Because the SFPCL is manually actuated and intermittent, the SFP contains a skimmer that removes impurities from the pool water surface helping maintain optical clarity of the SFP water as recommended in ANSI/ANS 57.2, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants," Section 6.3.2.9.1.

The design flow of the cleanup divisions is 1325 lpm (350 gpm) per filter, as described in DCD Section 9.1.3.2.1.5 "Spent Fuel Pool Cleanup Filters and Demineralizer Filters," which implies that all water from the SFP and IRWST can be processed by a single division in under 50 hours. Since there are two independent divisions, the entire system could be processed in about 25 hours, which supports the assertion that intermittent operation will satisfy the purity requirements and is well within the limit of 72 hours recommended by ANSI/ANS-57.2, Section 6.3.2.10.

The SFPCCS includes the necessary equipment to remove corrosion products, radioactive materials, and impurities from the pool water and reduce occupational exposures to radiation. On this basis, the staff concludes the SFPCCS satisfies GDC 61 with respect to the capability and capacity to remove corrosion products, radioactive materials, and impurities from the pool water and to reduce occupational exposures to radiation.

Materials Compatibility with the Environment

Per NUREG-0800, Section I.3, the staff reviewed the SFPCCS materials for compatibility with the SFP water and potential for metal corrosion degradation and compatibility of the materials of construction with service conditions. The material of construction of the cooling and purification system is austenitic stainless steel. This material has an acceptably low corrosion rate in boric acid solution at concentrations well above any experienced in the SFP. Therefore, the staff finds the materials of construction for the SFPCCS are appropriate and support meeting GDC 61 as it relates to containment and confinement, and prevention of significant reduction in the fuel storage coolant inventory.

Based on the review above, the staff concludes that the design of the SFPCS will be inspected, tested, shielded, and provided with containment, confinement, and residual heat removal capability to ensure that the system is capable of performing its intended safety function under normal and postulated accident conditions. The SFPCS, therefore, complies with the requirements of GDC 61.

9.1.3.4.5 GDC 63, Monitoring fuel and waste storage

Compliance with GDC 63 requires that appropriate systems be provided in the fuel storage area to detect conditions that may result in the loss of residual heat removal capability or excessive radiation levels, and to initiate appropriate safety actions.

DCD Tier 2, Table 9.1.3-3 compiles the results of evaluating the possible failures of the SFPCS components, how they are detected, and mitigation capability to ensure that the pool cooling capability is not jeopardized. The detection methods credited in the failure modes and effects analysis includes temperature, level, pressure, flow, and radiation monitors. DCD Tier 2, Section 9.1.3, includes a description of these instruments. The SFP includes safety-related and nonsafety-related temperature indication. The safety-related instruments are powered from Class 1E power sources and all instruments provide local and main control room (MCR) indication as well as annunciations in the MCR when there is a deviation from normal temperatures. The staff reviewed the table presented in the DCD and found that the SFPCS has means to detect, prevent, and mitigate conditions that may result in the loss of residual heat removal capability or excessive radiation levels.

Pressure instrumentation is used to provide indication of SFPCS pump discharge and also to identify pressure drop across the cleanup filter, demineralizer, and demineralizer filter.
A deviation from normal pressure in the SFP cooling pump discharge lines is alarmed in the MCR. The flow instrumentation is used to measure the SFP cooling flow; it is alarmed in the MCR to indicate a loss of cooling function when it detects low flow rates.

The handling area is continuously monitored with gamma radiation monitors, which are alarmed locally and annunciated in the MCR.

The water level instruments include two safety-related wide range SFP water level transmitters (from a 100 percent water level to the top level of the spent fuel assemblies). The instrument annunciates high water level, low water level, and low-low water level of the SFP to the MCR, remote shutdown room (RSR), and locally. The level instruments also actuate and interlock that stops the SFPCS pumps in order to protect the pumps from cavitation and failure.

Based on the review above, the staff concludes that the SFPCS design is provided with features to detect conditions that may result in the loss of residual heat removal capability or excessive radiation levels and initiate appropriate safety actions and, therefore, complies with GDC 63.

ALARA

Compliance with 10 CFR 20.1101(b) requires that the licensee use, to the extent practicable, procedures and engineering controls based on sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.

The applicant stated that the SFPCCS is provided with instrumentation and alarms on SFP water level, pool temperature, and pump flow. The SFPCL maintains radiation doses to plant personnel ALARA. The SFPCL maintains the dose rate at the surface of the SFP is 0.025 mSv. Additional ALARA discussion is evaluated by the staff in Section 12.1, “Ensuring that Operational Radiation Exposures Are As Low As (Is) Reasonably Achievable,” [sic] of this report.

In view of these reviews, the staff finds that the fuel pool cooling and purification system design meets the guidelines of RG 8.8, “Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable,” and complies with 10 CFR 20.1101(b) as it relates to radiation doses being kept as low as is reasonably achievable.

Minimization of Contamination

In DCD Tier 2, Section 9.1.3.2.3, “Design Features for Minimization of Contamination,” the applicant discusses design features built into the SFPCS to minimize the unintended contamination, early detection, reduction of cross-contamination, and reduction of waste generation. The SFP has been identified as a potential contamination source, therefore the SFPCCS is designed to facilitate early leak detection and to collect and properly handle any leakage. In order to prevent unintended contamination, the floors of the areas housing the SFPCCS components are coated with epoxy and the drains are routed to local drain hubs. Materials were specifically selected to prevent leakage (stainless steel) and to minimize waste generation. Finally, potential leakage is monitored by a variety of different methods including SFP level instruments and leak detection instruments such as building sump alarms and radiation monitors.

The SSCs are designed for the full service life and are fabricated as individual assemblies for easy removal, with the exception of the liner plates. The SFPCCS is designed with minimum embedded or buried piping. Piping between buildings is equipped with piping sleeves with leakage directed back to the auxiliary building for collection, thus preventing unintended contamination to the environment.

The applicant proposed two (2) COL information items to address SFPCCS operation and documentation. In COL 9.1(1), the DCD requires the COL applicant to provide operational procedures and maintenance program as related to leak detection and contamination control. COL 9.1(2) requires the COL applicant to maintain complete documentation of system design, construction, design modifications, field changes, and operations.

The staff evaluated the proposed COL 9.1(1) and determined that additional information is required. As the staff noted in RAI 246-8307 (ML15296A014), Question 09.02.02-03, radiological programs should be addressed in Chapter 11, and 12 of the DCD. The staff questions the need for a repetitive approach when identifying almost identical COL information items throughout the application. Duplicative COL information items can cause clarity problems for the staff reviewers and subsequent COL applicants. The staff considers that there should be a singular, encompassing COL information item addressing the whole plant operation. A COL information item addressing radiological monitoring program would be better identified under Chapter 12 in the DCD.

Therefore, the staff issued RAI 497-8622, Question 09.01.03-07, in which the staff requests the applicant to remove COL 9.1(1) and ensure that the concerns expressed by COL 9.1(1) are addressed in Chapter 11 and 12 of the DCD.

In its response to the staff’s RAI, the applicant referenced RAI 246-8307, Question 09.02.02-03, which indicated that in previous clarification telephone calls, the staff found it acceptable to represent these radiological programs with separate COL information items for each system, as

is currently presented in the DCD. The applicant decided to maintain the current arrangement and maintain the separate COL information items for each system for these programs.

In Revision 1 to the DCD the applicant renumbered COL 9.1(1) to COL 9.1(6) and expanded the COL information item to include additional details on the operational procedures and maintenance programs for the inspection, calibration, testing, and maintenance of the SFP supporting systems. The staff evaluated the proposed modifications to the COL information item and determined that the modifications are acceptable.

The staff evaluated the proposed COL 9.1(2) and determined that additional information is required. COL 9.1(2) requires the COL applicant to maintain complete documentation of system design, construction, design modifications, field changes, and operations. This COL information item, with the exception of the system design and design modifications, includes post licensing actions that cannot be completed prior to the issuance of a COL license. Since the SFPCCS is part of the design being certified, when referenced by a COL application, it will become part of the licensing basis for the COL. Design modification to the SFPCCS in the COL application would be considered a departure and would be required to be identified as such in a COL application, and the NRC will review the change if required. Once a COL is issued, changes to the COL must be in accordance with 10 CFR 52.98, "Finality of combined license; information requests," which provides information on what is required for changes to or departures from information within the scope of the reference design.

The staff finds it unclear as to what post-licensing commitments the applicant is seeking, because existing regulations require maintaining documentation of changes. Therefore, the staff issued RAI 497-8622, Question 09.01.03-08 in which the staff requests the applicant to remove the COL information item, or to provide the basis for the COL information item and to discuss why post licensing aspects such field changes and operations are included.

In its response to the staff's RAI, the applicant agreed with the staff's concerns and recommendations described in the RAI and propose to update the COL information item in order to include only the system design and design modifications.

In Revision 1 to the DCD, the applicant re-numbered COL 9.1(2) as COL 9.1(7). The staff evaluated the proposed modifications to the COL information item and determined that the modifications are acceptable. The staff confirmed that the proposed modifications to the COL information item have been incorporated into revision 1 of the DCD.

Additional information, details, and discussion related to the minimization of contamination is presented in Chapter 12, "Radiation Protection," of this Report.

9.1.3.4.6 Initial Test Program

DCD Tier 2, Section 14.2.12.1.77, "Spent Fuel Pool Cooling and Cleanup System Test," addresses the startup tests for the SFPCCS. This testing will involve demonstrations of both cooling capacity and purification capabilities. The system will be tested for various leakage paths, makeup capacity, system flow rates, pump-head, and related critical parameters.

The staff reviewed DCD Tier 2, Section 14.2.12.1.77, and finds that the tests described therein are comprehensive in that they confirm that the system as built will conform to the design

standards described in DCD Section 9.1.3. Additional discussion of these tests can be found in Chapter 14 of this report.

9.1.3.4.7 ITAAC

DCD Tier 1, Section 2.7.4.3, "Spent Fuel Pool Cooling and Cleanup System" provides the SFPCCS design description. DCD Tier 1 Table 2.7.4.3-1, "Spent Fuel Pool Cooling and Cleanup System Equipment and Piping Location/Characteristics," provides the locations, seismic design criteria, and applicable ASME code standard for the major piping components of the SFPCCS. DCD Tier 1, Table 2.7.4.3-2, "Spent Fuel Pool Cooling and Cleanup System Components List," provides the locations, seismic design criteria, safety function, electrical classification, and applicable ASME code standard for the major components of the SFPCCS. DCD Tier 1, Table 2.7.4.3-3, "Spent Fuel Pool Cooling and Cleanup System Instruments List," provides the locations, seismic design criteria, electrical classification, display location, and applicable ASME code standard for the monitoring instruments of the SFPCCS. DCD Tier 1, Table 2.7.4.3-4, "Spent Fuel Pool Cooling and Cleanup System ITAAC," specifies the inspections, tests, analyses, and associated acceptance criteria for the SFPCCS

In general, the ITAAC items include confirmations of functional arrangements, locations, separation, design codes, and hydrostatic testing. The staff reviewed the DCD Tier 1 information and the ITAAC requirements and determined that they adequately describe the design certification requirements for the fuel pool cooling and purification system. The staff further concluded that the ITAAC requirements are sufficient to demonstrate that the SFPCCS will operate in accordance with the design certification, the provisions of the AEA, and the Commission's regulations.

9.1.3.4.8 Technical Specifications

No specific TSs are provided to address the SFPCCS. However, DCD Tier 2, Chapter 16, TS Sections 3.7.14 to 3.7.16, and 4.3 all address SFP or SFP-related requirements. The staff's review these TS requirements and their bases are documented in Section 9.1.2 of this report.

9.1.3.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.1(6)	The COL applicant is to provide operational procedures and maintenance programs for the inspection, calibration, testing, and maintenance of the SFP leak detection provision (sight glasses), pool water temperature, pool water level,	9.1.3.2.3, 9.1.6

	SFP area radiation monitor, and the SFP steel liner. The COL applicant is also to provide the inspection interval for the maintenance program. In addition, the COL applicant is to provide operational procedures and maintenance programs for the design features implemented for SFP contamination control, including heat exchanger seals, epoxy coating, and SFP filters and demineralizers. The contamination control procedures and programs can be integrated into an overall plant-wide RG 4.21 program following the guidance from NEI 08-08A.	
9.1(7)	The COL applicant is to maintain complete documentation of system design and system design modifications.	9.1.3.2.3, 9.1.6

The staff finds these COL information items to be acceptable. The staff's evaluation of these COL action items has been documented earlier in this Section of the report.

9.1.3.6 Conclusion

Based on the review above, the staff concludes that the spent fuel pool cooling system meets the requirements of GDC 2, GDC 4, GDC 61, GDC 63, and 10 CFR 20.1101(b). Meeting the requirements of the applicable GDCs and 10 CFR 20.1101(b) provides assurance that components of the spent fuel pool cooling system are designed to withstand the effects of expected natural phenomena; will be inspected, tested, shielded, and provided with containment, confinement, and residual heat removal capability; and that system components will be provided with monitoring and detection capabilities to ensure that the system is capable of performing its intended safety function.

9.1.4 Light Load Handling System (Related to Refueling)

9.1.4.1 Introduction

The light load handling system (LLHS) handles, moves, and stores fuel assemblies and control element assemblies (CEA) during fuel transfer operation. The LLHS is an integrated system of equipment, tools, and procedures for refueling, handling, and storage of fuel assemblies from receipt of the new fuel container to shipment of the spent fuel cask.

9.1.4.2 Summary of Application

DCD Tier 1: The applicant has provided a general description of the light load and fuel handling system in DCD Tier 1, Section 2.7.4.4, "Light Load Handling System."

DCD Tier 2: The applicant has provided a detailed description of the light load and fuel handling system in DCD Tier 2, Section 9.1.4, "Light Load Handling System (Related to Refueling)."

The major components of the LLHS are the refueling machine (Figure 9.1.4-1), CEA change platform (Figure 9.1.4-2), fuel transfer system (Figures 9.1.4-3A and 9.1.4-3B), spent fuel handling machine (SFHM) (Figure 9.1.4-4), CEA elevator (Figure 9.1.4-5), and new fuel elevator (Figure 9.1.4-6). The fuel transfer system moves the fuel between the containment building and the fuel handling area in the auxiliary building through the transfer tube. The building layouts related to refueling operations are also shown in Figure 9.1.4-8, "Auxiliary Building Layout (Related to Fuel Handling)," and Figure 9.1.4-9, "Containment Building Layout (Related to Fuel Handling)." The main tools and servicing equipment used for refueling are listed in Table 9.1.4-1, "Major Tools and Servicing Equipment for Refueling Functions." Section 9.1.4.2.1 contains a brief description of the major components.

ITAAC: DCD Tier 1, Table 2.7.4.4-2, "Light Load Handling System ITAAC," specifies the ITAAC for the light load and fuel handling equipment.

Initial Test Program: DCD Tier 2, Section 14.2, "Initial Plant Test Program," contains the performance testing for fuel handling and storage test (14.2.12.1.33).

Technical Specifications: There are no TSs applicable to the LLHS.

9.1.4.3 Regulatory Basis

The relevant regulatory requirements for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.1.4, "Light Load Handling System and Refueling Cavity Design," and are summarized below. Review interfaces with other SRP sections also can also be found in NUREG-0800, Section 9.1.4.

1. GDC 2, "Design bases for protection against natural phenomena," 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 5, "Sharing of structures, systems, and components," as it relates to shared systems and components important to safety being capable of performing required safety functions.

3. GDC 61, "Fuel storage and handling and radioactivity control," as it relates to the requirement that the fuel storage system be designed to assure adequate safety under normal and postulated accident conditions.

4. GDC 62, "Prevention of criticality in fuel storage and handling," as it relates to preventing criticality in the fuel storage and handling system shall by the use of physical systems or processes, preferably by use of geometrically safe configurations.

5. 10 CFR52.47 Item (b)(1), which requires that a design certification (DC) 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 has been constructed and will be operated in accordance with the design certification, the provisions of the AEA and the NRC regulations.

9.1.4.4 Technical Evaluation

The staff's evaluation of the light load handling system is based upon the information provided in the applicant's DCD, Revision 1, including Tier 1 and Tier 2.

9.1.4.4.1 GDC 2, Design bases for protection against natural phenomena

The staff reviewed the LLHS for compliance with the requirements of GDC 2, with respect to its design for protection against the effects of natural phenomena. Compliance with the requirements of GDC 2 is based on meeting the guidance of RG 1.29, Regulatory Positions C.1 and C.2.

The LLHS, including fuel handling, should be capable of withstanding the effects of natural phenomena without loss of capability to safely carry loads that, if dropped, could cause unsafe conditions, which is a prerequisite for keeping exposures to within acceptable limits. All of the LLHS equipment is classified as nonsafety-related, except the double-blind flange located on the containment side of the fuel transfer tube assembly. The seismic and quality group classifications for the LLHS are specified in Section 3.2, "Classification of Structures, Systems, and Components," of the Tier 2 DCD. Table 3.2-1, "Classifications of Structures, Systems, and Components," specifies that the major components of the LLHS (refueling machine, CEA change platform, fuel transfer system, SFHM, CEA elevator, and new fuel elevator) are classified as Seismic II components to ensure no fuel or component fails as a result of a seismic event. DCD Tier 2, Section 9.1.4.3, "Safety Evaluation," also indicates the LLHS meets positions C.1 and C.2 of RG 1.29.

Table 3.2-1 specifies that the refueling machine bridge rails and SFHM bridge rails are designed to seismic Category III. In response to RAI 79-7990, Question 09.01.02-01 (ML15301A236), the applicant stated that the SFHM is designed to, in the event of a SSE, not derail due to the strength of the rail mounting design, although the rails of the SFHM are designed as seismic Category III. By definition, as seismic Category III, these rails cannot be credited to remain functional following an SSE; therefore, these rails cannot be credited to prevent the derailment of the SFHM. In RAI 480-8608 (ML16132A230), Question 09.01.02-55, the staff requested the applicant to provide additional information clearly identifying how the SFHM design prevents it from falling into the SFP following an SSE (assuming failure of the seismic Category III rails), and to update the DCD accordingly. The staff previously tracked the resolution of this RAI as an

open item. In its response to RAI 480-8608, Question 09.01.02-55, dated August 2, 2016 (ML16215A200), the applicant provided the seismic analysis for the affected rails, as well as proposed to revise DCD Tier 2, Table 3.2-1 to reflect an assigned "seismic Category II" classification to the rails. The staff finds this response acceptable because correct seismic classification is now assigned to the affected LLHS components with proper supporting design information. The staff also confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 480-8608, Question 09.01.02-55, to be resolved and closed.

Fuel handling is performed in buildings that are safety-related seismic Category I structures and, therefore, provide protection to LLHS from external events. The refueling machine (RM), CEA change platform (CEACP) and CEA elevator (CEAE) are located in the reactor containment building. The SFHM, new fuel elevator (NFE) and fuel handling hoist of the overhead crane are located in the fuel handling area of the auxiliary building. The fuel transfer system (FTS) is located in both the reactor containment building and the auxiliary building.

The RM is a traveling bridge and trolley that is located above the pool and rides on rails set in the concrete on each side of the refueling cavity. Motors on the bridge and trolley position the machine over each fuel assembly location within the reactor core or fuel transfer carrier. The refueling machine is seismic Category II and designed to hold its load during a SSE, a loss of power, or the loss of service air.

The CEAE is a seismic Category II component used to assemble new CEAs and to disassemble irradiated CEAs. The elevator is powered by a cable winch, and the CEAs are contained in a simple support structure whose wheels are captured at the two rails. Tooling used to handle CEAs within the elevator is supported from the CEA change platform.

The CEA change platform travels on the same rails as does the refueling machine. This seismic Category II platform operates above the upper guide structure (UGS) after the UGS has been placed in the storage area and the UGS lift rig is removed.

The major components of the fuel transfer system are a carriage, a carrier for two fuel assemblies, two upenders, and two hydraulic power units. The fuel transfer system is seismic Category II and used to transfer the fuel assemblies horizontally through the fuel transfer tube between the reactor cavity and the spent fuel pool. The fuel transfer tube extends through the containment wall. During reactor operation, the transfer tube is sealed by means of a safety-related, seismic Category I double-blind flange and a penetration sleeve, located inside the containment building.

The SFHM is a traveling bridge and trolley that rides on rails over the refueling canal, spent fuel pool, cask loading pit, and new fuel elevator. The SFHM is used to transfer fuel assemblies from the new fuel elevator to the upender, from the upender to the spent fuel storage racks, or from the spent fuel storage racks to the fuel shipping cask. The SFHM is a refueling machine modified for use in the fuel handling area and the major differences are the longer bridge span and SFHM zones interlocks. The SFHM has an auxiliary hoist that is provided to handle the light loads or fuel assemblies using the appropriate handling tool. Similar to RM, the SFHM is seismic Category II and designed to hold its load during a SSE. Since the SFHM auxiliary hoist has the capability of handling fuel assemblies, the staff was unclear whether ANS/ANSI 57.1 interlocks or other features are applied to the auxiliary hoist. Therefore, the staff issued RAI 181-8011 (ML15244B159), Question 09.01.04-02, requesting the applicant to provide

additional details on the controls provided to ensure safe fuel handling when using the auxiliary hoist.

In its response to staff RAI 181-8011, Question 09.01.04-02 (ML15280A322), the applicant stated that the auxiliary hoist is designed for use with the fuel handling tool for movement of fuel assemblies. The auxiliary hoist on the SFHM is provided with interlocks or controls to raise or lower the fuel handling tool at the spent fuel storage rack locations, the new fuel elevator, the damaged fuel container locations, the tool storage locations, spent fuel inspection device location, and the cask loading pit. A control pendant is used to control the auxiliary trolley, auxiliary hoist, and bridge motion. An interlock for overload, underload, and travel protection is included. Additionally, the auxiliary hoist has an interlock with the SFHM, which is operated only when the auxiliary hoist is parked in its storage location. The auxiliary hoist has limit switches for auxiliary trolley travel limit positions and hard stops, has a load weighing system including a load cell and load indication, and is designed to be a variable speed system.

The staff evaluated the applicant's response and determined that the auxiliary hoist includes adequate controls to ensure safe fuel handling when using the auxiliary hoist because they conform to design requirements specified in ANS/ANSI 57.1, Section 6.3, which is endorsed by the NRC. Therefore, the staff finds RAI 181-8011, Question 09.01.04-02, resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 181-8011, Question 09.01.04-02, closed.

The NFE is seismic Category II and is used to lower new fuel from the operating floor to the bottom of the pool, where it is grappled by the SFHM. The elevator is powered by a cable winch and fuel is contained in a simple support structure whose wheels are captured in two rails. New fuel is loaded into the elevator by means of the fuel handling hoist of the overhead crane and a new fuel handling tool.

The fuel handling hoist is used to handle new fuel loading into the new fuel elevator. The fuel handling hoist is located on the fuel handling area overhead crane and classified as a heavy load handling component (crane capacity exceeding weight of one fuel assembly and its handling tool) with rails that extend the entire length of the fuel handling area. Review of the fuel handling area overhead crane is included in Section 9.1.5 of this report. This overhead crane is non-single failure proof and designed as seismic Category II. During an SSE, the fuel handling area overhead crane and all its components retain control and hold all loads up to the maximum critical load for all loading conditions, and the bridge and trolley remain in place on their respective runways with their wheels prevented from leaving the tracks. This overhead crane contains interlocks to prevent moving heavy load over the spent fuel pool.

As stated in Tier 1, Section 2.7.4.4.1 of DCD, the seismic Category II equipment for the major components of LLHS retains structural integrity and does not impair the ability of a seismic Category I equipment to perform its design basis safety function during or following an SSE. Based on the review above, the staff finds that the LLHS design conforms to the guidance of RG 1.29, positions C1 and C2, and therefore meets GDC 2 requirements.

9.1.4.4.2 GDC 5, Sharing of structures, systems, and components

The LLHS of the APR1400 is not shared between multiple units in accordance with DCD Tier 2, Section 9.1.4.1, which states, "No components in the LLHS are shared among nuclear power plants." Therefore, the staff finds that the GDC 5 requirements are met for the LLHS design.

9.1.4.4.3 GDC 61, Fuel storage and handling and radioactivity control and GDC 62, Prevention of Criticality in fuel storage and handling

DCD Tier 2, Section 9.1.4 describes the LLHS, which handles, moves and stores fuel assemblies and CEAs during fuel transfer operation. Spent fuel transfer and storage operations are designed to be conducted underwater to provide adequate radiation shielding during refueling and to permit visual control of the operation at all times.

For new fuel handling, DCD Tier 2, Section 9.1.4.2.2 provides a description of new fuel handling process and includes Figure 9.1.4-7, "Fuel Movement Path," showing the new fuel transfer path. After arrival of the new fuel shipping containers, the containers are transferred to the fuel handling area and secured to the operating floor. The new fuel handling tool, attached to the fuel handling hoist on the fuel handling area overhead crane, is then locked to the fuel assembly and the fuel assembly is removed from the shipping container, inspected, and placed in new fuel racks. The new fuel is removed from the new fuel storage racks and transferred to the NFE by using the fuel handling hoist and the new fuel handling tool. The NFE lowers the fuel assembly into the cask loading pit to allow the SFHM to transfer the fuel assembly to the spent fuel racks or to the upender. For transfer to containment, the new fuel assembly is placed in the upender transfer carriage. If a spent fuel assembly is present in the fuel carriers, it is removed from the other position in the fuel carrier and transferred to a designated position in the spent fuel storage racks using the SFHM. The new fuel is then transferred through the transfer tube into the containment building where it is accessed by the refueling machine. In the containment building, the RM removes the fuel assembly from the upended fuel carrier and places the fuel assembly in its designated position in the core.

For spent fuel handling, DCD Tier 2, Section 9.1.4.2.2 provides a description of the refueling process and includes Figure 9.1.4-7 showing underwater spent fuel transfer path. Following reactor disassembly, the RM hoist mechanism is positioned at the desired location over the core. Alignment of the hoist to the top of the fuel assembly is accomplished through the use of a digital readout system and is monitored by closed-circuit television. The fuel assemblies are removed one at a time from the core using the refueling machine. After removal from the core, the spent fuel assembly is moved underwater to the transfer area of the refueling cavity. The refueling machine transfers the fuel assembly to the transfer carriage in the upender. The upender lowers the fuel assembly to a horizontal position and the transfer carriage moves to the fuel handling area upender while the refueling machine retrieves the next fuel assembly from the core. In the fuel handling area, the SFHM removes the fuel assembly from the upended fuel carrier and places the fuel assembly in its designated position in the spent fuel storage racks.

During the spent fuel cask loading process, the SFHM transfers the spent fuel assemblies from the spent fuel storage racks to the spent fuel cask. This operation is implemented when the spent fuel cask loading pit is filled with SFP water and the gate between the SFP and the spent fuel cask loading pit is opened. Once the spent fuel assemblies are loaded into the cask, the cask is sealed and transferred to the cask decontamination pit with the cask handling hoist for preparation for storage.

Acceptance criteria for meeting the relevant requirements of GDC 61 are based on meeting the guidelines of ANSI/ANS 57.1-1992, "Design Requirements for Light Water Reactor Fuel Handling Systems." Table 1, "Required Interlock Protection," in ANSI/ANS-57.1-1992 provides interlock protection guidelines for each component of the LLHS, related to refueling.

As specified in DCD Tier 2, Section 9.1.4.5 "Instrumentation Requirements," the required interlocks shown in Table 1 of ANS 57.1-1992 are provided for the SFHM, new fuel elevator, fuel transfer system including the upenders and refueling machine. Mechanical and electrical interlocks are provided to restrict movement of fuel and prevent a fuel assembly drop with the potential for a release of radioactive materials from damaged irradiated fuel or criticality accidents or unacceptable personnel radiation exposures. Mechanical stops in both the refueling machine and the SFHM restrict withdrawal of the spent fuel assemblies to ensure a minimum water depth from the spent fuel is provided for shielding. To avoid a dropped assembly, the fuel hoists are provided with load-measuring devices and interlocks to interrupt hoisting if the load increases above the overload setpoint and to interrupt lowering if the load decreases below the underload setpoint.

To avoid the potential of a heavy load drop onto spent fuel, the fuel building overhead crane in the auxiliary building has interlocks that prevent moving heavy loads such as a spent-fuel cask over the new- and spent-fuel racks.

Grapples and mechanical latches that carry fuel assemblies or CEAs are mechanically interlocked against the inadvertent opening and an anti-collision device at the bottom of the mast assembly prevents damage to the fuel, should the mast be inadvertently driven into an obstruction.

As indicated in Section 9.1.4.4, "inspection and Testing Requirements," of the Tier 2 DCD, hoisting equipment is also tested at no load, 100 percent, and 125 percent of the specified hoist capacity. Fuel handling tools are proof tested at 150 percent of the maximum handling load, setpoints are determined and adjusted, and adjustment limits are verified. Equipment interlock function and backup systems operations are checked. Those functions having manual operation capability are exercised manually. The DCD contains a COL information item requiring the applicant to provide plant operating procedure guidelines for preoperational load testing and checkouts of interlocks, blocks, hoisting cables, control circuitry, and lubrication of fuel handling equipment.

These design features (electrical interlocks, mechanical stops, grappling, and testing) help ensure that fuel damage, and subsequent criticality and radiation exposure, will not occur as a result of excessive stresses on the fuel which may occur as a result of dropping the fuel or exposing the fuel to excessive loads.

Based on the LLHS design and conformance with the guidelines provided in ANSI/ANS 57.1-1992, the staff concludes that the LLHS meets the requirements of GDC 61 as it relates to radioactivity release as a result of fuel damage and the avoidance of excessive personnel radiation exposure.

Section 9.1.1 of this report provides the staff's evaluation of the prevention of new and spent fuel criticality, including conformance with ANSI/ANS 57.1 and the assumptions and initial conditions in the criticality analysis that need to be addressed by administrative control procedures and checklists used during refueling and other fuel handling operations.

The relevant aspects of GDC 62 as they apply to fuel handling can be met by conformance to the guidelines of ANSI/ANS 57.1-1992.

As specified in DCD Tier 2, Section 9.1.4.5, the required interlocks shown in Table 1 of ANSI/ANS 57.1-1992 are provided for the SFHM, new fuel elevator, fuel transfer system

including upenders, and refueling machine. The fuel hoists are provided with load-measuring devices and interlocks to interrupt hoisting if the load increases above the overload setpoint and to interrupt lowering if the load decreases below the underload setpoint.

The two cavity fuel carriers are designed to meet the same criticality considerations as the spent fuel storage racks. DCD Tier 2, Section 9.1.4 states that "boric acid is added to the SFP water in an amount that provides reasonable assurance of maintaining subcritical conditions."

Based on design meeting requirements of ANSI/ANS 57.1-1992 and the staff's evaluation of the new and spent fuel criticality analysis in Section 9.1.1 of this report, the staff concludes that the LLHS meets the requirements of GDC 62 as it relates to prevention of criticality.

Refueling Seals

SRP Section 9.1.4.III.3.D states that the refueling cavity design should have features to preclude a catastrophic draindown of the refueling cavity using operating experience associated with Inspection and Enforcement (IE) Bulletin 84-03, "Refueling Cavity Water Seals," and Information Notice (IN) 84-93, "Potential for the loss of Water from the Refueling Cavity."

The reactor vessel flange is sealed to the bottom of the refueling pool to prevent leakage of refueling water into the reactor cavity as described in Subsection 9.1.4.2.1.11, "Refueling Pool Seal." As shown in Table 3.2-1, the refueling cavity seal is classified as non-safety, Quality Group D and seismic Category II.

With regard to operating experience considerations, IE Bulletin 84-03 was issued to all holders of operating licenses and construction permits to address the potential failure of refueling cavity seals to assure that fuel uncovery while refueling remains an unlikely event. The bulletin called for licensees to evaluate the potential for and consequences of a refueling cavity seal failure. Additional information concerning refueling cavity seal failures was provided by IN 84-93. IN 84-93 noted that refueling cavities can also be drained due to failures associated with other seals and as a consequence of valve misalignments. Inadvertent drain down of the refueling cavity can result in a loss of cooling for fuel in transit and may cause a loss of water inventory and cooling for fuel in the buffer pool. Since the water inventory in the refueling cavity is also needed for shielding purposes, high radiation levels can result from exposed fuel and reactor components. 10 CFR Part 50, Appendix A, GDC 61, "Fuel Storage and Handling and Radioactivity Control," requires that the system design for fuel storage and handling of radioactive materials shall include the capability to prevent reduction in fuel storage coolant inventory under accident conditions. GDC 63, "Monitoring Fuel and Waste Storage," requires that monitoring systems shall be provided to detect conditions that could result in the loss of decay heat removal, to detect excessive radiation levels, and to initiate appropriate safety actions.

The staff reviewed the DCD and determined that it was not clear that the applicant had addressed the operational experience regarding refueling cavity draindown. In RAI 161-7992 (ML15232A826), Question 09.01.04-01, the staff requested the applicant to (a) to provide a justification as to how the refueling cavity water seal design prevents a failure that significantly affects the refueling cavity water level, (b) to complete a refueling cavity drain down evaluation, as described in SRP 9.1.4.III.3.D.ii, (c) to describe the design provisions so that any leakage that occurs is readily identified, and (d) to provide a justification for classifying the refueling cavity water seal as non-nuclear safety (NNS) instead of Safety Class 3 (SC-3).

In response to RAI 161-7992, Question 09.01.04-01, Item (a) (ML15334A392), the applicant stated that the refueling pool seal is classified as seismic Category II and is a permanently installed, welded structure, composed of stainless steel components. The refueling pool seal is designed to permanently seal the annulus between the reactor vessel seal ledge and the embedment ring in the refueling pool floor.

The applicant’s response states that, by designing the refueling pool seal as a seismic Category II component, this maintains the structural integrity of continuous structure without the failure under all postulated design conditions according to the seismic Category II definition; therefore, the function of the seal will be assured.

The staff evaluated the applicant’s response and determined that the applicant has misinterpreted the definition of a seismic Category II component. According to DCD Tier 2, Section 3.2, seismic Category II SSCs are designed to preclude a gross structural failure resulting from an SSE that could degrade the ability of an adjacent safety-related SSC to function to an unacceptable level or result in incapacitating injuries to personnel in the MCR. Designing the refueling pool seal as a seismic Category II component does not preclude seal leakage as stated in the applicant’s response. Therefore, the staff requested the applicant to revise its response to RAI 161-7992, Question 09.01.04-01, Item (a). In its revised response to RAI 161-7992, Question 09.01.04-01 Item (a) dated August 3, 2016 (ML16216A576), the applicant agreed to revise DCD Table 3.2-1 to reflect an assigned “seismic Category I” classification to the refueling pool seal and add new Figure 9.1.4-15, “Refueling Pool Seal,” showing the seal design details with respect to its surrounding plant structure and component to DCD Section 9.1.4. The staff finds the revised response acceptable because it adequately addresses the concerns discussed above. The staff also confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 161-7992, Question 09.01.04-01, Item (a), to be resolved and closed.

Refueling Cavity Drainage Paths

In response to RAI 161-7992, Question 09.01.04-01, Item (b), the applicant discusses the different pathways capable of draining the refueling cavity. The applicant’s description states that leakage through the refueling pool seal would not occur since the seal is designed to seismic Category II standards.

As discussed above, the staff does not agree with this conclusion. Classifying a structure as a seismic Category II does not preclude failure of the structure; it, however, precludes catastrophic failure. This limits the amount of leakage through the seal.

The applicant’s RAI response also addressed the inadvertent draining due to system misalignments. The applicant identified that the refueling pool is provided with connections to the SFPCCS, the shutdown cooling system (SCS), and the IRWST. All the different connections mentioned in the RAI response are provided with several isolation valves or check valves to reduce the possibility of a draindown event. In addition, the availability of these valves provides the capability of mitigating the consequences of a draindown event.

The staff evaluated the applicant’s response and determined that it did not address the drainage caused by failures of non-seismic Category I SSCs that connect to the refueling pool. In RAI 474-8588 (ML16123A212), Question 09.01.04-06, the staff requested the applicant to identify all non-seismic Category I SSCs that connect to the refueling pool (including their

associated elevations), and to evaluate the drain-down scenario caused by failure of these non-seismic Category I SSCs. In its response to RAI 474-8588, Question 09.01.04-06, dated August 3, 2016 (ML16216A597), the applicant presented three possible drain-down scenarios and explained how plant operators would respond to these events upon detection of abnormal lowering of refueling pool water level. These re-evaluations show that each identified leakage path either has no direct or small effect on the refueling pool water level that can be easily managed by plant operators. The staff finds the response acceptable because it adequately addresses the above mentioned staff's concerns, and no further change to the DCD is necessary. Therefore, the staff considers RAI 474-8588, Question 09.01.04-06, to be resolved and closed.

Impact and Mitigation of Refueling Cavity Leakage

In RAI 161-7992, Question 09.01.04-01, Item (b), the staff requested the applicant to provide a refueling cavity drain-down evaluation, as described in SRP 9.1.4.III.3.D.ii. The applicant's response indicated the worst drain-down scenario as the one in which the spent fuel assembly is temporarily stored, in a vertical position, in the fuel carrier upender.

The staff evaluated the applicant's response and determined that additional information was needed. Taking into consideration the refueling operations, the staff would have expected the worst case to occur with fuel already located in the double-capacity upender and another fuel assembly in transit, elevated at the maximum lift elevation. It was not clear to the staff how the applicant determined the initial assumptions for evaluating a drain-down event. Therefore, in RAI 474-8588, Question 09.01.04-05, the staff requested the applicant to justify the basis for the assumed initial assumptions, or to re-evaluate the drain-down scenario with more limiting initial conditions. In its response to RAI 474-8588, Question 09.01.04-05, dated August 3, 2016 (ML16216A597), the applicant agreed with the staff's suggested worst scenario situation and included this assumed plant configuration as part of its re-evaluation of drain-down scenarios discussed above. The staff, therefore, considers RAI 474-8588, Question 09.01.04-05, to be resolved and closed.

In response to RAI 161-7992, Question 09.01.04-01, Item (c), the applicant stated that the design includes several means to identify refueling pool drainage. These instruments include temporary and permanently installed instrumentation, low level alarms, and local and control room indications. Some of these refueling pool level indication instrumentation are the

- Refueling water level monitor,
- Refueling pool level instrument,
- Spent fuel pool level instruments,
- In-core instrumentation (ICI) cavity sump level instruments, and
- Reactor cavity level instruments.

After the operator identifies that significant inventory loss has occurred in the refueling pool, the operator initiates the recovery actions and adds makeup to the refueling pool inventory. The applicant's RAI response identified at least three available makeup water sources. The shutdown cooling pump or containment spray pump can directly inject borated water through the direct vessel injection (DVI) nozzles to the refueling pool from IRWST. Use of the charging

pump or boric acid makeup pump also provides the flow delivery to refueling pool from BAST. The Safety Injection Tank (SIT) is capable of providing gravity feed makeup.

The staff evaluated the applicant's response and determined that the design does incorporate provisions so that any leakage that occurs is readily identified and corrected therefore addressing the staff concerns identified in RAI 161-7992, Question 09.01.04-01, Item (c). The staff considers RAI 161-7992, Question 09.01.04-01, Item (c), resolved.

In response to RAI 161-7992, Question 09.01.04-01, Item (d), the applicant stated that the refueling pool seal is a structure for sealing the refueling cavity and does not have the safety function of providing cooling for fuel stored temporarily in the fuel cavity. The applicant argues that the refueling pool seal is in the category of the fuel handling system in accordance with the ANSI/ANS-57.1(1980) Section 6.1. Based on this, the applicant classified the refueling pool seal as a Non-Nuclear Safety (NNS) Class.

The staff evaluated the applicant's response and determined that the refueling pool seal has been adequately included in the category of the fuel handling system, and based on ANSI/ANS-57.1 (1980) Section 6.1, the staff finds that the applicant has adequately classified the refueling pool seal as a NNS. Therefore, the staff concerns described in RAI 161-7992, Question 09.01.04-01, Item (d), are considered resolved.

Based on the above evaluation, the staff finds that the design of the refueling cavity seal is acceptable because it adequately addresses the safety issues raised by operating experience as documented in IE Bulletin 84-03, and as such, meets the underlying requirements of GDC 61 and 62.

9.1.4.4.4 Inspection and Testing Program

As discussed in Section 14.2, "Initial Test Program," of this report, the staff reviewed the applicant's initial test program in accordance with the review guidance contained in SRP Section 14.2, "Initial Plant Test Program – Design Certification and New License Applicants," and RG 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants."

Section A-1.n of RG 1.68, indicates that refueling equipment testing should be included in the initial test program. While DCD Tier 2, Section 9.1.4.4 indicates components are tested, the staff is unable to locate any detail or commitment of this testing in DCD Tier 2, Chapter 14. Therefore, the staff issued RAI 181-8011, Question 09.01.04-04 requesting the applicant to justify not including the capacity testing in the initial test program.

The applicant responded to Question 09.01.04-04 by letter dated January 6, 2016 (ML16006A568) and proposed to update the DCD Tier 2, Section 14.2.12.1.33 "Fuel Storage and Handling system Test," [sic] to include a static load test to the initial test program. The staff evaluated the proposed DCD changes and found them acceptable because the DCD now meets the guidance in RG 1.68; therefore, the staff concerns described in RAI 181-8011, Question 09.01.04-04 are resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 181-8011, Question 09.01.04-04 closed.

As indicated in DCD, the COL applicant is to provide plant operating procedure guidelines for preoperational load testing and checkouts of interlocks, blocks, hoisting cables, control circuitry, and lubrication of fuel handling equipment (COL 9.1(9)).

9.1.4.4.5 ITAAC

DCD Tier 1, Section 2.7.4.4, "Light Load Handling System," provides a general overview of the LLHS and ITAAC. DCD Tier 1, Table 2.7.4.4-2, "Light Load Handling System ITAAC," provides the APR1400 design certification ITAAC for the LLHS.

DCD Tier 1, Table 2.7.4.5-1, "Overhead Heavy Load Handling System ITAAC," includes an ITAAC to verify the interlocks on the fuel handling hoist (which is part of the overhead crane) preventing the movement of new fuel over the spent fuel storage racks.

DCD Tier 1, Table 2.7.4.4-2, ITAAC Item 7 addresses the RM, SFHM, and CEACP hoists and provides an acceptance criteria indicating that "the RM, SFHM and CEACP hoists are interlocked to limit upward hoist travel." The staff finds such statement an unmeasurable acceptance criteria. Therefore, the staff issued RAI 181-8011, Question 09.01.04-03, requesting the applicant to better describe the proposed acceptance criteria.

In its response to the staff's RAI by letter dated October 7, 2015 (ML15280A322) the applicant clarified that Item 7 in Tier 1, Table 2.7.4.4-2 describes the electrical interlocks of the RM, SFHM and CEACP and these are not utilized to prevent inadvertent criticality or for reducing the exposure to the operator during the movement of fuel or control components. Instead, mechanical stops (refer to ITAAC Item 8 in Table 2.7.4.4-2) are provided to prevent the fuel from being lifted above the minimum safe water depth and make sure that the operator is not exposed to more than 0.025 mSv/h at the spent fuel pool and refueling pool surface during the movement of fuel or control components.

The staff evaluated the applicant's response and confirmed that the electrical interlocks are not credited to prevent inadvertent criticality or reduce the minimum water coverage for personnel protection. This function is addressed by the mechanical interlocks, and their performance is verified by ITAAC Item 8 of Table 2.7.4.4-2. Based on this, the staff finds the applicant's response to RAI 181-8011, Question No. 09.01.04-03 is resolved.

Based on its review, the staff finds that that the DCD Tier 1 information and ITAAC requirements adequately describe the design certification requirements for the LLHS. Further the staff concludes that the ITAAC requirements are sufficient to demonstrate that the LLHS will be designed and will operate in accordance with the design certification and that, if the acceptance criteria are met, than there is reasonable assurance that the design is built and will operate in accordance with the design certification, the provisions of the AEA and NRC regulations, which include 10 CFR 52.47(b)(1).

9.1.4.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.1(8)	The COL applicant is to provide plant procedures for preventing and mitigating	9.1.4.2.1.11, 9.1.6

	inadvertent refueling pool drain down events, maintenance procedures for the maintenance and inspection of refueling pool seal, and emergency response procedures for the proper measures during pool drain down events.	
9.1(9)	The COL applicant is to provide plant operating procedure guidelines for preoperational load testing and checks of interlocks, blocks, hoisting cables, control circuity and lubrication of fuel handling equipment.	9.1.4.4, 9.1.6
9.1(10)	The COL applicant is to address the load-handling procedures. Load-handling procedures are established for component handling procedures and plant operating procedures in accordance with ASME B30.2. ASME B30.2 requires establishing component handling procedures that include (1) a safe load path for lifting heavy loads to perform special handling component inspections, (2) acceptance criteria prior to lift, and (3) use of steps and proper sequence in handling the load. ASME B30.2 requires plant operating procedure guidelines that include appropriate crane operator training and crane inspections. ASME B30.2 also requires that the load-handling procedures	9.1.5.2.4, 9.1.6

	include preparing operating procedures for preoperational load testing and checkouts of interlocks, brakes, hoisting cables, control circuitry, and lubrication of OHLHS equipment.	

The staff reviewed the proposed COL information items and found them acceptable. Requiring the COL applicant to develop and implement these procedures will ensure that an applicant can prevent or mitigate the consequences of a drain-down event and requiring the COL applicant to develop and implement these procedures will ensure that the applicant can minimize the likelihood of a fuel handling accident.

9.1.4.6 Conclusion

Based on the review above, the staff concludes that the design of the LLHS meets requirements of GDCs 2, 5, 61 and 62, and 10 CFR 52.47(b)(1) and is, therefore, acceptable.

9.1.5 Overhead Heavy Load Handling System

9.1.5.1 Introduction

Critical heavy loads may be handled during plant operation, shutdown, and refueling conditions. If a critical heavy load handling operation results in a load drop, extensive damage to safety-related equipment, stored spent fuel or fuel in the core may occur. Fuel damage could result in a potential release of radioactivity or unplanned criticality from the crushed, damaged fuel. Therefore, critical overhead heavy load handling system (OHLHS) operation includes multiple barriers to prevent a load drop and subsequent damage. Regulatory guidance and industry experience have resulted in OHLHS design recommendations that include single-failure-proof criteria, use of mechanical stops or electrical interlocks to keep heavy loads away from fuel and safe shutdown equipment, defining safe heavy load paths, heavy load handling procedures, crane operator training, guidance on design and use of slings and special lifting devices, crane inspection and maintenance, and detailed analysis of load drop consequences.

In accordance with SRP Section 9.1.5, “Overhead Heavy Load Handling Systems,” of NUREG-0800, the main emphasis in the OHLHS review is on critical load handling where inadvertent operations or equipment malfunctions, separately or in combination, could cause a release of radioactivity, a criticality accident, inability to cool fuel within the reactor vessel or spent fuel pool, or could prevent safe shutdown of the reactor.

9.1.5.2 Summary of Application

DCD Tier 1: The applicant has provided a general description of the heavy load handling system in DCD Tier 1, Section 2.7.4.5, “Overhead Heavy Load Handling System.”

DCD Tier 2: The applicant has provided a detailed description of the overhead heavy load handling system in DCD Tier 2, Section 9.1.5, "Overhead Heavy Load Handling System."

For the APR1400, a heavy load is defined as any load greater than the weight of a fuel assembly and its handling device, which is approximately 721 kg (1,590 lb).

Table 9.1.5-1, "Specification of Major Equipment," and Table 9.1.5-2, "Specification of Miscellaneous Equipment," provide a list of the cranes used in the APR1400 design and their loads to be handled.

Initial Test Program: DCD Tier 2, Section 14.2, contains the performance testing of the containment polar crane (14.2.12.1.91) and the fuel handling area cranes (14.2.12.1.92).

ITAAC: DCD Tier 1, Table 2.7.4.5-1 specifies the ITAAC for the heavy load handling cranes.

Technical Specifications: There are no TSs applicable to the OHLHS.

9.1.5.3 Regulatory Basis

The relevant guidance of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.1.5, "Overhead Heavy Load Handling Systems," and are summarized below. Review interfaces with other SRP sections also can also be found in NUREG-0800, Section 9.1.5. Acceptance criteria are based on meeting the relevant requirements of the following NRC regulations:

1. GDC 1, "Quality standards and records," of Appendix A to 10 CFR Part 50 as to the design, fabrication, and testing of SSCs important to safety to maintain quality standards.

2. GDC 2, "Design bases for protection against natural phenomena," as to the ability of structures, equipment, and mechanisms to withstand the effects of earthquakes.

3. GDC 4, "Environmental and dynamic effects design bases," as it relates to the protection of safety-related equipment from the effects of internally-generated missiles (i.e., dropped loads).

4. GDC 5, "Sharing of structures, systems, and components," as to the sharing of equipment and components important to safety.

5. 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. Acceptance for meeting the relevant aspects of GDC 1 is based in part on NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants," for overhead load handling systems and ANSI N14.6, "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 Kg) or More," or ASME B30.9, "Slings," for lifting devices.

2. Acceptance for meeting the relevant aspects of GDC 2 is based in part on position C.2 of RG 1.29, "Seismic Design Classification," and Section 2.5 of NUREG-0554.

3. Acceptance for meeting the relevant aspects of GDC 4 is based in part on position C.5 of RG 1.13.

4. Acceptance for meeting the relevant aspects of GDC 5 is embodied within the acceptance criteria for meeting GDC 1, 2, and 4.

In addition, the acceptance criteria for the staff's review of the OHLHS includes conforming to the guidelines of NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants – Resolution of Generic Technical Activity A-36," Section 5, regarding the general programmatic controls for design, operation, testing, maintenance, and inspection of the OHLHS. In NUREG-0612 the staff adopts a defense in depth approach for handling of heavy loads near spent fuel and safe shutdown equipment.

9.1.5.4 Technical Evaluation

The staff reviewed the information on the OHLHS located in DCD Tier 2, Section 9.1.5 and DCD Tier 1, Section 2.7.4.5, in accordance with the guidance provided in SRP Section 9.1.5 of NUREG-0800. Conformance to the acceptance criteria of SRP Sections 9.1.5 formed the basis for the evaluation of the OHLHS with respect to the applicable regulations. The results of the staff's review are provided below. The evaluation addresses whether the application satisfies the SRP acceptance criteria listed in Section 9.1.5.3 of this report.

The OHLHS consists of the components and equipment necessary for safe handling of heavy loads. Heavy loads are defined as loads weighing more than the weight of one fuel assembly plus its handling device. For the APR1400, a fuel assembly weighs approximately 639 kg (1,409 lb) and its handling device weighs approximately 82 kg (181 lb). Therefore, a heavy load is defined as any load greater than approximately 721 kg (1,590 lb). The OHLHS described in this section consists of equipment and components used for critical load handling. In DCD Tier 2, Section 9.1.5, critical load handling is defined as load handling operations with the potential inadvertent operations or equipment malfunctions, separately or in combination, which could cause the following:

- Significant release of radioactivity.
- Loss of margin to criticality.
- Uncovery of the irradiated fuel in the reactor vessel or SFP.
- Damage to equipment essential to achieve or maintain safe shutdown.

DCD Tier 2, Section 9.1.5, provides a description of the OHLHS in the fuel handling area of the auxiliary building and in the reactor vessel area of the reactor containment building, where the

system is used to transfer the largest heavy load of a spent fuel shipping cask and to lift the integrated head assembly (IHA) and/or reactor vessel (RV) internals during refueling.

To reduce the probability and mitigate the consequences of an accidental load drop, SRP 9.1.5.III.3 includes guidelines to be implemented for heavy load handling in all areas of the facility housing safety-related SSCs. As indicated in SRP 9.1.5, the application should conform to general programmatic guidelines for design, operation, testing, maintenance, and inspection as specified in Section 5.1.1 of NUREG-0612. As indicated in DCD Section 9.1.5.2.4 and COL 9.1(9), load-handling procedures will be established for component handling by the COL applicant.

9.1.5.4.1 GDC 1, Quality standards and records

GDC 1 requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards. The staff reviewed the OHLHS for compliance with the requirements of GDC 1. The staff determined whether the application complies with GDC 1, in part, by considering whether it meets NUREG-0554 for single-failure-proof cranes and ANSI N14.6 or ASME B30.9 for lifting devices.

The two major cranes of the APR1400 are the reactor containment building polar crane and the fuel handling area overhead crane. As shown in Table 3.2-1, the reactor containment building polar crane, the fuel handling area overhead crane, and cranes and/or hoists in safety-related areas are subject to augmented quality assurance (AQ) guidelines described in SRP 17.5. Table 3.2-1, footnote (13) also includes commitment to RG 1.29 for these cranes. This assignment of AQ program to the OHLHS cranes is acceptable because it is consistent with the staff’s positions delineated in RG 1.29 and NUREG-0554.

The containment polar crane is designed as a single-failure-proof crane, in accordance with ASME NOG-1, “Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder),” for Type I crane as endorsed in the SRP, and thus in conformance with guidance of NUREG-0554, as indicated in DCD Section 9.1.5.2.2, “Polar Crane.”

The fuel handling area overhead crane (for cask handling) and cranes and/or hoists in safety-related areas are designed in accordance with ASME NOG-1 for Type II crane, CMAA-70, “Specification for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes,” and Section 2-1 of ASME B30.2, “Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist).” Therefore, this fuel handling area overhead crane is not single-failure-proof.

NUREG-0554, Section 10, specifies that a quality assurance program should be established to the extent necessary to include the NUREG-0554 recommendations for design, fabrication, installation, testing, and operation of crane handling systems for safe handling of critical loads.

DCD Section 9.1.5.4 specifies the inspection and testing requirements as follows:

> During the manufacture of the overhead heavy load handling equipment at the manufacturer’s shop, various in-process inspections and checks are required, which include the certification of materials and heat treating, and liquid-penetrant or magnetic-particle inspection of critical welds as defined in Section 7200 and Paragraph 4251.4 of ASME NOG-1. Conformance with design and specification requirements is determined by assembling and testing the equipment in the

manufacturer's shop. The manufacturer's inspection and testing conform to the requirements of ASME NOG-1 and Section 2-2 of ASME B30.2. The manufacturer satisfies the quality assurance requirements specified by the owner. The OHLHS conforms to the requirements of ASME NOG-1 for receipt, storage, and installation. After the OHLHS has been installed, each crane is subjected to complete preoperational testing and inspection, no-load test, full-load test, and rated-load test in accordance with ASME NOG-1. The testing and inspection are performed by or under the direction of a designated or authorized person in accordance with ASME B30.2, and written reports are furnished by that person, confirming the load rating of the crane. Preoperational testing is carried out as described in Section 14.2 to demonstrate that the OHLHS operates in accordance with applicable test programs and specifications. The in-service inspection and testing of the OHLHS are performed in accordance with ASME B30.2.

Special lifting devices should satisfy the criteria of ANSI N14.6 or, if special lifting devices are not used, slings should be selected to satisfy the criteria of ASME B30.9. The DCD commits to use of lifting devices that conform to ASME B30.9 for the single-failure-proof polar crane and ANSI N14.6 for the IHA lifting device. However, the staff could not determine whether additional lifting devices are utilized for heavy load handled in safety-related areas of the plant and what codes are applied to their design. The staff issued RAI 124-8071 (ML15216A635), Question 09.01.05-01, requesting the applicant to specify all use of special lifting devices in all areas of the facility housing safety-related SSCs and to verify they are designed to the proper code classification. In addition, the applicant was requested to verify use of metallic material (chain or wire rope). In its response to RAI 124-8071, Question 09.01.05-01, dated December 10, 2015 (ML15344A113), the applicant identified the IHA lifting system and the RV Internals lift rig assembly as the only two special lifting devices used in critical areas of the facility and stated they are designed to meet design criteria of ANSI N14.6 and ASME Subsection NF. The applicant also stated that slings of metallic material are not used with these special lifting devices. The staff found this response acceptable because the applicant provided sufficient design details to demonstrate conformance with ANSI Standard N14.6. Therefore, RAI 124-8071, Question 09.01.05-01, is considered resolved and closed.

On the basis of the above evaluation, the staff finds the OHLHS complies with the requirements of GDC 1 as it relates to the systems and components of the OHLHS being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the function to be performed.

9.1.5.4.2 GDC 2 Design bases for protection against natural phenomena

The staff reviewed the OHLHS for compliance with the requirements of GDC 2. In accordance with SRP Section 9.1.5, GDC 2 can be met, in part, by meeting RG 1.29, Regulatory Position C.2, which describes the guidance for seismic Category II SSCs. This guidance states, in part, that seismic Category II SSCs are designed to preclude structural failure during a SSE to preclude interaction with safety-related SSCs. NUREG-0554, Section 2.5 further specifies that single-failure-proof cranes should be designed to retain control of and hold the load during an SSE.

The major cranes in the OHLHS are the containment polar crane and the fuel handling area overhead crane. In addition the OHLHS includes miscellaneous cranes and hoists in safety-related areas (shown in Table 9.1.5-2).

The containment polar crane and the fuel handling area overhead crane are used to handle critical heavy loads in areas of the reactor vessel and in the fuel handling area. The specifications for the fuel handling area overhead crane and the containment polar crane are given in Table 9.1.5-1. Additionally, as listed in Table 9.1.5-2, other hoists and cranes are used to handle critical heavy loads in other plant areas where their accidental drops could damage safe shutdown equipment.

Containment Polar Crane

The containment polar crane is located inside the reactor containment building and mounted on a circular rail along the containment inside wall and travels the entire circumference of the containment. The crane has a main hoist and an auxiliary hoist to handle the various loads during refueling. The safe load handling paths and laydown area are shown in Figure 9.1.4-9, "Containment Building Layout Related Fuel Handling."

The containment polar crane is designed as a single-failure-proof crane, in accordance with requirements of ASME NOG-1 for Type I crane, and thus is in conformance with guidelines in NUREG-0554. The containment polar crane is designed as single-failure-proof to minimize the crane losing the capability to perform its function through redundancy in braking components and two independent reeving systems. The containment polar crane is also designed as seismic Category II, in accordance with RG 1.29. The dynamic behaviors resulting from seismic activities are restricted by the seismic restraints to protect the bridge and the trolley during an SSE.

DCD Tier 1, Table 2.7.4.5-1 contains an ITAAC to verify the seismic Category II classification, and inclusion of seismic restraints which prevent the bridge or the trolley from leaving the rails during and after a SSE. In addition, the ITAAC commits to a report that concludes that the as-built OHLHS retains structural integrity and does not impair the ability of seismic Category I equipment to perform its design-basis safety function during or following an SSE.

As stated in DCD, the containment polar crane is designed in conformance with RG 1.29 and ASME NOG-1 criteria for Type 1 cranes. This is an acceptable method for meeting GDC 2 requirements and the associated guidelines in NUREG-0554.

Fuel Handling Area Overhead Crane

The fuel handling area overhead crane, located in the auxiliary building, includes two (2) hoists (cask handling hoist and fuel handling hoist) mounted on the rail that extends the entire length of the fuel handling area. During construction, the overhead crane travels the entire rail without any physical restrictions; however, once fuel assemblies are onsite, provisions are installed permanently to restrict movement of the crane over the SFP area.

The fuel handling area overhead crane is designed in accordance with requirements of ASME NOG-1 for Type II crane, CMAA-70, and Section 2-1 of ASME B30.2. As stated in DCD Section 9.1.5.2.1, "Fuel Handling Area Overhead Crane," the fuel handling area overhead crane commits to NUREG-0612 and RG 1.13, and is classified as seismic Category II, in accordance with RG 1.29.

DCD Tier 1, Section 2.7.4.5 states that the fuel handling area overhead crane is designed as seismic Category II. During an SSE, the fuel handling area overhead crane and all its components retain structural integrity, and the bridge and the trolley remain in place on their respective runways with their wheels prevented from leaving the tracks. This is consistent with NOG-1 definition of Type II crane, which specifies the crane shall be designed and constructed so that it will remain in place with or without a load during a seismic event.

DCD Tier 1, Section 2.7.4.5 also contains ITAAC to verify seismic Category II classification, and inclusion of seismic restraints which prevent the bridge or the trolley from leaving the rails during and after a SSE. In addition, ITAAC in Table 2.7.4.5-1 commits to a report that concludes that the as-built OHLHS retains structural integrity and does not impair the ability of a seismic Category I equipment to perform its design basis safety function during or following an SSE.

Since the crane is designed in accordance with NOG-1, Type II and RG 1.29, as discussed above, the staff finds this acceptable to meet the requirements of GDC 2.

Miscellaneous cranes and/or hoists in safety-related areas

As indicated in DCD Section 9.1.5.2.3, “Other Area Hoists and Cranes,” the OHLHS is used to handle heavy loads such as pumps, motors, valves, heat exchangers, and diesel generators in other areas of the auxiliary building and other buildings where, if such items are dropped in a certain location, they may damage safe shutdown equipment. Miscellaneous cranes and hoists used for handling critical loads are listed in Table 9.1.5-2 and designed as non-single-failure-proof cranes, seismic Category II components to prevent unacceptable structural interaction and failure during an SSE. The applicant states that a load drop involving these miscellaneous cranes and hoists located over or close to the safe shutdown system and equipment would impact safe shutdown equipment. The DCD describes the safe shutdown equipment or systems as physically separated and redundant so that the consequences of postulated accident load drops do not prevent the capability of their safe shutdown functions. The DCD further indicates that the safe shutdown equipment or systems in the load path will be out of operation when the cranes and hoists are used for handling critical heavy loads over them and, when the safe shutdown equipment or systems are in service, the use of these cranes and hoists is administratively controlled by load handling procedures.

The staff reviewed the cranes that makeup the OHLHS, and concluded that the cranes are designed to retain their structural integrity during and following an SSE. Therefore, based on the review described above, the staff finds the OHLHS design satisfies the guidelines of RG 1.29 and therefore meets GDC 2 requirements.

9.1.5.4.3 GDC 4, Environmental and dynamic effects design bases

The staff reviewed the OHLHS for compliance with the requirements of GDC 4. To meet the requirements of GDC 4, the OHLHS must be designed to prevent internally generated missiles (i.e., load drops) that could prevent safe shutdown, cause an unacceptable release of radioactivity, result in a criticality accident, or cause the inability to cool the fuel in the reactor vessel or spent fuel pool. SRP Section 9.1.5 indicates that the relevant aspects of GDC 4 can be met, in part, through conformance with RG 1.13, Regulatory Position C.5, which states that cranes capable of carrying heavy loads should be prevented, preferably by design rather than by interlocks, from moving over the spent fuel pool or designed to provide single-failure-proof handling of heavy loads.

Containment Polar Crane

The containment polar crane is located inside reactor containment building and mounted on a circular rail along the containment inside wall and travels the entire circumference of the containment. The crane has a main hoist and an auxiliary hoist to handle the various loads during refueling. The safe load handling paths and laydown area are shown in DCD Figure 9.1.4-9.

In DCD Section 9.1.5, the applicant stated that the containment polar crane, which has a 450-ton-rated capacity main hoist for normal operation, is used with various lifting rigs to remove the IHA and RV upper and lower internals. A 60-ton auxiliary hoist is used for routine maintenance and for in-service inspections. The crane is controlled from its bridge-mounted cab or a festooned pendant control.

The containment polar crane is designed as a single-failure-proof crane, in accordance with ASME NOG-1 for Type I crane, and thus in conformance with NUREG-0554. The probability for a load drop is minimized by designing the crane to conform to the guidelines of NUREG-0554 and the lifting devices that conform to ANSI N14.6 or an alternative based on ASME B30.9.

DCD Section 9.1.5 classifies the main hoist of the polar crane as single-failure-proof. However, it does not indicate classification of the auxiliary hoist as to whether it is also single-failure-proof.

RAI 124-8071, Question 09.01.05-04 was issued requesting the applicant to provide classification of the auxiliary hoist and describe what controls features are provided to avoid travel over critical components. The applicant was also requested to clarify the different rated-capacity values listed for the auxiliary hoist in Subsection 9.1.5.2.2 as "60 tons" and in Table 9.1.5-1 as "81.6 tons." In its response to RAI 124-8071, Question 09.01.05-04, dated October 12, 2015 (ML15286A034), the applicant proposed to revise the rated capacity for the main hoist to "475 tons" and for the auxiliary hoist to "90 tons" in both DCD Subsection 9.1.5.2.2 and DCD Table 9.1.5-1 for consistency of design information within DCD Section 9.1.5. Further, the applicant stated that the auxiliary hoist, which is used for routine maintenance and for in-service inspections, is not a single-failure-proof component. The applicant, however, proposed to revise Subsection 9.1.5.2.2 to only clarify that the main hoist is a single-failure-proof component. The staff considered this part of the response incomplete in that DCD Section 9.1.5 should also be revised to include the classification of the auxiliary hoist. Follow-up RAI 457-8558 (ML16097A189), Question 09.01.05-11 was issued requesting the applicant to address this discrepancy. In its response to RAI 457-8558, Question 09.01.05-11, dated May 16, 2016 (ML16137A645), the applicant proposed to revise DCD Section 9.1.5 to add the requested information. The staff finds this response acceptable because correct design features are now clearly identified for each of the two different hoists on the polar crane. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 457-8558, Question 09.01.05-11, to be resolved and closed

Fuel Handling Area Overhead Crane

The fuel handling area overhead crane, located in the Auxiliary Building, includes two (2) hoists (cask handling hoist and fuel handling hoist) mounted on the rail that extends the entire length of the fuel handling area. During construction, the overhead crane travels the entire rail without any provisions for restrictions; however, once fuel assemblies are onsite, permanent mechanical

stops are installed on the rails to restrict movement of the crane over the spent fuel pool. The operation limit area of the overhead crane is shown in DCD Figure 9.1.5-6, “Fuel Handling Area Safe Load Handling Paths.”

The design of the hoists on the fuel handling area overhead crane conforms to the requirements of ASME NOG-1 for Type II crane, CMAA-70, and Section 2-1 of ASME B30.2. The fuel handling area overhead crane is designed to meet guidelines in NUREG-0612 and RG 1.13.

The cask handling hoist is not a single-failure-proof component and is used to transfer the shipping cask among the cask loading pit, cask decontamination pit, and truck bay. The hoist has a minimum capacity of 150 tons and incorporates a variable-speed hoist and electrical interlocks to control bridge and trolley travel. The shipping cask is prevented from traveling over the new fuel storage racks by electrical interlocks.

The fuel handling hoist is not a single-failure-proof component and is used for handling the new fuel container and new fuel assemblies during transfer from the new fuel shipping container to the new fuel elevator, new fuel storage racks, or new fuel inspection station. The hoist has a minimum capacity of 10 tons and incorporates electrical interlocks to control the transfer path of the new fuel assemblies and to restrict fuel handling loads.

As indicated in DCD Tier 1, Section 2.7.4.5.1 “Design Description,” the fuel handling hoist is interlocked to prevent moving new fuel over the spent fuel storage racks. The shipping cask handling hoist is interlocked and equipped with mechanical stops to prevent moving a cask over the spent fuel storage racks and the new fuel storage racks. DCD Tier 1, Section 2.7.4.5.1 states that once fuel assemblies are received onsite, provisions are permanently installed to restrict movement of the crane over the SFP area for safe heavy load handling.

When using interlocks to restrict movement of hoist over spent fuel, NUREG-0612 (Section 5.1.2) provides guidance on specific aspects for the applicant to address. These include:

1. Mechanical stops or electrical interlocks should be provided that prevent movement of the overhead crane load block over or within 15 feet horizontal (4.5 meters) of the spent fuel pool. These mechanical stops or electrical interlocks should not be bypassed when the pool contains "hot" spent fuel, and should not be bypassed without approval from the shift supervisor (or other designated plant management personnel). The mechanical stops and electrical interlocks should be verified to be in place and operational prior to placing "hot" spent fuel in the pool.

2. Mechanical stops or electrical interlocks should also not be bypassed unless an analysis has demonstrated that damage due to postulated load drops would not result in criticality or cause leakage that could uncover the fuel.

3. To preclude rolling if dropped, the cask should not be carried at a height higher than necessary and in no case more than six (6) inches (15 cm) above the operating floor level of the refueling building or other components and structures along the path of travel.

4. Mechanical stops or electrical interlocks should be provided to preclude crane travel from areas where a postulated load drop could damage equipment from redundant or alternate safe shutdown paths.

5. Analyses for postulated load drops should conform to the guidelines of Appendix A.

The staff reviewed Section 9.1.5 and was unable to determine how the fuel handling area overhead crane meets these criteria. Therefore, the staff issued RAI 124-8071, Question 09.01.05-02 requesting additional details on how the interlocks meet the criteria of NUREG-0612. In its response to RAI 124-8071, Question 09.01.05-02, dated November 13, 2015 (ML15317A411), the applicant proposed to revise DCD Tier 2, Subsection 9.1.5.2.1, to reflect the interlock requirements for movement of the overhead crane load block, the restriction on the lift height of the shipping cask, and further stated that these interlocks cannot be bypassed, as well as there is no safe shutdown equipment within the travel path of the overhead crane in the fuel handling area. The staff found this response acceptable because sufficient interlock design details that meet the above NUREG-0612 guidelines will be added to the DCD. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 124-8071, Question 09.01.05-02 closed.

The DCD Subsection 9.1.5.3 states

> [T]he effects of a heavy load drop are analyzed. The results provide reasonable assurance that it does not damage stored fuel and preclude the operation of equipment required to achieve safe shutdown.

Subsection 9.1.5.2.1 further indicates the design of the fuel handling area overhead crane limits the impact energy of postulated dropped loads on the new fuel storage racks, spent fuel storage racks, fuel transfer system fuel carrier, and SFP. The staff was unable to locate any load drop analysis to verify the resultant impact will not exceed the design impact energy. Therefore, the staff issued RAI 124-8071, Question 09.01.05-03, requesting the applicant to specify what loads will be handled over the safe shutdown equipment, new fuel storage racks, spent fuel storage racks, spent fuel pool, and fuel transfer system fuel carrier by the fuel handling hoist and cask handling hoist of this non single-failure-proof crane and clarify what load drop analyses were completed and which cranes were evaluated for impact energy of postulated dropped loads and what assumptions were included. In its response to RAI 124-8071, Question 09.01.05-03, dated November 13, 2015 (ML15317A411), the applicant provided clarifying details as to plant components (e.g., a spent fuel assembly and its handling tools, the spent fuel pool swing gate) being handled over the spent fuel pool and the associated load drop analysis, but did not identify the specific crane used for heavy load handling in the analysis. Follow-up RAI 457-8558, Question 09.01.05-10, was issued requesting the applicant to provide this information. A response to RAI 457-8558, Question 09.01.05-10, from the applicant was previously tracked as Open Item 09.01.05-2. In its response to RAI 457-8558, Question 09.01.05-10, dated May 16, 2016 (ML16137A645), the applicant provided details on the load paths for all heavy load handling activities over the spent fuel pool including the handling of the swing gates by a 5-ton monorail hoist, and identified these activities to applicable handling equipment listed in DCD Tier 2, Table 9.1.5-2. The staff finds this response acceptable because clarifying details were provided for the concerned heavy load handling activities and no further change to the DCD is necessary. Therefore, the staff considers RAI 457-8558, Question 09.01.05-10, to be resolved and closed.

DCD Subsection 9.1.5.2.1 states

> During an SSE, the fuel handling area overhead crane and all its components retain control and hold all loads up to the maximum critical load for all loading conditions, and the bridge and trolley remain in place on their respective runways with their wheels prevented from leaving the tracks. The crane is not required to be functional during and after the SSE, but structural integrity is preserved.

As defined by NOG-1, a Type II crane is "a crane that is not used to handle a critical load." It shall be designed and constructed so that it will remain in place with or without a load during a seismic event; however, the crane needs not support the load nor be operational during and after such an event. Single-failure-proof features are not required." In RAI 124-8071, Question 09.01.05-09, the applicant was requested to describe any additional design features provided with this Type II crane to hold all loads up to the maximum critical load, as defined in ASME NOG-1, for all loading conditions during an SSE. In its response to RAI 124-8071, Question 09.01.05-09, dated October 12, 2015 (ML15286A034), the applicant proposed to revise DCD Subsection 9.1.5.2.1 to replace the phrase "control and hold all loads up to the maximum critical load for all loading conditions" with "structural integrity" to reflect the intent of the crane design description. The staff finds this response acceptable because conflicting design information will be removed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 24-8071, Question 09.01.05-09 closed.

The DCD Section 15.7.5 indicates radiological evaluations for a cask handling accident are not required based on plant design features and cask handling procedures of the APR1400. The staff agrees with the stated position because it is in line with the guidance of NUREG-0612.

Based on the review above, the staff finds that the OHLHS design conforms to RG 1.13, Regulatory Position C.5, and therefore meets GDC 4 requirements. .

9.1.5.4.4 GDC 5, Sharing of structures, systems and components

Compliance with GDC 5 requires that SSCs important to safety not be shared among nuclear power units unless it can be shown that such sharing will not impair their ability to perform their safety functions.

The OHLHS of the APR1400 is not shared between multiple units in accordance with DCD Tier 2, Section 9.1.5.1, which states "[T]he OHLHS is not shared by other units." Therefore, the staff concludes that GDC 5 is satisfied for the OHLHS design.

9.1.5.4.5 Inspections and Testing Program

The initial test program (ITP) is identified in DCD Tier 2, Section 14.2.12.1.91, "Containment Polar Crane Test," to demonstrate the functional performance of the containment polar crane and Section 14.2.12.1.92, "Fuel Handling Area Cranes Test," to demonstrate the functional performance of the cask handling and fuel handling cranes. As discussed in Section 14.2 of this report, the staff reviewed the applicant's initial test program in accordance with the review guidance contained in SRP Revision 3, Section 14.2, "Initial Plant Test Program – Design Certification and New License Applicants," and RGs 1.68 and 1.206, "Combined License Applications for Nuclear Power Plants." The staff's evaluation of the initial plant test program is documented in Section 14.2 of this report.

9.1.5.4.6 ITAAC

DCD Tier 1 provides a general overview of the system and the crane ITAAC. The ITAAC are designed to meet the requirements of 10 CFR 52.47(b)(1), to verify that the as-built system complies with the approved system design in the DCD. The ITAAC are described in DCD Tier 1, Table 2.7.4.5-1.

Tier 1, Section 2.7.4.5 contains ITAAC to verify that interlocks prohibit travel of heavy loads over storage racks, but do not address prohibiting travel over the complete spent fuel pool. The staff issued RAI 124-8071, Questions 09.01.05-07, requesting the applicant to provide ITAAC to clearly define the travel restrictions applied to the fuel handling area overhead crane. In the response to RAI 124-8071, Questions 09.01.05-07, dated October 12, 2015 (ML15286A034), the applicant proposed to revise both DCD Tier 1, Table 2.7.4.5-1, and DCD Tier 2, Subsection 9.1.5.2.1, to add clarifying details to clearly define the scope of ITAAC Item 7 for the fuel handling hoist and ITAAC Item 8 for the cask handling hoist. The staff finds this response to RAI 124-8071, Questions 09.01.05-07 acceptable. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 124-8071, Question 09.01.05-07 closed.

In addition, the staff issued RAI 124-8071, Questions 09.01.05-08, requesting the applicant to justify how the lift capacity testing specified in ITAAC Item 5 is sufficient to prevent the uncontrolled lowering of a heavy load, as described in the associated design commitment column of Table 2.7.4.5-1. In its response to RAI 124-8071, Questions 09.01.05-08, dated October 12, 2015 (ML15286A034), the applicant stated:

> [B]oth the containment polar crane and the fuel handling area overhead crane are designed to prevent a fuel handling equipment or fuel cask drop by providing special devices that are locked in a manner that will not allow the release of the fuel handling equipment or the fuel cask. Also, the overspeed switch is attached on the cranes to prevent uncontrolled lowering of a heavy load. NOG-1 load tests include the proper function testing of devices. However, the overspeed switch function test will be performed at the manufacturing shop, and it is impossible to test the overspeed switch function during power plant operation. Therefore, the testing and acceptance criteria of the ITAAC will be deleted.

The staff disagreed with the applicant's decision to delete ITAAC Item 5 from DCD Tier 1, Table 2.7.4.5-1, just because the required test can only be performed at the manufacturing shop. Follow-up RAI 457-8558, Question 09.01.05-12, was issued requesting additional information regarding revisions for ITAAC Item 5 to reflect the overspeed switch functional test by the crane manufacturer as well as whether a new ITAAC item in DCD Tier 1 Section 2.7.4.5 for applicable load tests required by ASME NOG-1 should be added. In its response to RAI 457-8558, Questions 09.01.05-12, dated May 16, 2016, (ML16137A645), the applicant clarified that the functional test of the overspeed switch is only a part of the crane required testing in accordance with ASME NOG-1 at the manufacturing shop, and as such proposed to reinstate the original ITAAC Item 5 back in DCD Tier 1, Table 2.7.4.5-1. The staff finds this response acceptable because sufficient clarifying details were given to justify verification of a specific crane function within the scope of ASME NOG-1 testing at the manufacturing shop. The staff confirmed that ITAAC Item 5 has been reinstated in Revision 1 of the DCD. Therefore, the staff considers RAI 457-8558, Question 09.01.05-12, to be resolved and closed.

Based on its review, the staff finds that that the DCD Tier 1 information and ITAAC requirements adequately describe the design certification requirements for the OHLHS. Further the staff concludes that the ITAAC requirements are sufficient to demonstrate that the OHLHS will be designed and will operate in accordance with the design certification and that, if the acceptance criteria are met, than there is reasonable assurance that the design is built and will operate in accordance with the design certification, the provisions of the AEA and NRC regulations, which include 10 CFR 52.47(b)(1).

9.1.5.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
3.5(1)	The COL applicant is to provide the procedure for heavy load transfer to strictly limit the transfer route inside and outside containment during plant maintenance and repair periods.	3.5.1.1, 3.5.1.1.1, 3.5.4
9.1(9)	The COL applicant is to address the load-handling procedures. Load-handling procedures are established for component handling procedures and plant operating procedures in accordance with ASME B30.2. ASME B30.2 requires establishing component handling procedures that include (1) a safe load path for lifting heavy loads to perform special handling component inspections, (2) acceptance criteria prior to lift, and (3) use of steps and proper sequence in handling the load. ASME B30.2 requires plant operating procedure guidelines that include appropriate crane operator training and crane inspections. ASME B30.2 also requires that the load-	9.1.4.4, 9.1.6

	handling procedures include preparing operating procedures for preoperational load testing and checkouts of interlocks, brakes, hoisting cables, control circuitry, and lubrication of OHLHS equipment.	

The staff reviewed the proposed COL information items and found them acceptable. Requiring the COL applicant to address the development and implementation of these procedures will ensure that an applicant can prevent consequences of a load drop event.

9.1.5.6 Conclusion

Based on the review above, the staff concludes that the design of the OHLHS meets the requirements of GDCs 1, 2, 4 and 5, and 10 CFR 52.47(b)(1).

9.2 Water Systems

9.2.1 Essential Service Water System

9.2.1.1 Introduction

The APR1400 essential service water system (ESWS) is an open system that takes suction from the ultimate heat sink (UHS) and provides cooling water to the CCW heat exchangers to remove heat released by the plant systems, structures, and components. The ESWS returns water to the UHS. The ESWS cools the essential and nonessential heat loads from the CCWS.

The system is reviewed from the service water pump intake to the points of cooling water discharge. Site-specific ESWS portions may not be within the scope of the design submitted by applicants for DC. The ESWS piping, valves, instrumentation, and controls within the design certification applicant's scope are reviewed as part of the design certification submission. Site-specific portions of the design are the responsibility of the COL applicant. Nevertheless, the design certification applicant's submission should provide a conceptual design and interface requirements for that ESWS portion outside the scope of the DC, as required by 10 CFR Part 52.47(a)(24) and (25).

9.2.1.2 Summary of Application

DCD Tier 1 and ITAAC: DCD Tier 1, Section 2.7.2.1, "Essential Service Water System," describes Tier 1 information for ESWS. Tier 1, Table 2.7.2.1-1, "Essential Service Water System Equipment and Piping Location/Characteristics," describes ESWS equipment and piping location and characteristics. Tier 1, Table 2.7.2.1-2, lists ESWS components. Tier 1, Table 2.7.2.1-3, "Essential Service Water System Instruments List," lists ESWS instruments. Tier 1, Table 2.7.2.1-4, "Essential Service Water System ITAAC," describes ESWS ITAAC. Tier 1, Figure 2.7.2.1-1, "Essential Service Water System," provides a simplified flow diagram of the ESWS.

DCD Tier 2: DCD Tier 2, Section 9.2.1, "Essential Service Water System," provides information on the ESWS. Tier 2 Figure 9.2.1-1, "Essential Service Water System Flow Diagram," shows the flow diagram. Tier 2 Table 9.2.1-1 provides information on ESWS component design parameter. Tier 2 Table 9.2.1-2, "Essential Service Water System Failure Modes and Effects Analysis," provides ESWS failure modes and effects analysis.

Technical Specifications: DCD Tier 2, Chapter 16, Section 3.7.8, "Essential Service Water System (ESWS)," provides plant TSs for the ESWS.

9.2.1.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.2.1, "Station Service Water System," Revision 5, March 2007, and are summarized below. Additional applicable regulatory criteria are also summarized below.

1. GDC 2, "Design basis for protection against natural phenomena," as it relates to the capabilities of structures housing the system and the system itself to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of safety-related functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to effects of missiles inside and outside containment, effects of pipe whip, jets, environmental conditions from high- and moderate-energy line-breaks, and dynamic effects of flow instabilities and attendant loads (e.g., water-hammer) during normal plant operation, as well as upset or accident conditions.

3. GDC 5, "Sharing of structures, systems, and components," insofar as it requires that SSCs important to safety not be shared among nuclear power units unless it can be shown that sharing will not significantly impair their ability to perform their safety functions.

4. GDC 44, "Cooling water," as it relates to the capability to transfer heat from systems, SSCs important to safety to an UHS during both normal and accident conditions, with suitable redundancy, assuming a single active component failure coincident with either the loss of offsite power or loss of onsite power.

5. GDC 45, "Inspection of cooling water system," as it relates to design provisions for inservice inspection of safety-related components and equipment.

6. GDC 46, "Testing of cooling water system," as it relates to design provisions for pressure and operational functional testing of cooling water systems and components.

7. 10 CFR 20.1406, "Minimization of Contamination," as it relates to the standard plant design certifications and how the design and procedures for operation will minimize contamination of the facility and the environment facilitate eventual decommissioning and minimize to the extent practicable, the generation of radioactive waste.

8. 10 CFR 52.47, Item (a)(24), which requires that a design certification application (DCA) contain a representative conceptual design for those portions of the plant for

which the application does not seek certification, to aid the NRC in its review of the DCD and to permit assessment of the adequacy of the interface requirements in paragraph (a)(25) of this section.

9. 10 CFR 52.47, Item (a)(25), which requires that a design certification application (DCA) contain interface requirements to be met by those portions of the plant for which the application does not seek certification. These requirements must be sufficiently detailed to allow completion of the DCD.

10. 10 CFR 52.47, Item (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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA and NRC regulations.

9.2.1.4 Technical Evaluation

The staff reviewed the ESWS described in DCD Tier 1 and Tier 2, Revision 1, in accordance with NUREG-0800, Section 9.2.1, “Station Service Water System,” Revision 5.

9.2.1.4.1 System Design Considerations

DCD Tier 2, Section 9.2.1.2.1, “General Description,” describes the ESWS as follows:

Design Information

- The flow diagram of the ESWS is shown in Figure 9.2.1-1, “Essential Service Water Flow Diagram.” The ESWS consists of two independent, redundant, once-through, safety-related divisions. Each division cools one of two divisions of the CCWS, which cools 100 percent of the safety-related loads.

- The maximum operation supply temperature of the ESW is 33.2 °C (91.8 °F) which allows the system to handle CCW heat load under all operating conditions.

The ESWS description was reviewed in accordance with SRP Section 9.2.1, Subsection III.1 for its design adequacy. In its review, the staff found some inadequacies in the design information and requested additional information in RAI 211-8236 (ML15295A508), Question 09.02.01-01. The applicant responded in a letter, dated March 23, 2016 (ML16083A540). The following are the staff’s questions and applicant’s responses:

a) Question: DCD Tier 2, Section 9.2.1.2.1 indicates that ESW pumps are located in the ESW building. However, ESW pump coolers and ESW building coolers are not addressed. Discuss the design of the ESW pump coolers and building coolers to maintain safety function of the ESWS pumps.

   Response: The ESW pump is not equipped with a pump cooler, but the ESW pump is air cooled by the room air, which is controlled by the ESW building heating, ventilating, and air conditioning (HVAC) system. The ESW building HVAC system design is a COL information item, as described in DCD Tier 2, Subsection 9.4.5.

b) Question: In DCD Tier 2, Table 9.2.1-2, “ESWS Failure Modes and Effects Analysis,” ESW pump discharge isolation motor operated valves SX-045, -046, -047, -048 are not included. Include these motor operated valves in the table.

   Response: The failure mode and effect for the SX-045, 046, 047, and 048 will be added into Table 9.2.1-2.

c) Question: In DCD Tier 2, Table 9.2.1-2, “ESWS Failure Modes and Effects Analysis,” check valves in pump discharge V1001, V1002, V1003, V1004 are identified. However, the valve numbers are inconsistent with the numbers listed in DCD Tier 1, Table 2.7.2.1-2, “Essential Service Water System Components List,” which shows different valve numbers of SX-1001, -1002, -1003, and -1004 for the check valves in pump discharge. Clarify the inconsistency of the valve numbering between these two tables.

   Response: The valve number in Table 9.2.1-2 will be changed from V1001, V1002, V1003, and V1004 to SX-1001, SX-1002, SX-1003, and SX-1004.

d) Question: Discuss the ESWS pump discharge MOV logic for opening and closing during any accident conditions. Describe the results if the MOV does not open with the pump operating, which system alarms in the MCR could provide operators information, and what the operator could do to mitigate the consequences.

   Response: The ESWS pump discharge motor operated valves are locked-open valves, and the valves are to remain in the open position during normal operation and during any accident condition. If any malfunction in an MOV, located downstream of the operating pump in a division, occurs and leads the MOV to be closed, then it could affect the cooling function of CCW heat exchangers in that division of the CCW system. However, since there are alarms in the MCR that would alert the operator of any trouble with the MOV, the operator can take adequate actions, such as stop the operating pump and initiate the operation of the other pump in the same division, in order to achieve the safety function of the ESWS.

e) Question: DCD Tier 1, Section 2.7.2.1.1, Item 8.d states that all displays and alarms exist in the RSR as defined in Tables 2.7.2.1-2 and 2.7.2.1-3. However, Tier 2 of the DCD Section 9.2.1 does not indicate any I&C for monitoring or control in the RSR. Tier 2 information should include all Tier 1 information. Provide in DCD Tier 2 a description of the ESWS instrument and control (I&C) in the RSR.

   Response: All ESWS instrument and control in the MCR are also provided in the RSR. For clarification Subsection 9.2.1 will be revised.

f) Question: The DCD does not discuss valve isolation and other means (such as procedures) that would be used to isolate the leakage in the event of radioactive leakage from the CCWS to ESWS. Provide a discussion to address the isolation of the radioactive contamination event in accordance with SRP Section 9.2.1, Subsection III.3.D.

   Response: In order to address the isolation of the radioactive containment event for ESWS, DCD Tier 2, Subsection 9.2.1.2.4 will be revised, and a COL information item will be added.

In response to the RAI, the applicant provided additional design information regarding ESW pump coolers, ESWS failure modes and effects analysis, ESWS pump discharge MOV, display and alarms in the RSR, and isolation of the radioactive contamination. The staff finds that the clarifications in the responses and associated DCD markups have adequately addressed the missing information identified in the RAI with the exception of Item (f). Item (f), relating to the minimization of contamination, is further reviewed in Section 9.2.1.4.13 of this report. Therefore, RAI 211-8236 Question 09.02.01-01 is resolved because the missing information is addressed in the RAI responses and the staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. In addition, DCD Revision 1 includes COL 9.2(7) to provide operational procedures and maintenance programs as related to leak detection and contamination control in the ESWS. Therefore, the staff considers RAI 211-8236, Question 09.02.01-01 to be resolved and closed

9.2.1.4.2 Piping Description

In its review, the staff identified the inadequacy on the ESWS piping description and requested additional information in RAI 211-8236, Question 09.02.01-02, as describe below.

DCD Tier 2, Section 9.2.1.2.2.2 states that:

> The ESW piping to the CCW heat exchanger building is routed through a seismic Category I reinforced concrete pipe tunnel buried in the yard. The ESW piping to the UHS structures is routed through a seismic Category I reinforced concrete pipe tunnel.

The staff found that these ESW piping sections are an essential part of the ESWS certified design to carry the cooling water for its heat removal function. However, these piping sections are not shown in the classification table of DCD Tier 2, Table 3.2-1; or in the ESWS equipment and piping table of DCD Tier 1, Table 2.7.2.1-1; and are not considered in the failure modes and effects analysis of DCD Tier 2, Table 9.2.1-2.

The applicant is requested to include the piping information in the applicable tables, as identified above.

The applicant responded in a letter, dated May 18, 2016 (ML16139A792). In the response, the applicant revised DCD Tier 1, Table 2.7.2.1-1 and Tier 2, Table 3.2-1, to include the requested information on the ESW piping, and justified that the failure modes and effects analysis do not include piping failures because piping is considered as passive component. The staff finds the response acceptable because the revised DCD adequately addressed the requested piping information being identified in the RAI. Therefore, Question 09.02.01-02 is resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 211-8236, Question 09.02.01-02 to be resolved and closed.

Piping Materials

In reviewing the description of ESWS piping materials, the staff identified the following inadequacy, and requested additional information in RAI 211-8236, Question 09.02.01-03, as described below.

DCD Tier 2, Section 9.2.1.2.2.2 states that:

> Piping is carbon steel pipe or internally lined carbon steel pipe depending on the ESW chemistry. Cathodic protection is applied to the pipe depending on the ESW chemistry.

However, such information about the ESWS piping is identified as conceptual design information for which the application does not seek certification. The staff found that the application may need an additional COL information item.

The applicant is requested to address establishment of a COL information item providing detailed information concerning materials that will be used for the ESWS including the basis for determining that the materials being used are appropriate for a given COL site location and for the fluid properties that apply.

The applicant provided the following response in a letter, dated March 23, 2016 (ML16083A540).

> The ESW piping material is classified as a COL information item because it is determined in consideration of the COL site condition and fluid properties. DCD Tier 2, Table 1.8-2 ["Combined License Information Items"], Subsection 9.2.1.2.2.2 and Subsection 9.2.10 will be revised to add the COL information item, providing detailed information for ESW piping material.

The staff's review of the response finds it acceptable because incorporating the new COL item satisfies 10 CFR 52.47(a)(25) for those portions of the plant that the application does not seek certification. The staff confirmed the DCD markups in the RAI response in DCD Revision 1. In addition, COL 9.2(5) in DCD Revision 1 is to provide the detailed information for the ESWS piping material including the basis for determining that the materials being used are appropriate for a given site location and for the fluid properties that apply. Therefore, the staff considers RAI 211-8236 Question 09.02.01-03 is resolved and closed.

In summary, the staff's review of the ESWS design adequacy in the DCD and the applicant's responses to the RAIs along with the associated DCD markups has resulted in two new COL information items and one follow-up item. The follow-up item is addressed in Section 9.2.1.5.13 of this report. The remaining items are found acceptable because the revised DCD adequately addressed all the deficiencies identified in the RAIs according to the guidance in SRP Section 9.2.1, Subsection III.1 for the design adequacy.

9.2.1.4.3 GDC 2, Design bases for protection against natural phenomena

The staff reviewed the ESWS system for compliance with GDC 2 in accordance with SRP Section 9.2.1. RG 1.29 Position C.1 states that safety-related system and components are to be designated as seismic Category I. The staff reviewed DCD Tier 2, Section 9.2.1 and Table 3.2-1 and confirmed the conformance with Position C.1 of RG 1.29. To confirm the conformance with RG 1.29 Position C.2 that a failure of nonsafety-related SSCs would not result in the failure of safety-related SSCs performing their safety-related functions, the staff found some inadequacies and requested additional information as described in the following RAI 211-8236, Question 09.02.01-04.

> The GDC 2 requires that the ESWS SSCs providing essential cooling for safety-related equipment be designed to withstand the effects of seismic events.

> The staff finds that DCD Tier 2, Section 9.2.1 lacks information such as demonstrating how the ESWS conforms to Position C.2 in RG 1.29 where the failure of non-safety-related SSCs would not result in the failure of safety-related SSCs. Also missing is the identification of the boundary isolation valves separating the non-safety-related from the safety-related portions of the ESWS.
>
> The applicant is requested to demonstrate that the ESWS conforms to RG 1.29, Position C.2 including the identification of boundary isolation valves. These valves should be listed in DCD Tier 2, Table 3.2-1, with their safety classification and seismic qualification. Also requested is a clarification on whether these boundary isolation valves are included for inservice testing and inspection.

The applicant responded in a letter, dated March 23, 2016 (ML16083A540), as described below.

> The ESWS is designed as Safety Class 3 and seismic Category I with the exception of the piping provided below, which is non-safety related and designed to seismic Category II.
>
> - ESW blowdown piping excluding the isolation valve SX-1063, SX1065 in the division I, and SX-1064, SX-1066 in the division II.
> - Radiation monitoring piping excluding the isolation valve SX-2071, SX-2073 in the division I, and SX-2072, SX-2074 in the division II.
> - Backwash discharge piping excluding the isolation valve SX-3102 and SX-3104.
>
> Based on the above, the safety-related SSCs in the ESWS are designed to seismic Category I and the nonsafety-related SSCs are designed to seismic Category II, not seismic Category III. Therefore, the failure of nonsafety-related SSCs would not result in the failure of safety-related SSCs. The boundary isolation valves separating the nonsafety-related portions from the safety-related portions are SX-1063 thru 1066, SX-2071 thru 2074, SX-3102 and 3104. These valves are classified safety-related and seismic Category I.
>
> The boundary isolation valves are not included for in-service testing and inspection, because they are used only for system or component maintenance, in accordance with ASME ISTC code requirements.
>
> DCD Tier 1, Table 2.7.2.1-1, and Tier 2, Table 3.2-1 will be revised to clarify the safety classification and seismic qualification for ESWS SSCs through the response to RAI 211-8236, Question 09.02.01-02.
>
> Figure 9.2.1-1 will be revised to indicate the classification break of the piping portion to the radiation monitoring system.

The staff's review of the responses finds that the responses have addressed the staff's question on GDC 2 with one exception as described in the follow-up Question 09.02.01-8.

In RAI 479-8605 (ML16131A616), Question 09.02.01-08, the applicant was requested to clarify the following statement.

> The boundary isolation valves are not included for in-service testing and inspection, because they are used only for system or component maintenance, in accordance with ASME ISTC code requirements.

The applicant responded in a letter, dated June 10, 2016 (ML16162A029), and clarified the above statement as the following:

> The boundary isolation valves for the ESWS are hand-wheel operated manual valves to separate the non-safety/safety systems. These valves are SX-V1063 through V1066 to the blowdown header piping, SX-V3102 and V3104 to the plant discharge piping, and SX-V2071 through V2074 to the radiation monitoring system piping.
>
> ASME ISTC-1200 (a) states that valves used only for operating convenience, such as vent, drain, instrument, and test valves that are not required to perform a specific function, are excluded from in-service testing and inspection. Valves SX-V2071 through 2074, which are used for the instrumentation of radiation monitoring system fit into this category. Furthermore, ASME ISTC-1200 (c) describes an exemption from in-service testing and inspection for valves that are used only for system or component maintenance. Valves SX-V1063 through V1066 are utilized while valves SX-V043 and V044 are in maintenance. Analogously, valves SX-V3102 and V3104 are utilized while SX-V3101 and V3103 are in maintenance. Therefore, these boundary isolation valves are not included for in-service testing and inspection.
>
> V1065 of Figure 9.2.1-1 in DCD Tier 2 will be corrected to V1066 as indicated in the DCD markups.

The staff finds the response acceptable because the basis for not including these boundary valves in the in-service testing and inspection was adequately explained, and is consistent with ASME ISTC code requirements, as discussed in the applicant's above response. Because the ASME code is consistent with RG 1.29, the applicant's response is, therefore, consistent with RG 1.29 and is acceptable. Therefore, RAI 479-8605 Question 09.02.01-8 and the related RAI 211-8236 Question 09.02.01-04 are resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 479-8605, Question 09.02.01-08 and RAI 211-8236 Question 09.02.01-04 to be resolved and closed.

Based on above, the staff concludes that the ESWS meets the requirement of GDC 2 because RG 1.29, Positions C.1 and C.2 are satisfied as discussed above.

Freezing, Icing, and Other Adverse Environmental Conditions

SRP Section 9.2.1, Subsection III.3.G states that the ESWS should be protected from potential failures or malfunctions caused by freezing, icing, and other adverse environmental conditions. DCD Tier 2, Section 9.2.1.3, Item (n) addresses this item by identifying a COL information item, which requires the COL applicant to evaluate freeze protection for the ESWS if required. Because freezing is a site-specific issue, the staff agrees with the applicant that the freezing issue is to be addressed by COL applicants in accordance with COL 9.2(10).

9.2.1.4.4 GDC 4, Dynamic and environmental effects design bases

Per GDC 4 requirement, the staff reviewed the dynamic effects of water hammer and environmental effects of flood hazards in accordance with the guidance in SRP Section 9.2.1, Subsection II.2.

9.2.1.4.5 Dynamic Effects of Water Hammer

The staff reviewed DCD Tier 2, Section 9.2.1.2.1, to confirm that the applicant has adequately addressed water hammer considerations in the ESWS. Water hammer can seriously damage ESWS components, rendering the system incapable of meeting safety functions. Conditions that allow for full or partial ESWS train drainage, resulting in air voids within the system piping could result in a severe water hammer event.

DCD Tier 2, Section 9.2.1.2.1 states that the ESWS is designed to minimize the potential for water hammer by providing means for adequate filling and high-point venting. DCD Tier 2, Section 9.2.1.2.1 states the following:

> The ESWS together with the UHS is designed to minimize the potential for water hammer by implementing the features described in NUREG-0927. Vents are installed at high points, and drains are installed at low points in the ESWS. Vents are located to provide reasonable assurance that the piping is filled with water to reduce the potential for water hammer after pump starts. When a division is restarted after shutdown of the division, one pump in the division is initially energized to fill the system with water. Because the system is initially empty, the pump discharge valve is throttled to prevent the pump from the runout condition and water hammer. In addition, pump discharge valve opening/closing times are selected to minimize water hammer effects when a pump is switched to standby pump operation in the same division or when a standby pump starts due to operating pump trip or control signal.
>
> The ESW pipe layout also minimizes water hammer. To prevent the void formation in the pipe and to minimize water hammer, ESW piping continuously goes up from the pump discharge to the UHS. The COL applicant is to develop procedures for system filing, venting, and operational procedures to minimize the potential for water hammer; to analyze the system for water hammer impacts; to design the piping system to withstand potential water hammer forces; and to analyze inadvertent water hammer events in accordance with NUREG-0927 in an ESWS COL item. The COL applicant is to develop the layout of the site-specific portion of the system to minimize the potential for water hammer in an ESWS COL item.

Based on the DCD description of the design to minimize water hammer, the commitment to the guidance in NUREG-0927, "Evaluation of Water Hammer Occurrences in Nuclear Power Plants," and the COL information items, COL 9.2(2) and COL 9.2(3), to address the procedures and site-specific portions of the system to minimize the water hammer, the staff has determined that the water hammer issue has been adequately addressed for the design certification of the ESWS because it conforms to the guidance in SRP Section 9.2.1, Subsection III.5.

9.2.1.4.6 Environmental Effects of Flood Hazards

The staff reviewed the ESWS for the conformance of GDC 4 in accordance with SRP Section 9.2.1, Subsection II.2, which indicates that the safety-related ESWS should be designed in accordance with GDC 4 to consider the environmental effects (such as flood hazards) of pipe failures.

The safety-related portion of the ESWS is subject to flood protection, and the ESWS is a water carrying system such that its failure could cause flood hazards. In its review of DCD Tier 2, Section 9.2.1, the staff requested additional information relating to the ESWS flood hazards in RAI 211-8236, Question 09.02.01-05 as described below.

> For the consideration of flood hazards due to ESWS pipe failures, the applicant is requested to address the following:
>
> 1. How the system and components of ESWS are protected from internal and external flooding?
> 2. How the ESWS pumps are isolated in order to address the flooding protection?
> 3. What the design features are to mitigate the consequences of flooding from ESWS?
> 4. Why a failure of the ESWS piping would not result in the failure of its heat removal functional capability?
> 5. Why the failure of ESWS piping would not result in the internal flood hazards for other safety-related SSCs?

The applicant responded in a letter, dated March 23, 2016 (ML16083A540), and provided the following information:

1. The design basis flood level for the APR 1400 standard design is at least 0.3 m (1 ft) below the plant grade, as specified in Table 2.0-1. All safety-related SSCs including ESWS components located on the dry site, as defined in RG 1.102, “Flood Protection for Nuclear power Plants,” are protected from an external flood event, as described in DCD Tier 2, Subsection 3.4.1.1, “Design Bases.” The COL applicant is to provide site-specific information on protection measures for the design basis flood.

   The internal flood analysis with protection and mitigation features of the site specific safety structures such as ESW building is to be provided by the COL applicant.

2. The ESWS design consists of two independent 100% divisions, with two redundant pumps in each division. The divisions are located in two physically separated ESW/CCW heat exchanger (HX) buildings as indicated in DCD Tier 2, Figure 1.2-1, “Typical APR1400 Site Arrangement Plan.” Key characteristics of the protective provisions against internal flooding hazards are identified in ITAAC Table 2.2.5-1 and a COL information item. The external flooding is site specific and is to be addressed by the COL applicant.

3. The flood mitigation features from internal flooding are to be provided by the COL applicant.

4. The ESWS consists of two totally independent 100% divisions, including two separate sets of pumps, piping, and instrument and control. The piping connecting from the ESW pumps, through the debris filters, CCW heat exchangers, to the UHS cooling towers, is independent and redundant. Hence, a single failure of the ESWS piping would not result in the failure of its heat removal functional capability.

5. All the ESWS components including the CCWS interface are located in the ESW/CCW HX buildings. Components supporting safety-related SSCs are not in the ESW/CCW HX buildings. The division isolation for the flooding protection is stated above in Response (b).

SRP Section 3.4.1 provides the staff with guidance in evaluation of protection against flooding. Based on the above RAI response and the COL information items, the staff finds that the applicant had adequately addressed potential flooding in the ESWS because it conforms to the guidance in SRP Section 3.4.1 and the COL applicants will provide further details of the site-specific system and its conformance with GDC 4. In DCD Tier 2, Revision 1, the staff verified that COL 3.4(2), COL 3.4(5), and COL 3.4(7) as discussed above were included in DCD Tier 2, Section 3.4.3. Therefore, the staff considers RAI 211-8236 Question 09.02.01-5 to be resolved and closed.

9.2.1.4.7 GDC 5, Sharing of structures, systems, and components

The staff finds that the design of the ESWS as described in the DCD does not share safety-related SSCs with any other nuclear power units. Therefore, the ESWS complies with the provisions of GDC 5.

9.2.1.4.8 GDC 44, Cooling water

The ESWS must be capable of removing heat from SSCs important to safety during normal operating and accident conditions over the life of the plant in accordance with GDC 44 requirements. The acceptance criteria in SRP Section 9.2.1 Subsection II.4 provide guidance for the staff to review ESWS for the conformance with GDC 44.

9.2.1.4.9 Heat Removal and Flow Requirements

The ESWS description in DCD Tier 2, Section 9.2.1 was reviewed to assess the design adequacy of the ESWS for performing its heat removal functions. In its review, the staff identified the request for additional information as described in RAI 211-8236, Question 09.02.01-06 as summarized below.

The DCD Tier 2, Section 9.2.1.2.1 states that Table 9.2.5-3, “Ultimate Heat Sink Design Parameters,” provides information on heat loads and water flow balance for various operating modes. However, the information in Table 9.2.5-3 is denoted as a conceptual design of the UHS for which the application does not seek certification. The ESWS removes heat from the CCWS and transfers the heat to the UHS. The above DCD statement on a conceptual design does not provide the necessary ESWS heat load information for the portion of the design that is subject to certification.

The applicant was requested to include additional information in DCD Tier 2, Section 9.2.1, to fully describe and explain the heat loads on the ESWS for normal operating, refueling, and accident conditions. The flow and temperature requirements and the cooling capability are also to be provided.

The applicant responded in a letter, dated May 2, 2016 (ML16123A185), and provided the following information.

> Information on the heat loads and water flows for the ESWS is part of the standard plant design certification information, and is provided in Table 9.2.5-1 "Ultimate Heat Sink Maximum Heat Loads for All Modes of Operation." The original reference "Table 9.2.5-3" in DCD Tier 2, Subsection 9.2.1.2.1 will be revised to "Table 9.2.5-1." The heat load for refueling mode will be added in DCD Tier 2, Table 9.2.5-1 and Table 9.2.5-3.
>
> Based on the inputs listed in Table 9.2.2-3 (A/B) and Table 9.2.5-1, the response also demonstrates the evaluation for each operating heat exchanger for different modes of operation. DCD Tier 2 Section 9.2.1.2.1, Table 9.2.5-1, and Table 9.2.5-3 of DCD Tier 2 will be revised.

The staff's review finds that the RAI response and DCD markups have adequately addressed the heat load question identified in the RAI because the heat loads on the ESWS are provided in Table 9.2.5-1, which is not conceptual design information, and is subject to staff review. Therefore, RAI 211-8236 Question 09.02.01-06 is resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 211-8236, Question 09.02.01-06 to be resolved and closed.

Based on the staff's review described above in accordance with SRP Section 9.2.1, Subsection II.4, the RAI responses, and DCD markups, the staff finds that the applicant has adequately addressed the design adequacy of the ESWS for performing its heat removal functions with respect to GDC 44 because the applicant adequately addressed the capability to transfer heat loads from safety-related SSCs to a heat sink under both normal and accident conditions. Further discussion of the heat loads on the ESWS are discussed in Section 9.2.2 of this report.

Conceptual Design Information

In its review, the staff found in the DCD the improper use of the "conceptual design information," and requested additional information in RAI 211-8236 Question 09.02.01-7 as described below.

> DCD Tier 2, Section 9.2.1.2.1 states the following:
>
> The ESWS blowdown line is installed at the ESW pump discharge common pipe to remove impurities concentrated in the UHS. The ESWS is designed with the capability to isolate nonessential portions of the system. The ESW blowdown operation is terminated by the engineered safety features actuation signal (ESFAS), ESW pump stop signal, or UHS basin low-level signal. An ESW blowdown bypass line is provided to bypass the ESW blowdown flow during the ESW blowdown isolation valve maintenance.

> The ESW flow of 71,923 L/min (19,000 gpm) excluding ESW blowdown is maintained during normal operating conditions. During shutdown and refueling, the ESW flow of 100,692 L/min (26,600 gpm) excluding ESW blowdown is maintained. The ESW flow of 75,708 L/min (20,000 gpm) is maintained during accident and safe shutdown conditions.
>
> The above information is denoted as "conceptual design information," which the application does not seek certification. However, the staff finds that the above information is an essential part of the standard design and should be subject to the certification review.
>
> The applicant is requested to review whether the above information is properly included in the standard design, and revise DCD Tier 2 accordingly. If any portions that may be determined as conceptual design not being subject to NRC review, the applicant should provide justification for its determination and establish an appropriate COL information item to require COL applicants to provide such information.

The applicant responded in a letter, dated February 26, 2016 (ML16057A093), and provided the following information:

> The ESW blowdown flow rate and operation are dependent on the site-specific environmental conditions and the cooling tower vendor's design characteristics. Therefore the designs related to the ESW blowdown are determined as conceptual design information. DCD Tier 2, Subsection 9.2.1.2.1 will be revised to establish a COL information item to require COL applicants to provide the ESW blowdown design. In addition, DCD Tier 2 will be revised to identify the CDI for the ESW blowdown and UHS cooling tower design, and the standard design for the others.

The staff finds the applicant's response acceptable because the revised DCD Tier 2 in Section 9.2.1.2.1, 9.2.1.2.2.3, 9.2.1.3, 9.2.5.2.1, 9.2.5.2.2, and 9.2.5 have properly redefined the scope of the CDI and COL 9.2 (1) is to provide ESW blowdown design to address site-specific information. Therefore, RAI 211-8236 Question 09.02.01-07 is resolved. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 211-8236, Question 09.02.01-07 to be resolved and closed.

9.2.1.4.10 Single Active Component Failure and LOOP

DCD Tier 2, Section 9.2.1.2.1 describes the ESWS system:

> The ESWS consists of two independent, redundant, once-through, safety-related divisions. Each division cools one of two divisions of the CCWS, which cools 100 percent of the safety-related loads. This arrangement provides reasonable assurance that failures and postulated events in one division do not affect the safety-related functions of the other division during accident conditions, such as a LOCA or safe shutdown with loss of offsite power (LOOP), or in a postulated single active component failure.
>
> The ESWS design heat loads are based on the maximum safe shutdown heat loads with only one operable ESWS division. The other division is assumed to be failed due to a single active component failure.

Further, DCD Tier 2, Section 9.2.1.5.5 states that, in the event of LOOP or LOOP coincident with a design basis accident, the ESW pumps stop running and restart in accordance with the EDG load sequencing. If the ESW pump chosen by the sequencer fails to start, the sequencer starts the other pump immediately.

Based on the above, the staff has determined that the DCD has adequately addressed the issue of single active component failure of ESWS, because the design conforms to the guidance in SRP Section 9.2.1, Subsections III.2 and III.3.F, regarding single active component failure and LOOP.

9.2.1.4.11 Net Positive Suction Head

SRP Section 9.2.1, Subsection III.3.C states that the ESWS pumps should have sufficient available net positive suction head at the pump suction locations with low water levels. DCD Tier 2, Section 9.2.1.2.2.1, "ESW Pumps," describes the available NPSH as follows:

> The available NPSH is based on the lowest probable water level in the UHS basin and the basin water design temperature at the end of the 30-day-accident mitigation without makeup. The COL applicant is to (1) determine the required pump design head, using pressure drop from the certified design portion of the plant and adding site-specific head requirements, (2) determine the pump shutoff head to establish system design pressure, which does not exceed APR1400 system design pressure, and (3) evaluate the potential for vortex formation at the pump suction based on the most limiting applicable conditions in an ESWS COL item.

Based on above, the staff has determined that the applicant requires COL applicants to address NPSH. The staff finds this approach acceptable because incorporating the requirements of COL 9.2(4) to determine site-specific required pump design head adequately addresses the guidance in SRP Section 9.2.1, Subsection III.3.C for the NPSH requirement.

9.2.1.4.11.1.1 GDC 45, Inspection of cooling water system

The staff reviewed the ESWS for compliance with the acceptance criteria for GDC 45 as described in SRP Section 9.2.1 Subsection II.5 related to the design provisions for inservice inspection of safety-related components and equipment. DCD Tier 2, Section 9.2.1.1.1 states that components of the ESWS are capable of being fully tested during normal plant operation. In addition, parts and components are accessible for inspection. The system is designed for periodic inservice testing and inspection to provide reasonable assurance of the integrity and capability of the system in accordance with GDC 45 and ASME Section XI. DCD Tier 2, Section 9.2.1.4.2, "Inservice Testing and Inspection," describes the inservice testing and inspection at system level and at component level.

Based on the above, the staff has determined that the ESWS periodic inservice testing and inspection conform to GDC 45, because they are consistent with the guidance in SRP Section 9.2.1, Subsection II.5 related to the design provisions for inservice inspection of safety-related components and equipment.

9.2.1.4.11.1.2 GDC 46, Testing of cooling water system

The staff reviewed the ESWS for compliance with the acceptance criteria for GDC 46 as described in SRP Section 9.2.1, Subsection II.6 related to design provisions for operational

functional testing of safety-related system and components. In addition to the inservice testing and inspection, DCD Tier 2, Section 9.2.1.4 states that periodic verification of the ESWS component performance, such as the heat exchangers cooled by the ESW, is conducted to detect any degradation in performance caused by fouling. Also, heat exchangers are monitored according to a test program based on the requirements of generic letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment." As part of its inservice testing program, a COL applicant will establish acceptance criteria for performance verification to allow for degradation and maintain acceptable heat exchanger performance for all modes of plant operation.

Moreover, the COL 9.2(11) requires the COL applicant to address conducting periodic inspections, monitoring, maintenance, performance testing, functional testing, and verification of the function of the ESWS pipes and components such as the heat transfer capability of the CCW heat exchangers based on Generic Letter (GL) 89-13 and GL 89-13, Supplement 1.

The staff reviewed the above information and requested the applicant in RAI 211-8236, Question 09.02.01-04, and RAI 479-8605, Question 09.02.01-08 to provide a discussion addressing whether the boundary isolation valves between the safety-related and nonsafety-related systems are included for inservice testing and inspection. This is reviewed above in Section 9.2.1.4.2 and the staff found it to be acceptable. The staff has determined that the design of the ESSWS meets GDC 46 because the design permits appropriate pressure and functional testing.

9.2.1.4.11.1.3 Conformance with 10 CFR 20.1406

The staff reviewed the ESWS for compliance with 10 CFR 20.1406 related to minimization of contamination in accordance with SRP Section 9.2.1, Subsection III.3.D. DCD Tier 2, Section 9.2.1.2.1 states that the CCWS serves as an intermediate barrier between the reactor coolant systems (RCS) and the ESWS. Thus, no radioactive contamination leaks directly from the RCS to the ESWS. DCD Tier 2, Section 9.2.1.2.4 "Design Features for Minimization of Contamination," states that a radiation monitor is provided at the outlet of the CCW heat exchangers to detect any radioactive leakage from the CCWS to the ESWS. The monitor is indicated and alarmed in the MCR and displayed locally. Further, Section 9.2.1.2.4, states the following:

> The ESWS is designed to minimize the potential for contamination through leakage in the heat exchangers. Through monitoring, inservice inspection, and lessons learned from industry experiences, the integrity of the CCW heat exchangers is expected to be well maintained, resulting in no contamination or a very low level of contamination of the system. Leakage from the system to the facility and the environment is captured by the design. Hence, the ESWS has low risk and low radiological consequence and this design is in compliance with RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning."

The staff reviewed the above information and requested the applicant in RAI 211-8236, Question 09.02.01-01, Item (f) to address the valve isolation and other means (such as procedures) in the event of radioactive leakage from CCWS to ESWS. In response, the applicant incorporated a COL information item requiring the COL applicant to provide operational procedures and maintenance programs as related to leak detection and contamination control in the ESWS.

The staff reviewed the applicant's response and determined it to be incomplete. A followed-up RAI 493-8621 (ML16152A050), Question 09.02.01-09 was developed. SRP Section 9.2.1, Subsection III.3.D asks for the ESWS system piping and instrumentation diagrams (P&IDs) to show radiation monitors located on the system discharge and at components susceptible to leakage, and that these components can be isolated by one automatic and one manual valve in series. The staff reviewed the P&ID of Figure 9.2.1-1 and the RAI response, and could not find the above information. The applicant is requested to provide the information on the radiation monitors and isolation valves in the P&ID in accordance with the SRP guidance.

The applicant responded to the RAI in a letter, dated July 13, 2016 (ML16195A540). In the response, the applicant states that the radiation monitoring system in the ESWS is provided in each discharge line of the CCW heat exchanger cold side (ESW) as described in DCD Tier 2, Figure 9.2.1-1 for the early detection feature of any potential radioactive leakage from the CCWS to the ESWS. Prior to any radiation leakage being detected in the ESWS, radiation alarms on the CWS side alerts the operators of contamination in the CCWS. The affected CCWS division is immediately isolated followed by the isolation valves (V1005 ~ V1016) on the inlet and outlet lines of the CCW heat exchanger cold side (ESW) to prevent possible contamination of the UHS and the environment. PR (radiation monitoring system) in Figure 9.2.1-1 in DCD Tier 2 will be corrected to PR: RE/RT-113, 114 in accordance with Figure 11.5-1, "Radiation Monitoring System (PR)."

Based on above, the staff found that RAI 493-8621 Question 09.02.01-09 is resolved, because the requested information regarding radiation monitors and isolation valves is now identified in the P&ID. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 493-8621, Question 09.02.01-09 to be resolved and closed. Based on the review above, the staff concludes that the ESWS has adequately addressed 10 CFR 20.1406 related to minimization of contamination in accordance with SRP 9.2.1, Section III.3.D.

9.2.1.4.12 Initial Test Program

DCD applicants must include plans for preoperational testing and initial operations in accordance with 10 CFR 50.34, "Contents of applications; technical information," Item (B)(6)(ii) requirements. DCD Tier 2, Section 14.2.12.1.75, "Essential Service Water System Test," describes the ESWS preoperational test to demonstrate the cooling capability of the ESWS and to verify that the ESWS operates within the design limits described in DCD Tier 2 Section 9.2.1. The initial test program for the APR1400 is evaluated in Section 14.2 of this report.

9.2.1.4.13 ITAAC

DCD Tier 1, Section 2.7.2.1, "Essential Service Water System," describes Tier 1 information for ESWS. Tier 1, Table 2.7.2.1-1 describes ESWS equipment and piping location and characteristics. Tier 1, Table 2.7.2.1-2 lists ESWS components. Tier 1, Table 2.7.2.1-3 lists ESWS instruments. Tier 1, Table 2.7.2.1-4 describes ESWS ITAAC. Tier 1, Figure 2.7.2.1-1 provides a simplified flow diagram of the ESWS. The staff's evaluation of Tier 1 plant systems SSCs is provided in Section 14.3.7, "Plant Systems – Inspections, Tests, Analyses, and Acceptance Criteria," of this report.

The staff finds that there is reasonable assurance that, if the proposed ITAAC are performed and the acceptance criteria met, the ESWS will be constructed and operated in accordance with

the certified design, the AEA and NRC regulations. Therefore, the staff finds the proposed ITAAC comply with 10 CFR 52.47(b)(1).

9.2.1.4.14 Technical Specifications

DCD Tier 2, Chapter 16, Section 3.7.8, “Essential Service Water System (ESWS),” provides plant TSs including limiting condition for operation (LCO), LCO action statement, and surveillance requirements (SR) for the ESWS. TS requirements are evaluated in Chapter 16, “Technical Specifications,” of this report. The staff finds that the proposed TS requirements are consistent with the standard technical specifications (STS) for Combustion Engineering Plants (NUREG-1432, Revision 4), and therefore, acceptable. DCD Tier 2, Chapter 16, Section 3.7.8, “Essential Service Water System (ESWS),” provides plant TSs including LCO, LCO action statement, and SR for the ESWS. TS requirements are evaluated in Chapter 16 of this report. In Chapter 16, the staff also finds that the proposed TS requirements are consistent with the STS for Combustion Engineering Plants (NUREG-1432, Revision 4), and therefore, acceptable.

9.2.1.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(1)	The COL applicant is to provide the UHS-related systems such as blowdown, chemical injection, and makeup water system.	9.2.1.2.1, 9.2.5.2, 9.2.10
9.2(2)	The COL applicant is to develop procedures for system filling, venting, and operational procedures to minimize the potential for water hammer; to analyze the system for water hammer impacts; to design the piping system to withstand potential water hammer forces; and to analyze inadvertent water hammer events in accordance with NUREG-0927 in the ESWS.	9.2.1.3, 9.2.10
9.2(3)	The COL applicant is to develop layout of the site-specific portion of the system to minimize the water	9.2.1.2.1, 9.2.10

	hammer potential in the ESWS.	
9.2(4)	The COL applicant is to (1) to determine required pump design head, using pressure drop from the certified design portion of the plant and adding site-specific head requirements, (2) determine pump shutoff head to establish system design pressure, which is not to exceed APR1400 system design pressure, and (3) evaluate potential for vortex formation based on the most limiting applicable conditions in the ESWS.	9.2.1.2.1, 9.2.10
9.2(5)	The COL applicant is to provide the detailed information for the ESWS piping material including the basis for determining that the materials being used are appropriate for a given site location and for the fluid properties that apply.	9.2.1.2.2.2, 9.2.10
9.2(6)	The COL applicant is to determine the design details of the backwashing line and vent line and their discharge locations in the ESWS.	9.2.1.2.2.3, 9.2.10
9.2(7)	The COL applicant is to provide operational procedures and maintenance programs as related to leak detection and contamination control in the ESWS.	9.2.1.2.4, 9.2.10
9.2(8)	The COL applicant is to provide the evaluation of the ESW pump at the high and low water levels of the UHS. In the event of approaching low UHS water level, the	9.2.1.3, 9.2.10

	COL applicant is to develop a recovery procedure.	
9.2(9)	The COL applicant is to provide measures to prevent long-term corrosion and organic fouling that may degrade system performance in the ESWS.	9.2.1.3, 9.2.10
9.2(10)	The COL applicant is to evaluate the need and design and install freeze protection in the ESWS if required.	9.2.1.3, 9.2.10
9.2(11)	The COL applicant is to conduct periodic inspection, monitoring, maintenance, performance and functional testing, of the ESWS and UHS piping and components, including the heat transfer capability of the CCW heat exchangers based on GL 89-13 and GL 89-13 Supplement 1.	9.2.1.4, 9.2.10
9.2(22)	The COL applicant is to provide the location and design of the ESW building, and makeup water source.	9.2.5.2, 9.2.10
9.2(23)	The COL applicant is to provide isolation between the UHS and the non-safety-related systems.	9.2.5.2, 9.2.10
9.2(24)	The COL applicant is to provide the design of UHS cooling tower basin so the minimum water level will provide adequate NPSH to ESW pumps under accident conditions.	9.2.5.2.1, 9.2.10
9.2(27)	The COL applicant is to verify the piping layout of the ESWS and UHS to prevent water hammer and develop operating procedures to	9.2.5.2.1, 9.2.10

	provide reasonable assurance that the ESWS and UHS water pressure are above saturation conditions for all operating modes.	
9.2(28)	The COL applicant is to develop maintenance and testing procedures to monitor debris buildup and flush out and to remove the debris in the UHS.	9.2.5.2.1, 9.2.10
9.2(30)	The COL applicant is to provide the material specifications for piping, valves, and fittings of the UHS system based on site-specific conditions and meteorological conditions.	9.2.5.2.2.2, 9.2.10
9.2(37)	The COL applicant is to develop the following procedures for the water system: filling, venting, keeping it full, and operating it to minimize the potential for water hammer. The COL applicant is also to analyze the system for water hammer impacts, design the piping system to withstand potential water hammer forces, and analyze inadvertent water hammer events in the ECWS in accordance with NUREG-0927.	9.2.7.2.1, 9.2.10
9.2(38)	The COL applicant is to confirm that there are no departures and shall meet the interface requirements (i.e., cooling duties and temperature requirements, piping and control interface).	9.2.8.1, 9.2.10
9.2(39)	The COL applicant is to provide operational procedures and maintenance programs as related to leak	9.2.8.2.3, 9.2.9.2.3, 9.2.10

	detection and contamination control in accordance with RG 4.21.	

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for this system.

9.2.1.6 Conclusion

The staff reviewed the APR1400 application in accordance with the guidance provided in SRP Section 9.2.1, "Station Service Water System." Based on the review above, the staff finds the ESWS acceptable in meeting GDCs 2, 4, 5, 44, 45, 46, 10 CFR 52.47 Items (a)(24) and (a)(25), 10 CFR 52.47(b)(1), and 10 CFR 20.1406.

9.2.2 Component Cooling Water System

9.2.2.1 Introduction

The CCWS is a closed-loop cooling water system that serves as an intermediate barrier between radioactive or potentially radioactive heat sources and the ESWS. It provides cooling to safety-related and nonsafety-related plant components during normal operation and shutdown, and to safety-related components during accident and emergency condition.

9.2.2.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in Tier 1, Section 2.7.2.2, "Component Cooling Water System," of the APR1400 DCD. The information includes a design description of the CCWS, identification of the CCWS functional requirements, illustration of the CCWS configuration, and the CCWS ITAAC.

DCD Tier 2: The design description and operational details of the CCWS are provided in DCD Tier 2, Section 9.2.2, "Component Cooling Water System," and the CCWS flow diagrams can be found in DCD Tier 2, Figure 9.2.2-1, "Component Cooling Water System Flow Diagram."

The CCWS consists of two separate, independent, redundant closed-loop safety-related divisions, each of which is capable of supporting 100 percent of the cooling functions required for a safe reactor shutdown following a postulated accident coincident with a LOOP. Each CCWS division includes three CCW heat exchangers, a surge tank, two CCW pumps, a CCW chemical addition tank, a CCW radiation monitor, piping, valves controls, and instrumentation. There is also cross connection capability between divisions.

The safety design bases for CCWS are given in DCD Tier 2, Section 9.2.2.1.1, "Safety Design Bases," and includes the following CCWS thermal performance requirements related to establishing and maintaining the plant in safe shutdown.

- The CCWS, in conjunction with the ESWS, is capable of removing heat from the essential components to provide reasonable assurance of a safe shutdown and cooling following a postulated accident coincident with a LOOP.

- The CCWS, in conjunction with the ESWS, is capable of maintaining the temperature at the outlet of the CCW heat exchanger between 18.3 °C (65 °F) and 43.3 °C (110 °F) during a design-basis accident with a LOOP pursuant to the requirements of GDC 44.

- A single failure of any component in the CCWS does not impair the ability of the CCWS to meet its functional requirements of mitigating the consequences of an accident pursuant to GDC 44.

The essential cooling loops of the CCWS supply water to safety-related SSCs. DCD Tier 2, Section 9.2.2.2.4, "System Operation and Control" identifies the following as safety-related heat loads to which the CCWS supplies cooling water:

- Shutdown Cooling heat exchanger (one per division).

- Shutdown Cooling mini-flow heat exchanger (one per division).

- Containment Spray heat exchanger (one per division).

- Containment Spray mini-flow heat exchanger (one per division).

- Emergency Diesel Generator (EDG) coolers (two per division).

- Essential chiller condensers (two per division).

- Spent Fuel Pool (SFP) cooling heat exchanger (one per division).

The CCWS also provides cooling water to the nonessential SSCs listed in DCD Tier 2, Section 9.2.2.2.4, which include the reactor coolant pump (RCP) coolers and letdown heat exchangers located inside containment, and several other SSCs outside containment, including (for example) the essential chillers and spent fuel pool heat exchangers. The nonessential cooling loops are automatically isolated and CCW flow to nonessential equipment is terminated in the event of an accident.

Initial Test Program: Initial plant testing for the component cooling water system is described in DCD Tier 2, Section 14.2.12.1.76, "Component Cooling Water System Test."

ITAAC: ITAAC for the CCWS are included in DCD Tier 1, Section 2.7.2.2, "Component Cooling Water System."

Technical Specifications: The TSs associated with the CCWS are given in DCD Tier 2, Chapter 16, Section 3.7.7, "Component Cooling Water System."

9.2.2.3 Regulatory Basis

The relevant requirements for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.2.2, "Reactor Auxiliary Cooling Water System," and are summarized below.

1. GDC 2, "Design basis for protection against natural phenomena," as it relates to the capability of structures housing the system and the system itself to withstand the

effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of safety-related functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to the capability of the system and the structure housing the system to withstand the effects of missiles inside and outside of containment, pipe whip, jets and environmental conditions from high and moderate energy line breaks and dynamic effects of flow instabilities and loads (e.g., water hammer) during normal plant operation, as well as during accident conditions.

3. GDC 5 "Sharing of structures, systems, and components," insofar as it requires that SSCs important to safety not be shared among power units unless it can be shown that sharing will not significantly impair their ability to perform their safety functions.

4. GDC 44, "Cooling water," as it relates to the capability to transfer of heat from systems, SSCs important to safety to an UHS during both normal and accident conditions, with suitable redundancy, assuming a single active component failure coincident with either the loss of offsite power or loss of onsite.

5. GDC 45, "Inspection of cooling water system," as it relates to design provisions made to permit periodic in-service inspection of system components and equipment.

6. GDC 46, "Testing of cooling water system," as it relates to design provisions made to permit appropriate pressure and operational functional testing of the system and components in regards to:

   - Structural integrity and system leak-tightness of its components;

   - Operability and adequate performance of active system components; and

   - Capability of the integrated system to perform credited functions during normal, shutdown, and accident conditions.

7. 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.

8. 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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA, and NRC regulations.

9.2.2.4 Technical Evaluation

The staff reviewed the CCWS in accordance with the review procedures in SRP Section 9.2.2, "Reactor Auxiliary Cooling Water System," Revision 4. The results of the staff's review are provided below.

9.2.2.4.1 System Design Considerations

Design Basis

The safety design basis for the CCWS states that the CCWS, in conjunction with the ESWS, is capable of removing heat from the essential components to provide for safe shutdown and cooling following a postulated accident coincident with a LOOP. The design basis is that the CCWS be designed to maintaining a CCW heat exchanger outlet temperature between 18.3 C (65 °F) and 43.3 °C (110 °F) during a design basis accident with a LOOP.

The system design basis also requires that the system be designed to isolate nonessential portions of the system during a design basis accident, and be designed so that a single failure of any component in the CCWS does not impair the ability of the CCWS to meet its functional requirements of mitigating the consequences of an accident.

Additional safety design basis includes the requirement that the system be designed to seismic Category I requirements to withstand the effects of a SSE, and that all essential CCWS components be fully protected from floods, fire, tornadoes, hurricanes, internal and external missiles, pipe breaks and whip, jet impingements, and interactions with non-seismic systems in the vicinity.

The design basis also requires that that CCWS components be capable of being fully tested during normal plant operation. In addition, parts and components are to be accessible for inspection, and the system designed for periodic inservice testing.

The staff reviewed the information on the CCWS design bases provided in DCD Tier 2, Section 9.2.2.1 and found the design criteria in that section addressed those items identified in Section C.I.9.2.2.1 of RG 1.206. Based on its review, the staff finds the design basis appropriate relative to the safety function that the CCWS is designed to perform.

System Design and Operation

Information pertaining to the design and operation of the CCWS is included in DCD Tier 2, Section 9.2.2.2, "System Description," and DCD Tier 2, Section 9.2.2.2.4, "System Operation and Control." The CCWS provides cooling water to essential and nonessential components listed in DCD Tier 2, Subsection 9.2.2.2.2, "CCW Pumps," and has two safety-related divisions that are separate, independent, redundant, and closed-loop. The CCW cooling loops serving essential components are classified as safety-related, seismic Category I, Safety Class 3. The CCW cooling loops serving nonessential components are non-nuclear safety class and, upon receipt of a safety injection actuation signal (SIAC) or a low-low surge tank level signal, a nonessential cooling loop is automatically isolated.

The CCWS design also incorporates two CCW surge tanks, one per division, connected to the suction side of the CCW pumps, to accommodate surges which may occur due to expansion and contraction of the fluids in the system due to temperature changes and to assure that adequate available NPSH is maintained for CCW pump operation. In addition, the surge tank provides a surge volume to accommodate fluid loss from a piping failure in the nonsafety-related piping and equipment and is designed to have sufficient capacity for seven days of operation without makeup. The as-built CCW surge tank volume will be verified by ITAAC 11c, in Tier 1, Table 2.7.2.2-4, "Component Cooling Water System ITAAC."

Six plate-type heat exchangers, three per division, are used in the design. The CCW system is designed to have the CCW return water temperature at 95 °F or less during normal operation or 110 °F or less during normal shutdown or when in emergency operating modes. Therefore, the heat exchanger must be sized to provide the required heat removal based on the heat loads being cooled for the given mode of operation, and the system flow and alignment used to support system operation in that mode. During normal operation one pump and two heat exchangers per division are used. In safe shutdown and post LOCA modes one pump and two heat exchangers in a single division are used.

Based on its review of the information provided about the design and operation of the CCWS, the staff has confirmed that essential CCWS portions of the system have been identified and are separated from non-essential portions of the system by automatically operated isolation valves. Therefore, the staff finds the system design and operation, as described, to be consistent with the guidance provided in SRP 9.2.2.

9.2.2.4.2 GDC 2, Design bases for protection against natural phenomena

The staff reviewed the CCWS for compliance with the requirements of GDC 2 with respect to its design for protection against the effect of natural phenomena such as earthquakes, tornados, hurricanes, and floods. Compliance with the requirements of GDC 2 is based on the CCWS being designed to withstand the effects of natural environmental phenomena without losing the ability to perform its safety function and on meeting the guidance of RG 1.29, Regulatory Position C.1, for the safety-related portions of the system, and RG 1.29, Regulatory Position C.2 for the nonsafety-related portions of the system.

All of the buildings housing CCWS equipment are shown in DCD Tier 2, Figure 1.2-1, to be in scope of the standard plant, and thus the DCD. The auxiliary building, EDG building (EDGB), and component cooling water heat exchanger (CCWHX) building are all designed as seismic Category I and protect the CCWS components from external environmental hazards such as wind, tornado, hurricane, flood, and earthquakes, as described in Sections 3.3, "Wind and Tornado loadings"; 3.4, "Water Level (Flood) Design"; and 3.7, "Seismic Design," of the APR1400 DCD. While the building structure provides protection for the SSCs inside the buildings, the staff was unable to verify that the SSCs in piping tunnels would be adequately protected against external environmental hazards since DCD Tier 2, Figure 1.2-1 does not identify the pipe tunnels to be in scope of the DCD, and protection of the CCWS SSCs inside the pipe tunnels is not discussed in the DCD. The staff did note, however, that in the discussion in DCD Tier 2, Section 9.2.2.2.5, "Design Features for Minimization of Contamination," the applicant does indicate that "piping to the component cooling water heat exchanger structures is routed through seismic Category I reinforced concrete pipe tunnels (one per division) under the yard." In order to clearly identify the design responsibility and requirements for the CCWS pipe tunnels, the staff issued RAI 256-8321 (ML15293A570), Question 09.02.02-05, requesting that the applicant identify whether or not the tunnels are within the scope of the DCD, identify any requirements to ensure CCWS SSCs are protected from the environment hazards, and discuss addition of a COL information item specifying the COL applicant requirements regarding the CCWS tunnels, if the tunnels are not in scope of the DCD.

In its response to RAI 256-8321, Question 09.02.02-5, dated March 2, 2016 (ML16062A085) the applicant stated that the CCW piping tunnels between the auxiliary building and the CCW heat exchanger buildings are site-specific structures and their design is the responsibility of the COL applicant. They also indicated that the CCW piping tunnels are designed to Safety Class 3 and

seismic Category 1. In order to provide requirements to ensure CCWS SSCs are protected from environmental hazards the applicant proposed adding COL 9.2(37) (later re-numbered as COL 9.2(13)) to have the COL applicant address providing adequate freeze protection if necessary.

The staff has reviewed the applicant's RAI response and found it acceptable since it includes a revised COL information item that now addresses the staffs concerns related to the CCW piping tunnels and protection of the SSCs in the tunnels from natural environmental phenomena. Therefore, RAI 256-8321, Question 09.02.02-05 is resolved. The staff confirmed that the RAI response markup has been incorporated into revision 1 of the DCD. Therefore, RAI 256-8321, Question 09.02.02-05 is closed.

DCD Tier 2, Table 3.5-4, "Essential Systems and Components to be Protected from Externally Generated Missiles," contains a list of protected SSCs and their associated missile barrier. In reviewing Table 3.5-4, the staff noticed that the CCWHX building was identified as the missile barrier for all of the protected components associated with the CCWS but, based on the staff's review of the general arrangement drawings in DCD Tier 2, Figures 1.2-11-1.2-19 (General Arrangement of the Auxiliary Building at various levels) and the information provided in DCD Tier 1, Table 2.7.2.2-1, "Component Cooling Water System Equipment and Piping Location / Characteristics," the only CCWS components contained in the CCWHX building is the component cooling water system heat exchangers. The CCW pumps and CCW makeup pumps are located in the Auxiliary Building, and staff believes that the identification of the CCWHX building as the missile barrier for the CCW pumps and CCW makeup pumps may be in error; therefore the staff issued RAI 256-8321, Question 09.02.02-06, requesting that the applicant update Table 3.5-4 to be consistent with the design presented in the application.

In its response to RAI 256-8321, Question 09.02.02-04, dated June 17, 2016 (ML16169A063), the applicant confirmed that CCW pumps and CCW makeup pumps are located in the auxiliary building and proposed a revision to DCD Tier 2, Table 3.5-4 to include the auxiliary building as a missile barrier for the CCWS system components, and included with the response was the revised Table 3.5-4. Since the information in the revised table is consistent with the design described in DCD Tier 2, Section 9.2.2, the staff finds the response acceptable and the issue resolved. The staff confirmed that the RAI response markup has been incorporated into revision 1 of the DCD. Therefore RAI 256-8321, Question 09.02.02-04 is closed. Based on the above review the staff finds the CCWS to be adequately protected from external environmental hazards such as wind, tornado, hurricane, and floods, as required by GDC 2.

The DCD Tier 2, Section 3.2, "Classification of Structures, Systems and Components," categorizes SSCs based on safety importance and other considerations. The location, safety classification and seismic Category for the CCWS components are listed in DCD Tier 2, Table 3.2-1. The staff reviewed the information on the CCWS in DCD Tier 2, Figure 9.2.2-1 and Table 3.2-1, and confirmed that CCWS components and piping essential to CCWS operation are designed as seismic Category I and are located in either the auxiliary building, CCW heat exchanger building, or the diesel generator building, all of which are seismic Category I structures. The staff also confirmed that that CCWS components and piping that provide cooling to nonsafety-related plant components were properly classified as seismic Category II when they were in proximity of safety-related SSCs in the auxiliary building, DG building and CCWSHX buildings, and seismic Category III when they were not in proximity of safety-related equipment (i.e., yard piping and SSCs in the compound building). Therefore, the staff finds that

the CCWS design is in conformance with RG 1.29, Positions C.1 and C.2, and the requirements of GDC 2, as they relate to protecting the system against natural phenomena.

9.2.2.4.3 GDC 4, Environmental and dynamic effects design bases

The staff reviewed the CCWS for compliance with the requirements of GDC 4 with respect to the capability of the system and the structures housing the system to withstand the effects of pipe breaks, including the effect of pipe whip, jet impingement, and the environmental conditions resulting from high and moderate energy line breaks, as well as the effect of flow instabilities and attendant loads (water hammer). 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, pipe whip and jets and the system being capable of continuing to perform its safety function in the environmental conditions that may result from high and moderate energy line breaks and the resulting discharged fluid.

The CCWS is designed to meet single-failure criteria. It has two physically separated, independent redundant divisions, each powered by a separate class 1E AC power distribution system and separate EDG. A single failure of any component in the CCWS does not impair the ability of the CCWS to meet is functional requirement of mitigating the consequences of an accident.

In the APR1400 design, the CCWS equipment is located inside the auxiliary building and the component cooling water heat exchanger building, both of which are designated as seismic Category I structures. The piping connecting the CCWS components in the auxiliary building to those in the CCWHX building is also designated to be a seismic Category I pipe tunnel. Since these structures are designed to withstand the effects of severe natural phenomenon, including external missiles, as discussed in Section 3.5, "Missile Protection," of this report, the safety-related portions of the CCWS are protected from external missiles. With respect to internal hazards, the design basis for the CCWS calls for the safety-related portions of these systems to be appropriately protected against the possible effects of postulated high- or moderate-energy pipe failure including whip or jet impingement, as described in Section 3.6 of the DCD, and internal flooding, and internal missiles, as described in DCD Sections 3.4 and 3.5 respectively.

The protection of the safety-related CCWS SSCs from the effects of the above mentioned internal hazards is generally accomplished in the APR1400 design by physical separation of redundant trains, and by enclosing redundant trains in separate compartments which provide both a physical/structural barrier for the SSCs in the compartment and separation distance between the redundant trains. The staff reviewed the general plant arrangement drawings (DCD Tier 2, Figures 1.2-11 through 1.2-19) and confirmed that the general arrangement of the system is such that the redundant components of the CCWS are protected from internal hazards due to separation of the two safety related trains, and their location in enclosures provide protection.

The discussion of design provisions to mitigate water hammer is included in DCD Tier 2, Section 9.2.2.2.2.4, "Piping, Valves, and Fittings." The CCWS is designed to minimize the potential for water hammer by providing relief valves as required for equipment protection, and having vents installed in high points, and drains installed in low points in the CCWS. The DCD also states that valves opening/closing times are selected to minimize water hammer. Since the vents and drains will be located to ensure that all piping is filled with water; the chance of water hammer after pump startup is minimized.

To ensure that adequate precautions are taken to prevent water hammer once the system has been put into operation, the applicant states in DCD Tier 2, Section 9.2.2.2.2.4, that the COL applicant is to develop procedures for water systems filling, venting, keeping the system full, and operation to minimize the potential for water hammer; to analyze the system for water hammer impacts; to design the piping system to withstand potential water hammer forces; and to analyze inadvertent water hammer events in accordance with NUREG-0927. The DCD applicant has included COL 9.2(12) in the application in order to address all these maintenance operating procedures. While the staff concurs with the need for the COL item to have the COL applicant develop appropriate procedures to address water hammer concerns, the staff does not understand the need for requirements related to system design, since the system design is fully within the scope of the DCD. Therefore the staff issued RAI 256-8321, Question 09.02.02-07, requesting the applicant clarify why the COL information item includes the design related requirement.

In its response to RAI 256-8321, Question 09.02.02-07, dated March 21, 2016 (ML16081A183), the applicant indicated that the COL applicant was not responsible for the analysis of water hammer impacts and that the analysis of inadvertent water hammer events is the responsibility of the CCWS designer. As a result the applicant revised the COL information item and removed design related requirements to clarify that the scope of the COL applicant is limited to the operational and procedural aspects for the CCWS. The staff found the applicant's response acceptable since the revised COL information item will no longer differ to the DCD applicant system design that belongs to the DCD being certified. The staff has confirmed that in APR1400 DCD, Revision 1, the applicant has revise the COL information item as indicated in the RAI response. This item is considered resolved and the RAI closed.

Based on the staff's review, summarized above, of information in the DCD concerning the CCWS design, and the COL information items proposed to be included in the DCD, the staff concludes that the essential portions of the CCWS are protected against the effects of pipe breaks and internally and externally generated missiles, pipe whip and jet impingement due to high- and moderate-energy pipe breaks, and water hammer, and therefore meets the requirements of GDC 4.

9.2.2.4.4 GDC 5, Sharing of structures, systems, and components

The APR1400 is designed as a single facility, so the requirement of GDC 5 for sharing of systems between units is satisfied.

9.2.2.4.5 GDC 44, Cooling water

The staff reviewed the CCWS for compliance with the requirements of GDC 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. In order to ensure that the design is in compliance with GDC 44, the staff examined the CCWS system performance requirements and reviewed the CCWS equipment and system heat removal capability as described in the DCD. The staff also reviewed the CCWS design for redundancy of components, and the ability, under accident conditions, of the system to perform its safety function assuming a single active component failure, and the capability of the CCWS to isolate components, subsystems, or piping if required.

The CCWS consist of two divisions and its safety-related components are redundant and equally distributed on both divisions. One CCWS division is adequate to accomplish all safety-

related functions and mitigate consequences of an accident. Each division is connected to its corresponding ESWS division through the CCW heat exchangers. Heat is transferred from the hot CCW side to the cold ESW side of the CCW heat exchanger and dissipated by the ESWS to the UHS. The essential and nonessential heat loads for the CCWS are provided in Tables 9.2.2-3A and 9.2.2-3B of the DCD Tier 2.

To accomplish its safety function, the CCWS must be designed to remove heat loads associated with the various modes of plant operation. The heat loads to the CCWS for the various modes of operation are summarized below:

Normal Operation:	Division I – Heat load	128.73 MBtu/hr
	Division 2 – Heat load	128.73 MBtu/hr
Shutdown:	Division 2 – Heat load	273.83 MBtu/hr
	Division 2 – Heat load	255.00 MBtu/hr
Refueling:	Division I – Heat load	112.40 MBtu/hr
	Division 2 – Heat load	129.63 MBtu/hr
DBA - (SIAS)	Division I – Heat load	83.63 MBtu/hr
	Division 2 – Heat load	76.30 MBtu/hr
DBA - (CSAS)	Division I – Heat load	191.43 MBtu/hr
	Division 2 – Heat load	184.10 MBtu/hr
Safe Shutdown	Division I – Heat load	361.80 MBtu/hr
	Division 2 – Heat load	361.80 MBtu/hr

The CCWS is cooled by transferring heat to ESWS using six plate-type CCW heat exchangers (three per division). The design heat load for each of the heat exchangers is 64.4 MBtu/hr, as indicated in DCD Tier 2, Table 9.2.2-4, "Component Cooling Water System Component Design Parameters," and thus the total designed heat removal capacity for the CCWS is 386.4 MBtu/hr, based on a design flow of 11, 500 gpm per heat exchanger, at 200 °F design temperature and a 95 °F cooling water outlet temperature.

DCD Tier 2, Section 9.2.2.2.2.1 identifies the different CCW heat exchanger alignments based on the plant operational mode. When the plant is operating in the normal operation mode, one CCW pump and two heat exchangers per division are in use, providing a design heat removal capability of 128.8 MBtu/hr per division, which matches the normal operation divisional heat load. During normal shut down, four CCW pumps and all six heat exchangers from both divisions are used. The total heat removal capacity is then 386.4 MBtu/hr. The normal shutdown heat load is 273.8 MBtu/hr for Div I, and 255 Btu/hr for Div II, and is based on the heat load corresponding to 3.5 hours after shutdown, which is the time at which shutdown cooling is assumed to be initiated. Therefore the CCWS capacity is sufficient to handle the heat removal requirement for this mode of operation.

When the CCWS is operating in an emergency mode due to a LOOP or in response to an accident, the component cooling water flow to the nonessential headers is isolated. In this mode of operation the CCWS provides cooling using one CCW pump and two heat exchangers in a single division. With the information provided in the application, the staff was unable to verify that the heat exchanger was sized with adequate margin to remove the accident heat load specified for this system. Therefore the staff issued RAI 256-8321, Question 09.02-02-08, requesting that the applicant provide additional design information on the CCW heat exchanger, and include discussion on the available margin in the design.

In its response to RAI 256-8321, Question 09.02.02-08, dated April 22, 2016 (ML16113A452), the applicant stated that it performed a heat load evaluation for each operating heat exchanger based on the heat load requirements for the different modes of operation and concluded that the normal power operation should be the CCW heat exchanger sizing condition. The applicant also stated in its response that the design includes a minimum of 10 percent margin in consideration of uncertainties, component wear and aging effects and fouling of heat transfer surfaces, and that the use of plate-type heat exchangers for the CCWS allows for an addition of 20 percent increase in the plates.

The staff reviewed the applicant response and found it acceptable because at plant startup the CCWS will begin operation with a design capacity that includes significant heat rejection margin (10 percent) to offset expected fouling of CCWS heat exchanger surfaces. In addition, inspection, monitoring, and assessment activities will detect significant component degradation before safety margins are compromised, and the use of plate-type heat exchangers for the CCWS allows for an addition of 20 percent increase in the plates to offset reductions in heat removal capacity due to degradation over time.

The required cooling water flow that assures that sufficient heat transfer is provided by the heat exchangers and that the temperature of the CCW cooling water being supplied to the components being cooled by the CCWS does not exceed its design temperatures limits 95 °F during normal operation or 110 °F during normal shutdown or emergency mode operation is given in DCD Tier 2, Table 9.2.2-3A. “Typical Component Cooling Water System Heat Loads and Flow Requirements (International System Unit),” and Table 9.2.2-3B, “Typical Component Cooling Water System Heat Loads and Flow Requirements (British Unit).” During normal operation the CCWS flow is 20,070 gpm for Div. 1 operation, 28,670 gpm for shutdown operation, 17,770 gpm for refueling operation, 21,130 gpm for post-accident operation, and 22,360 gpm for safe shutdown operation. The CCW has 4 CCW pumps (2 per division), each with a design flowrate of 25,000 gallons per hour and a total dynamic head (TDH) of 285 ft. For the safe shutdown and post-LOCA operation, the system has sufficient pump capacity so that using one pump in a single division could provide the required flow. In normal operation, one pump per division will provide the required flow, and in normal shutdown, four pumps from both divisions are utilized.

One of the specific areas of review identified in Section I of SRP 9.2.2 is the system’s capability for adequate cooling of all RCP seals and bearings. The review also looks to see if controls to ensure that the component cooling water loop to the RCP seal does not automatically isolate and provisions for the control room operators to isolate the RCP seal coolant line by remote manual means are provided.

The staff reviewed the system to determine if the design and operation of the system is such that necessary cooling is provided to the RCP seals and bearings during normal plant operating

conditions, anticipated operational occurrences, and following postulated accidents. The review also looked to confirm that the system is instrumented with alarms in the control room to detect a loss of cooling water to ensure that the operator has a period of 20 minutes to initiate manual protection of the plant if necessary. In addition, the system design was also reviewed to confirm that there are design provisions for isolation of the CCWS supply and return lines to the RCPs by remote means, and that provisions are made for the control room operators to have the necessary information to determine when it is appropriate to isolate the lines by remote means and how soon the lines should be isolated if they become a release path from containment during a LOCA.

The CCW headers supplying the RCPs are isolated by a low-low surge tank level signal. In DCD Tier 2, Section 9.2.2.2.2.4, "Piping, Valves, and Fittings," the applicant identifies the RCP cooler isolation valves as CC-231, 249, 250, and 1099, and states that they provide for the ability to isolate the CCW flow to and from the RCP, and automatically close on a low-low surge tank level signal. It also indicates that the valves can be manually opened or closed from the MCR.

The staff reviewed information on the design and operation of the CCWS to verify that the essential CCWS portions are identified correctly and can be isolated from non-essential portions, and that the system is designed to provide adequate cooling to the RCP seals and bearing during normal plant operating conditions, anticipated operational occurrences and following postulated accidents. In DCD Tier 2, Figure 9.2.2-1, the RCP coolers are included as nonessential division I components. The loss of RCP seal cooling could result in RCP seal failure and excessive leakage of reactor coolant. For the APR1400 the normal provider of coolant to the RCP coolers is the CCWS, with chemical and volume control system (CVCS) injection providing a redundant means of RCP seal cooling from a source independent of the CCWS. It is also indicated in the DCD that RCP seal integrity during a SBO is maintained by the auxiliary charging pump of the CVCS, powered from an alternate AC (AAC) power source. However, as indicated in SRP 9.2.2 Section I, Items 7 and 12, the staff reviews the design to see that the CCWS is capable of adequately cooling all RCP seals and that the component cooling water loop to the RCP seal does not automatically isolate and that there are provisions for the control room operators to isolate the RCP seal coolant line by remote manual means.

In DCD Tier 2, Section 9.2.2.3, "Safety Evaluation," it is indicated that the CCW supply to the RCP coolers is isolated on a low-low surge tank level signal, and that the isolation signal can be overridden by manual operation from the MCR to protect the RCP seal. The staff finds that the applicant did not provide justification for the automatic isolation of CCW supply to the RCP seals, therefore the staff issued RAI 256-8321, Question 09.02.02-04, requesting that the applicant discuss how they adhere to the guidance in SRP 9.2.2, Section IV.4, concerning not having the RCP cooling loop automatically isolated during an accident.

In its response to RAI 256-8321, Question 09.02.02-04, dated June 17, 2016 (ML16169A063), the applicant indicated that even though the RCP coolers isolation valves are automatically closed on a low-low surge tank level signal, the isolation valves can be overridden in the MCR and, therefore, adequate cooling of RCP coolers is possible with the operator's prompt action within 30 minutes. The applicant also stated that the RCP can be operated for at least 30 minutes without bearing seizure, which could affect normal RCP coastdown, if seal injection water is available to the seals, as described in DCD Subsections 5.4.1.2, "Description," and 5.4.1.3, "Evaluation."

The staff has reviewed the applicant's RAI response and found that although the APR1400 CCWS design does not adhere to SRP 9.2.2 subsection III.4.F in regards to the isolation of RCP seal cooling by remote means only, the alternate approached employed by the APR1400 does provide an acceptable method of assuring cooling of the RCP seals. The staff's review of the RCP seals is discussed in Section 5.4, "Reactor Coolant System Component and Subsystem Design," of this report.

In meeting GDC 44, the SRP also looks to see that the system can withstand a loss of power without damage to the RCP seals, and that the RCP seal coolant lines do not isolate automatically.

The staff reviewed the CCWS flow diagram provided in the DCD Tier 1, Figure 8-4, "Component Cooling Water System," and Tier 2, Figure 9.2.2-1, and found that the RCP is inside containment and is supplied cooling water by the quadrant A supply header. In DCD Tier 2, Section 9.2.2.3, Item I states that the RCP coolers are isolated on a low-low surge tank level signal. It also states that the isolation signal can be overridden by manual operation from the MCR to protect the RCP seal, and that RCP seal integrity during a station blackout (SBO) is maintained by the auxiliary charging pump of the CVCS powered by an AAC power source.

The CCWS design provides a single supply and return line from the CCWS to all four RCPs. The RCP seals, the motors, seals, and bearings of the RCPS generally require continuous cooling. DCD Section 5.4.1 states that the RCP shaft seals are cooled by (1) seal injection water from the CVCS, and (2) the component cooling water system through a high pressure seal cooler. It also states that pump seal operation may continue indefinitely provided either seal injection water or CCW is available.

Based on its review of the CCWS cooling of the RCP support systems, the staff found that the RCP cooling loop of the CCWS is not isolated on a safety injection signal (SAIS) and therefore, the CCWS will continue to provide cooling to the RCS coolers following a small-break LOCA with an LOOP in accordance with the requirements of 10 CFR 50.34(f)(1)(iii). As indicated in DCD Section 9.2.2.5 RCP cooler outlet temperature and flow rate is displayed in the MCR, and alarms are provided to alert operators of low and high outlet header flows.

On the basis of the above discussion, the staff finds that the CCWS meets the requirements of GDC 44, with respect to transferring heat from the reactor system SSCs important to safety to a heat sink under both normal operating and accident conditions. There will be adequate cooling to RCP bearings during normal operations, anticipated operational occurrences, and postulated accidents. Furthermore, there are adequate instruments and alarms in the control room to ensure that operators can make timely decisions and to isolate the system if necessary.

9.2.2.4.6 GDC 45, Inspection of cooling water system

The staff reviewed the CCWS for compliance with the requirements of GDC 45 regarding provisions to permit appropriate inservice inspection of safety-related components and equipment.

DCD Tier 2, Section 9.2.2.1, "Safety Design Bases," states that the CCWS is designed in accordance with the requirements of GDC 45. In addition, in Section 9.2.2.1.1 it is stated, in the Safety Design Basis, that CCWS components are capable of being fully tested during normal plant operation and CCWS parts and components are accessible for inspection. DCD Tier 2,

Section 9.2.2.4, "Inspection and Testing Requirements," states that the CCWS is designed and installed to permit inservice inspections and tests in accordance with the appropriate ASME Section XI and ASME OM Code. Based on the above, the staff has determined that the inspection of CCWS conforms to GDC 45.

9.2.2.4.7 GDC 46, Testing of cooling water system

The staff reviewed the CCWS for compliance with the requirements of GDC 46 regarding provisions to permit appropriate functional testing of the system and components. DCD Tier 2, Section 9.2.2.1 states that the CCWS is designed in accordance with the requirements of GDC 46. In addition, in Section 9.2.2.1.1 it is stated, in the Safety Design Basis, that CCWS components are capable of being fully tested during normal plant operation and the system's parts and components are accessible for inspection, and that the system is designed for periodic inservice testing and inspection.

The staff reviewed the CCWS DCD Tier 2 Section and found that the CCW pumps and the appropriate system valves were included in the plant In-service Testing (IST) program (Table 3.9-13, "Inservice Testing of Safety-Related Pumps and Valves") as described in DCD Tier 2, Section 3.9.6, "Functional Design Qualification, and In-service Testing Programs for Pumps, Valves, and Dynamic Restraints." Based on the above, the staff has determined that the inspection of CCWS conforms to GDC 46.

9.2.2.4.8 Compliance with 10 CFR 20.1406

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 CCWS reduces the possibility of radioactive leakage to the environment by providing an intermediate barrier between radioactive or potentially radioactive systems and the ESWS. The CCWS which uses demineralized water to cool various plant components during normal operation, shutdown, emergency, and accident conditions can become radioactively contaminated as a result of heat exchanger leakage.

In DCD Tier 2, Section 19.2.2.2.5, "Design Features for Minimization of Contamination," the applicant states that the CCWS is designed with features that meet the requirements of 10 CFR 20.1406 using the guidance in RG 4.21. It also states that the CCWS is designed to facilitate early leak detection and allow for prompt assessment and response to manage collected fluids. Thus unintended contamination to the facility and the environment is minimized and/or prevented by the SSSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Primary features of the design to facilitate minimization of contamination include locating the CCWS heat exchangers in a separate structure close to the ESW building to minimize radiation exposure to the ESW piping, the designing of utility connections with a minimum of two barriers to prevent contamination of clean systems, and minimizing the use of embedded or buried piping. Piping between buildings is equipped with piping sleeves or tunnels, as applicable, with leak detection features. Piping to the component cooling water heat exchanger structures is routed through a seismic Category I reinforced concrete pipe tunnels (one per division) under the yard. The tunnel is coated with epoxy and is designed with a collection sump with a level switch to initiate an alarm signal in the MCR for operator actions in the event liquid is detected.

This design approach thus minimizes unintended contamination of the facility and the environment.

The cubicles housing the CCWS SSCs are designed with sloped floors, epoxy coating to provide drainage and cleanable surfaces, and local sumps to collect leakages and overflows. Cubicle curbs are also provided to reduce cross-contamination and the spread of contamination to other areas. CCWS heat exchangers are located in a separate structure that is close to the ESW building in order to minimize radiation exposure to the ESW piping.

While the applicant has provided the information on leak detection and the collection of leaked fluids, information on the measures taken to minimized contamination during transport of collected fluids from the sumps to the location for treatment or storage is not addressed. Therefore, the staff issued RAI 256-8321, Question 09.02.02-09, requesting the applicant to specify where sumps contents are routed for treatment, and discuss measures taken to prevent contamination during that routing.

In the response to RAI 256-8321, Question 09.02.02-09, dated March 25, 2016 (ML16085A353), the applicant stated that the transfer of the sumps content to where it is ultimately treated and/or stored is performed by the equipment and floor drain system and that the measures taken to prevent potential contamination due to the potential for system leakage during the transfer of the sumps content are discussed in DCD Tier 2, Subsection 9.3.3, "Equipment and Floor Drainage System." The applicant also included a markup of DCD Section 9.3.3.2.2 adding the statement that "the CCW heat exchanger building drains are monitored for radiation contamination by radiation monitors."

The staff's reviewed the applicant's response and found that it adequately addressed the staff's concern because details on how the handling of fluids collected in the local sumps was provided. The staff's review of the Equipment and Floor Drainage System is included in Section 9.3.3, "Equipment and Floor Drainage System," of this report.

The CCWS is designed for automated operation with manual initiation for the different modes of operation. Protection against cross-contamination is achieved through design and operation. The CCWS surge tanks are located at a high elevation to maintain liquid pressure in order to prevent infiltration and cross-contamination of the CCWS, which helps to prevent unintended contamination of the environment because any leaks from the tanks are drained to the local sumps for collection and forwarded to the liquid waste management system (LWMS) for treatment and disposal.

In addition to design features, the minimization of contamination is achieved through the use of appropriate operational procedures and maintenance programs. The programs are to be developed by the COL applicant, and COL 9.2(14) requires the COL applicant provide operational procedures and maintenance programs as related to leak detection and contamination control in the CCWS. It also requires the procedures and maintenance programs to be completed before fuel is loaded for commissioning.

Based on the above discussion, the staff concludes that the CCWS, as described in the DCD, complies with 10 CFR 20.1406 since it provides monitoring an leakage detection, collection and control of potential contamination, and since it provides accessibility for inspection and maintenance so the leaks can be readily identified and corrective action taken.

9.2.2.4.9 Initial Test Program

Applicants for standard plant design approval must provide plans for preoperational testing and initial operations in accordance with 10 CFR 50.34(b)(6)(iii) requirements. Preoperational test requirements for CCWS are listed in DCD Tier 2 Section 14.2.12.1.76, "Component Cooling Water System Test."

The initial test program for APR1400 is evaluated in Section 14.2 of this report, and evaluation of the CCWS initial test program in this section is an extension of the evaluation provided in Section 14.2 of this report.

9.2.2.4.10 ITAAC

DCD Tier 1, Section 2.7.2.2, "Component Cooling Water System," provides APR1400 design certification information and ITAAC for the CCWS. DCD Tier 1 information for plant system SSCs is evaluated in Section 14.3.7, "Plant Systems ITAAC," of this report. The evaluation of DCD Tier 1 information in this section is an extension of the evaluation provided in Section 14.3.7.

The staff reviewed the descriptive information, safety-related functions, arrangement, mechanical, I&C and electric power design features, environmental qualification, as well as system and equipment performance requirements provided in DCD Tier 1, Section 2.7.2.2-1, to confirm completeness and consistency with the plant design basis as described in DCD Tier 2, Section 9.2.2.

Important acceptance criteria related to the CCWS include functional arrangements, physical separation, ASME Code Data reports, ASME welding, ASME pressure testing, seismic classifications, equipment qualification for harsh environment, 1E power, electrical separation, CCWSHX performance, surge tank sizing, CCWS pump flow, CCWS NPSH, CCWS component flow rates, valve testing, system alarms, controls and displays. The staff finds that all the necessary CCWS equipment has been adequately identified in the applicable tables. The staff concludes that, if the ITAAC for CCWS are performed and the acceptance criteria met, there is reasonable assurance that the design is built and will operate in accordance with the DC, the provisions of the AEA, and NRC regulations which include 10 CFR 52.47(b)(1).

9.2.2.4.11 Technical Specifications

DCD Tier 2 Chapter 16, TS 3.7.7, "Component Cooling Water (CCW) System," provides LCOs and SR for the CCWS. TS 3.7.7 requires two CCW divisions to be operable in Modes 1, 2, 3 and 4. There is a 72 hour LCO entry if one CCW division is inoperable.

Chapter 16 of this SE also addresses the staff's evaluation of the CCWS to assure that the proposed LCOs and associated Bases adequately address and reflect system-specific design considerations as described in Section 9.2.2.

9.2.2.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(12)	The COL applicant is to develop procedures for water system filling, venting, keeping the system full, and operation to minimize the potential for water hammer; in accordance with NUREG-0927 in the CCWS.	9.2.2.2.2.4
9.2(13)	The COL applicant is to evaluate the effects of exposure to subfreezing environments for the CCWS piping and SSCs located outside of plant buildings, and, if required, to provide measures to protect from the subfreezing effects.	9.2.2.2.2.4
9.2(14)	The COL applicant is to provide operational and maintenance programs as related to leak detection and contamination control in the CCWS.	9.2.2.2.5
9.2(15)	The COL applicant is to maintain complete documentation of the system design, construction, design modifications, field changes, and operations.	9.2.2.2.5
9.2(16)	The COL applicant is to include a site-wide radiological environmental monitoring program to monitor environmental contamination in the CCWS.	9.2.2.2.5

9.2.2.6 Conclusion

The staff finds the APR1400 component cooling water system design acceptable because, for the reasons discussed in the evaluation above, it meets applicable regulatory requirements; GDC 2 regarding protection from natural phenomena; GDC 4, regarding protection against missiles and effects of pipe breaks; GDC 5, regarding shared systems; GDC 44, regarding transferring heat to the UHS; GDC 45, regarding inspections; GDC 46, regarding periodic testing: 10 CFR 20.1406, regarding minimizing contamination; and 10 CFR 52.47(b)(1) regarding including necessary and sufficient ITAAC. In addition, the applicant included

appropriate COL information items to ensure that a future COL applicant will address programmatic and site specific information.

9.2.3 [Reserved]

9.2.4 Domestic Water and Sanitary Systems

9.2.4.1 Introduction

The domestic water and sanitary drainage systems provide clean and potable water for domestic use and human consumption, and collects and transfers site sanitary waste water to a sanitary water treatment facility for treatment and discharge during normal operation.

9.2.4.2 Summary of Application

DCD Tier 1: There are no entries in DCD Tier 1 Section 2.7.5.3 of Tier 1 associated with the domestic water and sanitary systems.

DCD Tier 2: In DCD Tier 2, Sections 1.2.12.13, "Domestic Water and Sanitary System," and 9.2.4, "Domestic Water and Sanitary Systems," the applicant provides information on the domestic water and sanitary drainage systems, indicating that these systems serve no safety function and that any malfunction of the systems will not adversely affect any safety-related system. The applicant also identifies, as part of the design basis in DCD Tier 2, Section 9.2.4.1, "Design Basis," that (a) per the requirements of GDC 60, there will be no interconnections between the domestic water and sanitary systems and the systems with the potential to contain radioactive material, and (b) the domestic water system is to be protected by air gaps, when necessary.

The domestic water and sanitary systems are generally site-specific and, for the APR1400, the applicant has provided in DCD Tier 2, Section 9.2.4, a representative conceptual design for these two systems. As conceptual design information (CDI), the application does not seek certification of this information. However, the staff found information, identified as conceptual design, which is essential to the standard design and, as such, subject to the certification review. In RAI 265-8327 (ML15295A256), Question 09.02.04-01, the staff requested the applicant to clearly identify: the portions of the domestic and sanitary systems design that are within the scope of the DCD, the portions that are to be treated as conceptual design, and the necessary interface requirements.

In its response to Question 09.02.04-01, dated December 16, 2015 (ML15350A362), the applicant stated that the design configuration of the domestic and sanitary systems is CDI but the design features that prevent the potential contamination from radioactive sources are not CDI. The application includes a statement that there will be no cross connections between the domestic water system and any potentially radioactive systems, and that for portions of the system located in areas which access is restricted due to a potential radiological hazard, backflow prevention devices would be used.

The Domestic Water and Sanitary Systems flow diagram is provided in DCD Tier 2, Figure 9.2.4-1, "Domestic Water and Sanitary Systems Flow Diagram." Major component data are provided in DCD Tier 2, Table 9.2.4-1, "Domestic Water and Sanitary Water Systems Component Data"; however this has been classified by the applicant as CDI.

ITAAC: The Domestic Water and Sanitary Systems do not have associated ITAAC.

Technical Specifications: There are no TSs for this area of review.

9.2.4.3 Regulatory Basis

The relevant requirements of the Commission's regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, SRP Section 9.2.4, "Potable and Sanitary Water Systems," and are summarized below. There are no review interfaces identified for this Section.

1. GDC 60, "Control of Release of Radioactive Materials to the Environment," as it relates to design provisions provided to control the release of liquid effluents containing radioactive material from contaminating the Domestic Water and Sanitary Systems.

2. CFR 52.47(a)(24), which requires the inclusion of a representative conceptual design for those portions of the plant that are not included within the scope of the certified design.

3. 10 CFR 52.47(a)(25), which requires the identification of interface requirements that must be met by those portions of the plant that are not included within the scope of the certified design.

4. 10 CFR 52.47(b)(1), which requires that a design certification application include 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, the facility has been constructed and will operate in conformity with the COL, the provisions of the AEA, and the NRC's regulations.

9.2.4.4 Technical Evaluation

The staff reviewed the APR1400, "Domestic Water and Sanitary Systems," as described in the APR1400 Design Control Document (DCD). The review, which was performed in accordance with SRP Section 9.2.4, "Potable and Sanitary Water Systems," Revision 3, March 2007, was based on the Tier 1 and Tier 2 information contained in Revision 1 of the APR1400 DCD. The results and conclusions of the staff's review of the Domestic Water and Sanitary Systems are discussed below.

9.2.4.4.1 Adherence to 10 CFR 52.47(a)(24) and 10 CFR 52.47(a)(25)

10 CFR 52.47(a)(24) requires the inclusion of a representative conceptual design for portions of the plant that are not included in the certified design, and10 CFR 52.47(a)(25) requires the identification of interface requirements that must be met by those portions of the plant that are not included within the scope of the certified design.

As indicated in SER Section 9.2.4.2 above, the Domestic Water and Sanitary Systems are site-specific systems and the applicant has provide a representative conceptual design as part of the DCD application. As such, the information included in the DCD does not require the staff's approval; however, the information is used by the staff to assess the adequacy of the interface requirements, as required by 10 CFR 52.47(a)(25).

While the staff found it reasonable for much of the information in DCD Tier 2, Section 9.2.4, to be designated as conceptual design, the staff found that information pertaining to provisions to protect these systems against contamination and to conform to the requirements of GDC 60 should be addressed by the DCD, and not just treated as conceptual design. Therefore, the staff requested in RAI 265-8327, Question 09.02.04-01 that the applicant clearly identify in the DCD which portion of the systems are within the scope of the DCD and which portions are conceptual design, and for those which are conceptual design to identify the applicable interface requirements.

In its response to RAI 265-8327, Question 09.02.04-1, dated December 16, 2015 (ML15350A362), the applicant indicated that the design and configuration of the domestic water and sanitary systems is conceptual design information. However, design features that ensure that the systems do not become contaminated by other interfacing systems such as not having interconnections between the domestic water system and other systems that might potential contain radioactive material, the use of backflow prevention devices or air gaps when necessary, are not conceptual design and are in the scope of the DCD. The applicant also provided a markup of DCD Subsections 9.2.4.1 and 9.2.4.2.1, "Domestic Water System," that removes the conceptual design designation for system design features used to prevent interfacing systems from contaminating the Domestic Water and Sanitary Systems.

The staff reviewed the applicant's response and determined it to be acceptable since it clearly identified the portions of the Domestic Water and Sanitary Systems that were in the scope of the DCD, and those that were conceptual design. Also the staff found that the applicant's response identified appropriate interface requirements and included them in the DCD with an appropriate COL information item. The RAI is therefore closed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD, therefore, the staff considers RAI 265-8327, Question 9.02.04-01, closed.

9.2.4.4.2 GDC 60, Control of releases of radioactive materials to the environment

The staff reviewed the design of the domestic water and sanitary systems in accordance with guidance provided in NUREG-0800, Section 9.2.4. Information that addresses the requirements of GDC 60 in regard to controlling radioactive effluent releases is considered acceptable if the following are met:

- There are no interconnections between the domestic water and sanitary systems and systems having the potential containing radioactive material
- The domestic water and sanitary systems are protected by an air gap, where necessary.
- An evaluation of potential radiological contamination, including accidental, and safety implications of sharing (for multi-unit facilities) indicates that the system will not result in contamination beyond acceptable limits.

In DCD Tier 2, Section 9.2.4.1, "Design Bases," Item (a), the applicant indicates that "per the requirements of GDC 60, there are no interconnections between the domestic water and sanitary systems and the systems with the potential to contain radioactive materials," and in Item (b) the applicant states that the domestic water system is protected by an air gap when necessary. In terms of design provisions aimed at preventing the contamination of the domestic water system, DCD Tier 2, Section 9.2.4.2, states that no cross connections exist between the

domestic water system and any potentially radioactive systems, and that all branches of the system plumbing fixtures which are located in areas where access is restricted due to a potential radiological hazard are provided with backflow prevention devices. Hence the interface requirements that are to be met by the COL applicant in its site-specific design of the domestic and sanitary water system, to ensure compliance with GDC 60, are established in the DCD, as required by 10 CFR 52.47(a)(25).

In addition to the interface requirements pertaining to compliance with GDC 60, the applicant also provided the necessary interface requirements to ensure that the system is adequately sized to provide the required performance. COL 9.2(14), 9.2(15), and 9.2(16) requires the COL applicant to identify the source of domestic water and any necessary treatment, confirm the sizing of domestic water tank and associated pumps if used, and confirm whether the sanitary waste is sent to an onsite treatment facility or the city sewage system. DCD Tier 2, Table 9.2.4-1 contains information on design parameters for domestic water and sanitary systems components, and DCD Tier 2, Figure 9.2.4-1 shows the conceptual flow diagram for the domestic water and sanitary systems. The staff noted that the COL information items referred to above were renumbered in Revision 1 of the DCD, and are now listed as COL 9.2(18), 9.2(19), and 9.2(20).

The staff reviewed DCD Tier 2, Figure 9.2.4-1 to verify that the system would not become contaminated due to interfaces with potential radioactive system. The staff also verified that that the design will incorporate backflow protection as discussed in DCD Tier 2, Section 9.2.4. The staff found that the COL information items included in this Section of the DCD will ensure that the domestic water and sanitary systems complies with all state and local departments of health and environmental protection standards, and that the DCD has sufficient interface requirements to ensure that plant-specific designs for these systems will comply with the requirements of GDC 60.

9.2.4.4.3 Initial Plant Test Program

There are no tests in DCD Tier 2, Section 14.2 that relate to the domestic water and sanitary systems, although in DCD Tier 2, Section 9.2.4.4, "Inspection and Testing Requirements," the applicant's conceptual design proposed hydrostatic test of the system. The staff finds hydrostatic test to be an acceptable means to verify the system will perform as described in DCD Tier 2, Section 9.2.4.

9.2.4.4.4 ITAAC

There is no ITAAC for the domestic water and sanitary systems shown in Tier 1. The staff agrees that no ITAAC is required for the Domestic Water and Sanitary Systems under 10 CFR 52.47(b)(1).

9.2.4.4.5 Technical Specifications

There are no TS requirements associated with the domestic water and sanitary systems. The staff finds this acceptable because the Domestic Water and Sanitary Systems were not addressed by the standard TS.

9.2.4.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(17)	The COL applicant is to determine all state and local department of health and environmental protection standards to be applied and followed for the domestic water system.	9.2.4
9.2(18)	The COL applicant is to determine the source of domestic water to the site and the necessary required treatment plant.	9.2.4
9.2(19)	The COL applicant is to confirm the sizing of domestic water tanks and associated pumps, if used.	9.2.4
9.2(20)	The COL applicant is to confirm whether the sanitary waste is sent to an onsite treatment facility or the city sewage system.	9.2.4

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for this system.

9.2.4.6 Conclusion

Since the design of domestic water and sanitary systems are generally site specific, the applicant has provided in DCD Tier 2, Section 9.2.4, a representative conceptual design for the domestic water and sanitary systems. Based on the above, the staff has determined that the standard design criteria and guidance as described in the DCD are consistent with SRP Section 9.2.4 and that sufficient interface requirement and COL information items are described in the DCD. According to 10 CFR 52.47(c)(1), the staff will verify the conformance to the criteria of GDC 60 and the guidance of SRP Section 9.2.4 for site-specific COL applications. In addition the applicant included appropriate COL information items to ensure that a future COL applicant will address programmatic and site-specific information.

9.2.5 Ultimate Heat Sink

9.2.5.1 Introduction

The function of the UHS is to dissipate the heat rejected from the ESWS during all modes of operation, including accident conditions. The UHS is not part of the standard plant design and, for this reason, the details of the design provided as part of this DCD application are considered CDI that will be reviewed by the staff for the COL applications. However, the UHS standard plant design does identify some non-CDI requirements that all applicants referencing this design shall incorporate or provide an appropriate departure for the staff to review. In addition, the UHS standard plant design outlines COL information items and interface requirements for COL applicants.

9.2.5.2 Summary of Application

DCD Tier 2: DCD Tier 2, Section 9.2.5, “Ultimate Heat Sink,” provides information on the UHS. Tier 2 Figure 9.2.5-1, “Ultimate Heat Sink (Cooling Tower) Flow Diagram,” shows a conceptual design of the cooling tower. Tier 2 Tables 9.2.5-1 through 9.2.5-4 provide UHS heat loads, design parameters, and failure modes and effects analysis.

DCD Tier 1 and ITAAC: DCD Tier 1, Section 3.2, “Ultimate Heat Sink,” describes the interface requirements for COL applicants. There are no function arrangement figures or tables since the UHS is CDI. In addition, there are no ITAACs for the UHS in the DCD. COL applicants must meet these interface requirements using a detailed design and must also generate site-specific ITAAC for each interface requirement. These site-specific ITAAC will be in addition to any other ITAAC already committed to by the DCD applicant.

Technical Specifications: DCD Tier 2, Chapter 16, Section 3.7.9, “Ultimate Heat Sink (UHS),” provides plant TSs for the UHS.

APR1400 Plant Interfaces: DCD Tier 1, Section 3.2, “Ultimate Heat Sink,” describes the interface requirements for COL applicants. Tier 2 Section 9.2.10, “Combined License Information,” identifies UHS COL information items.

9.2.5.3 Regulatory Basis

The relevant requirements of the Commission Regulations for this area of review, and the associated acceptance criteria ,are given in SRP Section 9.2.5, “Ultimate Heat Sink,” of NUREG-0800, Revision 4 – March 2007. Review interfaces with other SRP sections can be found in Section 9.2.5 of NUREG-0800. However, since UHS is not part of the standard plant design, these regulatory bases and associated general design criteria (GDC) will be evaluated when site-specific applications are reviewed. The remaining requirements for portions of the DCD that are not part of the standard plant design are as follows:

1. 10 CFR 52.47(a) (24), which requires that a design certification application (DCA) contain a representative conceptual design for those portions of the plant for which the application does not seek certification, to aid the NRC in its review of the DCD and to permit assessment of the adequacy of the interface requirements in 10 CFR 52.47(a)(25).

2. 10 CFR 52.47(a) (25), which requires that a design DCA contain interface requirements to be met by those portions of the plant for which the application does not seek certification. These requirements must be sufficiently detailed to allow completion of the DCD.

3. 10 CFR 20.1406, "Minimization of Contamination," as it relates to the standard plant design certifications and how the design and procedures for operation will minimize contamination of the facility and the environment facilitate eventual decommissioning and minimize to the extent practicable, the generation of radioactive waste.

9.2.5.4 Technical Evaluation

DCD Tier 2, Section 9.2.5 describes the design of the UHS including both the standard plant design and conceptual design. DCD Tier 2, Section 16.1.2.4, "Combined License Information," states that double brackets [[X]] indicate the conceptual design information for those portions of the plant for which the application does not seek certification. The conceptual design portions of the UHS are to be addressed in the COL application, and will be reviewed for COL applications. The following is an evaluation of the standard plant design information not inside brackets and COL information items.

9.2.5.4.1 System Functional Design

SRP Section 9.2.5 states that availability of adequate heat sinks for the UHS dissipating decay heat and essential heat loads is a requirement for nuclear power plants. There are various methods for satisfying the requirement (e.g., a large body of water like an ocean, lake, natural or manmade reservoir, a river, spray ponds, and cooling towers, or such combinations). SRP Section 9.2.5 identifies the applicable regulatory requirements and guidance of GDC 2, 4, 5, 44, and 45. RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," describes methods and procedures acceptable to the staff that applicants can use to establish UHS features of plant systems required by NRC rules and regulations.

DCD Tier 2, Section 9.2.5 states that the function of the UHS is to dissipate the heat rejected from the ESWS during all modes of operation including accident conditions under the worst combination of adverse environmental conditions, including freezing. The ESWS is described in DCD Tier 2, Section 9.2.1. DCD Tier 2, Section 9.2.5 identifies a conceptual design for the UHS cooling towers as the heat sink, and provides the heat loads in DCD Tier 2, Table 9.2.5-1, "Ultimate Heat Sink Maximum Head Loads for All Modes of Operation," and Table 9.2.5-2, "Ultimate Heat Sink Head Loads for LOCA and Safe Shutdown with LOOP." The UHS is designed to provide suitable redundancy under loss of coolant accident (LOCA) and LOOP assuming a single active failure. ANSI/ANS 5.1, "Decay Heat Power in Light Water Reactors," American Nuclear Society, 1979, provides the referenced decay heat. The DCD states that the UHS is safety-related and meets the requirements of RG 1.27 to supply cooling capacity for at least 30 days without makeup water. The UHS is designed to provide maximum UHS water temperature of 33.2 °C (91.8 °F) to the ESWS.

DCD Tier 2, Section 9.2.5.1, "Design Bases," states the following to address the requirements in the guidance:

1. The UHS SSCs are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions (GDC 2). The UHS-related structures are

designed as seismic Category I based on site-specific and meteorological conditions following RG 1.29 and to have the capability to withstand the design loadings.

2. UHS SSCs are designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing and postulated accidents, including a LOCA. They are appropriately protected against dynamic effects, including the effects of external missiles, pipe whip, and discharging fluids, that may result from equipment failure and external events (GDC 4).

3. UHS SSCs are not shared with other nuclear power units because the UHS is designed for a single nuclear power unit (GDC 5).

4. The safety function of the UHS is to dissipate the maximum heat load during all modes of operation including that of a LOCA and LOOP under the worst combination of adverse environmental conditions, including freezing. The UHS maximum heat loads for all modes of operation including LOCA and safe shutdown with a LOOP are shown in Tables 9.2.5-1 and 9.2.5-2. The safety function of the UHS is also to supply cooling capacity for at least 30 days without makeup water, in accordance with RG 1.27. The UHS is designed to provide suitable redundancy under LOCA and LOOP assuming a single active failure. The UHS is designed to provide the capability to isolate components, systems, or piping so that safety functions are not compromised (GDC 44).

5. The UHS is designed to permit appropriate periodic inspection of important components to provide reasonable assurance of the integrity and capability of the system (GDC 45).

6. The UHS is designed to permit appropriate periodic pressure and functional testing to provide reasonable assurance of (1) the structural and leaktight integrity of its components, (2) the operability, and (3) the performance of the active components, the operability of the system, and the performance of the full operational sequence that brings the system into operation for reactor shutdown and for LOCAs, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources (GDC 46).

The staff finds that the above standard plant design criteria are consistent with the guidance in SRP Section 9.2.5. However, large portions of DCD Tier 2, Section 9.2.5 are CDI. The CDI contains a representative conceptual design for those portions of the plant for which the standard plant design application does not seek certification. The staff will review the site-specific UHS with respect to the conformance to above criteria of GDC 2, 4, 5, 44, 45, 46, and guidance of RG 1.27 for COL applications. In addition, the applicant identified COL information items in DCD Tier 2, Sections 9.2.5.2, 9.2.5.3, 9.2.5.4, 9.2.5.5, which are described in SER Section 9.2.5.5 below. The staff will review the conformance of the information provided to address the COL information items against the criteria discussed above in site-specific COL applications.

9.2.5.4.2 UHS Cooling Towers

DCD Tier 2, Section 9.2.5.2.2.1, "[[UHS Cooling Towers]]" describes UHS cooling towers in CDI. In addition, the applicant identified the COL information items in DCD Tier 2, Section 9.2.5.2.2.1, and described in SER Section 9.2.5.5) below.

10 CFR 52.47(a)(24), which requires that a DCD contain a representative conceptual design for those portions of the plant for which the application does not seek certification, to aid the NRC in its review of the DCD and to permit assessment of the adequacy of the interface requirements in 10 CFR 52.47(a)(25). The staff finds the CDI approach for UHS cooling towers is in accordance with 10 CFR 52.47(a)(24) and (a)(25) because it provides sufficient information for the staff to conduct its safety review for those parts of the design for which certification is requested.

In accordance with 10 CFR 52.47(c)(1), the staff will review the site-specific UHS for COL applications, but will not review the adequacy of the UHS cooling towers, at this time, based on the CDI described in the standard plant design.

9.2.5.4.3 10 CFR 20.1406

10 CFR 20.1406 requires, in part, that applicants for standard plant design certifications 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.

DCD Tier 2, Section 9.2.5.1 states that the cooling water for the UHS does not contain radioactive materials nor release radioactive contaminants to the environment. Radiation monitors are provided in each ESW division. This is described in DCD Tier 2, Section 9.2.1.2.1, "General Description." The path for radioactive fluid to reach the UHS must pass through two barriers – the CCWS and ESWS. Minimization of contamination is described in DCD Tier 2, Section 9.2.1.2.4, for the ESWS and DCD Tier 2, Section 9.2.2.2.5, for the CCWS and evaluated in SER Sections 9.2.1 and 9.2.2.

9.2.5.4.4 Initial Test Program

Applicants for standard plant design approval must provide plans for preoperational testing and initial operations in accordance with 10 CFR 50.34(b)(6)(iii), requirements. The UHS supports the ESWS to provide the capability to reject heat under normal and accident conditions (safe shutdown or post-accident). Therefore, the UHS is tested as part of the ESWS preoperational test described in Subsection 14.2.12.1.75, "Essential Service Water System Test." As indicated in Subsection 14.2.13, "Combined License Information," the COL applicant is responsible for testing outside the scope of the certified design. Section 14.2 of this report addresses the staff's evaluation of the initial test program for APR1400.

The staff reviewed the information provided and finds that the applicant has adequately addressed the UHS with respect to 10 CFR 20.1406.

9.2.5.4.5 ITAAC

DCD Tier 1, Table 2.7.2.2-4 specifies an ITAAC to confirm the CCWS, in conjunction with the ESWS and UHS, has the capacity to dissipate the required heat loads. DCD Tier 1,

Figure 2.7.2.1-1 shows the UHS interfacing with the ESWS and CCWS. There are no ITAAC for the UHS in the DCD as the design is mostly CDI.

DCD Tier 1, Section 3.2, "Ultimate Heat Sink," describes the interface requirements for COL applicants. COL applicants must meet these interface requirements using a detailed design and must also develop site-specific ITAAC for the interface requirements. The interface requirements are as follows:

1. The UHS provides the capability to reject heat under normal and accident conditions (safe shutdown or post-accident) assuming a single active failure concurrent with a loss of offsite power.

2. The UHS provides cooling capacity for at least 30 days without makeup water under the worst case meteorological conditions, in accordance with RG 1.27.

3. The UHS provides the maximum supply temperature of 33.2 °C (91.8 °F) to the ESWS.

4. The UHS design provides isolation between the UHS and the nonsafety-related system.

5. The UHS provides the means to ensure adequate NPSH to the ESW pumps under all operation modes, if applicable to the site-specific design.

6. The UHS provides the means to prevent long-term fouling and mitigate short-term clogging anticipated at the site that may degrade system performance.

7. The UHS is designed to prevent water hammer if applicable to the site-specific design.

8. The UHS is designed to consider the evaluation of maximum evaporation and other losses, if applicable to the site-specific design.

9. The components and piping including supports of the UHS are fabricated, installed, and inspected in accordance with ASME Section III requirements, if applicable to the site-specific design.

10. Pressure boundary welds in ASME Code components and piping of UHS meet ASME Section III requirements, if applicable to the site-specific design.

11. The ASME Code components and piping of UHS maintain their pressure boundary integrity as its design pressure, if applicable to the site-specific design.

12. The seismic Category I structure, components, piping including supports, and instruments of the UHS can withstand seismic design basis loads without loss of safety function, if applicable to the site-specific design.

13. The Class 1E components and instruments can withstand the harsh environmental conditions during design basis accident without loss of safety function, if applicable to the site-specific design.

14. Each of Class 1E components and instruments is powered from its respective Class 1E division, and separation is provided between Class 1E divisions, and between Class 1E division and non-Class 1E division, if applicable to the site-specific design.

15. Alarms and indications for the UHS water temperature and level are provided in the MCR and RSR.

16. Controls required for the safety-related functions of the UHS are provided in the MCR and RSR, if applicable to the site-specific design.

The staff finds that all the necessary UHS interface requirements have been identified using the CDI provided in the DCD, and these interface requirements can be developed for site-specific ITAACs for the UHS. Thus, the staff finds that the requirements of 10 CFR 52.47(a)(24) and (25) are met.

9.2.5.4.6 Technical Specifications

DCD Tier 2, Chapter 16, Section 3.7.9, "Ultimate Heat Sink (UHS)," provides limiting conditions of operations (LCOs) and surveillance requirements (SR) for the UHS. Since the UHS is mostly CDI, all site-specific UHS TSs will be evaluated based on COL applications.

9.2.5.5 Combined License Information Items

The following is a list of applicable COL Information items.

Combined License Information Items

Item No.	Description	Tier 2 DCD Section
9.2(1)	The COL applicant is to provide the UHS-related systems such as blowdown, chemical injection, and makeup water system.	9.2.1.2.1, 9.2.5.2, 9.2.10
9.2(21)	The COL applicant is to provide the UHS-related design information based on the site characteristics, including meteorological conditions.	9.2.5.1, 9.2.10
9.2(22)	The COL applicant is to provide the location and design of the ESW building, and makeup water source.	9.2.5.2, 9.2.10
9.2(23)	The COL applicant is to provide isolation between the UHS and the non-safety-related systems.	9.2.5.2, 9.2.10
9.2(24)	The COL applicant is to provide the design of UHS cooling tower basin so the minimum water level will provide adequate NPSH to	9.2.5.2.1, 9.2.10

	ESW pumps under accident conditions.	
COL 9.2(25)	The COL applicant is to provide the non-safety-related makeup water source and capacity for normal operation loss and evaporation in the UHS.	9.2.5.2.1, 9.2.10
COL 9.2(26)	The COL applicant is to specify the following UHS chemistry requirements for bio-fouling and chemistry control: a. A chemical injection system to provide non-corrosive, non-scale-forming conditions to limit biological film formation b. The type of biocide, algaecide, pH adjuster, corrosion inhibitor, scale inhibitor, and silt dispersant, if necessary to maintain system performance based on site conditions.	9.2.5.2.1, 9.2.10
COL 9.2(27)	The COL applicant is to verify the piping layout of the ESWS and UHS to prevent water hammer and develop operating procedures to provide reasonable assurance that the ESWS and UHS water pressure are above saturation conditions for all operating modes.	9.2.5.2.1, 9.2.10
COL 9.2(28)	The COL applicant is to develop maintenance and testing procedures to monitor debris buildup and flush out and to remove the debris in the UHS.	9.2.5.2.1, 9.2.10
COL 9.2(29)	The COL applicant is to evaluate the potential wind and recirculation effects of cooling towers based on meteorological condition.	9.2.5.2.2.1, 9.2.10
COL 9.2(30)	The COL applicant is to provide the material specifications for piping,	9.2.5.2.2.2, 9.2.10

	valves, and fittings of the UHS system based on site-specific conditions and meteorological conditions.	
COL 9.2(31)	The COL applicant is to provide the evaluation of maximum evaporation and other losses based on the site-specific conditions and meteorological conditions in the UHS.	9.2.5.2.2.3, 9.2.10
COL 9.2(32)	The COL applicant is to provide the detailed evaluation for UHS capability with consideration of site-specific conditions and meteorological data in the UHS.	9.2.5.3, 9.2.10
COL 9.2(33)	The COL applicant is to provide chemical and blowdown to prevent bio-fouling and long-term corrosion, considering site water quality in the UHS.	9.2.5.3, 9.2.10
COL 9.2(34)	The COL applicant is to provide the inspection and testing of the UHS to demonstrate that fouling and degradation mechanisms applicable to the site are effectively managed to maintain acceptable heat sink performance and integrity.	9.2.5.4, 9.2.10
COL 9.2(35)	The COL applicant is to provide the design provisions to permit the preoperational and in-service testing and inspection based on the type of UHS.	9.2.5.4, 9.2.10
COL 9.2(36)	The COL applicant is to provide the alarms, instrumentation, and controls required for the safety-related functions of the UHS.	9.2.5.5, 9.2.10

The staff finds the above list of COL information items adequate with one exception, which is identified as the following request for additional information, RAI 76-8024 (ML15196A604), Question No. 09.02.05-01, and is described below.

GDC 45, "Inspection of Cooling Water System," requires that the cooling water system be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system. Design provisions for in-service inspection of safety-related components and equipment should be provided. SRP Section 9.2.5 identifies the applicability of GDC 45 for the UHS. Further, SRP Section 9.2.5, Subsection II.4, specifically states that UHS should provide design provisions to permit access for in-service inspection of safety-related components and equipment.

DCD Tier 2, Sections 9.2.5.4.1 and 9.2.5.4.2 describe the preoperational testing and inspection and in-service testing and inspection as part of the CDI in the double bracket [[X]]. Therefore, the adequacy of the design provisions for in-service inspection will be reviewed for COL applications instead of the standard plant design. The applicant is requested to provide a COL information item so that the site-specific UHS will be required to address the above SRP provisions.

The applicant responded to the RAI in a letter dated September 24, 2015 (ML15269A010), and amended its response in a letter (ML16125A530), dated May 4, 2016. In the responses, the applicant added a COL information item in the DCD markups for COL applicants to provide the design provisions to permit the operational and in-service testing and inspection based on the type of UHS. The staff found the response adequately addressed the concern identified in the RAI, and therefore, is acceptable. The markup in the RAI response to RAI 76-8024, Question 09.02.05-01, and COL 9.2(35) to provide the provisions to permit the preoperational and in-service testing and inspection are confirmed in DCD Revision 1. Therefore, the staff considers RAI 76-8024, Question 09.02.05-01 to be resolved and closed.

9.2.5.6 Conclusion

Large portions of DCD Tier 2, Section 9.2.5, are CDI and, as such, only contain a representative conceptual description for which the standard plant design application does not seek certification. Based on the above, the staff has determined that the standard design criteria and guidance as described in the DCD are consistent with SRP Section 9.2.5 and that sufficient interface requirement and COL information items are described in the DCD. According to 10 CFR 52.47(c)(1), the staff will verify compliance with the criteria of GDC 2, 4, 5, 44, 45, 46 and conformance to the guidance of RG 1.27, RG 1.29 during review of future site-specific COL applications.

9.2.6 Condensate Storage Facilities

9.2.6.1 Introduction

The condensate storage facilities (CSF) function as the water supply or makeup source for various auxiliary systems, providing demineralized water for the initial fill of the condensate and feedwater system, and surge capacity for secondary system inventory changes during normal operation and transient conditions.

9.2.6.2 Summary of Application

DCD Tier 1: There are no Tier 1 entries for this area of review in the APR1400 DCD.

DCD Tier 2: The applicant has provided a Tier 2 system description in Section 9.2.6, "Condensate Storage Facilities," of the DCD, summarized here in part, as follows:

The CSF system consists of two systems: (1) makeup demineralizer system, and (2) condensate storage and transfer system.

The makeup demineralizer water system consists of one 100-percent capacity demineralized water storage tank (DWST), two 100-percent-capacity demineralized water transfer pumps, and two 100-percent membrane oxygen removal subsystems (MORS), associated piping valves, piping, and instrumentation from fresh water storage tanks up to the connections at each usage point. It supplies filtered and demineralized water to the AFWST for makeup and to other systems during all modes of operation. It also provides demineralized and degasified water to the condensate storage tank (CST) and reactor water makeup tank (RMWT) through the MORS, which reduces oxygen concentration in the demineralized water. With the exception of the DWST, the system is located on the ground floor of the water treatment building in the yard. The DWST is located in the yard. The makeup demineralizer water system is shown schematically in DCD Figure 9.2.6-1 “Makeup Demineralizer System Flow Diagram.”

The condensate storage and transfer system consist of two 50 percent capacity CSTs, associated piping and valves from the CSTs up to the connection of the condenser hotwell and other systems. It provides condensate to the condenser hotwell and auxiliary feedwater (AFW) pump suction as an alternate non-safety backup supply. The condensate storage and transfer system is shown schematically in DCD Tier 2, Figure 9.2.6-2, “Condensate Storage and Transfer System Flow Diagram.” The design parameters of the CSF system main components are shown in Table 9.2.6-1, “Tank and Pump Design parameters.”

ITAAC: There are no ITAAC for this area of review.

Technical Specifications: There are no TSs for this area of review.

Initial Test Program: In DCD Tier 2, Section 9.2.6.5, the applicant described the CSF inspection and testing program, which includes the performance of hydrostatic test for piping and valves. CFS related preoperational and startup testing is performed as described in DCD Tier 2, Section 14.2.12.1.79, “Condensate Storage System Test.”

9.2.6.3 Regulatory Basis

In general, the relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.2.6, “Condensate Storage Facilities,” Revision 3, and are summarized below. Review interfaces with other SRP sections can be found in Section 9.2.6.I, “Areas of Review,” of NUREG-0800.

1. GDC 2, “Design bases for protection against natural phenomena,” as it relates to the system’s capability to withstand the effects of natural phenomena including earthquakes and tornadoes.

2. GDC 5, “Sharing of structures, systems, and components,” as it relates to the capability of shared systems and components to perform required safety functions.

3. GDC 44, “Cooling water,” as it relates to ensuring the following:

- Redundancy of components so that, under normal and accident conditions, the safety functions can be performed assuming a single active component failure coincident with the loss of offsite power.

- The capability to isolate components, subsystems, or piping if required so that the system safety function will not be compromised.

- The capability to provide sufficient makeup water to safety-related cooling systems.

4. GDC 45, “Inspection of cooling water system,” as it relates to design provisions to permit in-service inspection of safety-related components and equipment.

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

6. GDC 60, “Control of releases of radioactive materials to the environment,” as it relates to tanks and systems handling radioactive materials in liquids.

7. 10 CFR 50.63, “Loss of all alternating current power,” as it relates to design provisions to support the plant’s ability to withstand and recover from a SBO.

8. 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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA, and the NRC regulations.

9. 10CFR 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.

Because the CSF is a nonsafety-related system, is not credited for providing water to safety-related cooling systems, and has no safety-related functions, and the APR1400 application is for a single unit plant, only GDC 2, GDC 5, GDC 60 and 10 CFR 20.1406, are relevant to this particular design.

9.2.6.4 Technical Evaluation

The staff reviewed the CSF design in accordance with SRP 9.2.6. For the APR1400 design, the CSF is non safety-related and has no safety-related functions. The safety-related function of assuring that adequate supply of water is provided to the emergency feedwater system, in the event that it is required for safe shutdown of the reactor often performed by CSF system in other designs, is accomplished using AFWSTs. The design of the AFWSTs is included in DCD Tier 2, Section 10.4.9, “Auxiliary Feedwater System.” The results of the staff’s review of the AFWSTs

and their compliance with SRP Section 9.2.6 is included in Section 10.4.9 of this report. The APR1400 design does not rely on the CSF in response to a SBO.

9.2.6.4.1 GDC 2, Design bases for protection against natural phenomena

Compliance with the requirements of GDC 2 is based on adherence to Position C.1 of RG 1.29, "Seismic Design Classification," for the safety-related portion of the system, and position C.2 for the non-safety-related apportions of the system.

In DCD Tier 2, Section 9.2.6, the applicant states that all demineralized water system components are nonsafety-related except for the containment isolation valves and associated piping. The containment isolation valves and associated piping are seismic Category I. Nonsafety-related components and piping located in safety-related areas are seismic Category II, and other piping and components (including the DWST) are seismic Category III.

The staff reviewed the makeup demineralized water system for compliance with GDC 2 by reviewing DCD Tier 2, Figure 9.2.6-1 and DCD Tier 2, Table 3.2-1. The only safety-related SSCs found were those that support containment isolation, which include the containment isolation valves and their associated piping. In DCD Table 3.2-1 (Item 106a) the containment isolation valves and associated piping are listed as seismic Category I SSCs. Therefore, position C.1 of RG 1.29 is satisfied. Non-safety-related portions of the makeup demineralized water system are also contained in the reactor and auxiliary buildings. These SSCs are listed as seismic Category II in DCD Tier 2, Table 3.2-1, which is consistent with guidance in regulatory guide 1.29. The remainder of the system is located either in the yard or fire pump and water / wastewater treatment area and is classified in DCD Tier 2, Table 3.2-1, as seismic Category III.

In DCD Tier 2, Section 9.2.6.2.2, "Condensate Storage and Transfer System," the applicant states that all the condensate storage and transfer system components including the CST and piping are nonsafety-related. It is also indicated that system components including the CST are normally designed as seismic Category III, but piping within safety-related structures (containing safety-related components) is designed in accordance with seismic Category II requirements. The remainder of the system is located either in the yard or the fire pump and water/wastewater treatment area and is classified in DCD Tier 2, Table 3.2-1, as seismic Category III. The design is consistent with guidance pertaining to position C.2 in Regulatory guide 1.29.

The storage tanks associated with the condensate storage facilities are listed in DCD Tier 2, Table 9.2.6-1, "Tank and Pump Design Parameters," and include two 255,000 gallon condensate storage tanks and one 300,000 gallon demineralized water storage tank. The tanks are not safety-related and are classified as seismic Category III (non-seismic). As indicated in Section I of SRP 9.2.6, the staff's review of the condensate storage facilities includes the review of provisions for mitigating the environmental effects of system leakage or storage tank failure. DCD Tier 2, Section 9.2.6 does not address the environmental impact of system leakage or tank failure or its potential for impact on SSCs important to safety. Therefore, the staff issued RAI 135-8001 (ML15220A036), Question 09.02.06-01, requesting that the applicant describe the provisions and design features of the CFS that will be relied on for mitigating the environmental effects of system leakage or storage tank failure. In its response to Question 09.02.06-01, dated April 16, 2016 (ML16107A045), the applicant indicated that while the failure of nonsafety-related onsite tanks such as the condensate storage facilitates could result in a potential flood source, the CSF tank failure would not adversely affect safety-related

SSCs since site grading and drainage will ensure water does not collect near safety-related SSCs. The applicant also indicated that water tight doors will be installed at exterior entrances of safety related buildings, and has added COL 3.4(5) requiring the COL applicant to provide the supporting information on the site-specific plant grading and drainage that will show how water is drained away from the safety-related SSC's in the event of a tank failure.

The staff has reviewed the applicant response to RAI 135-8001, Question 09.02.06-01, and found that it adequately addresses the staff's concern and therefore is acceptable. The staff considers the RAI closed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 135-8001, Question 09.02.06-01, to be resolved and closed.

Based on the above evaluation, the staff finds that CSF design as described in the DCD complies with the requirements of GDC 2.

9.2.6.4.2 GDC 5, Sharing of structures, systems, and components

The staff finds that the design of the ESWS as described in the DCD does not share safety-related SSCs with any other nuclear power units. Therefore, the ESWS complies with the provisions of GDC 5.

9.2.6.4.3 GDC 60, Control of releases of radioactive materials to the environment

The staff reviewed the design of the CSF for compliance with the requirements of GDC 60 with respect to control of releases of radioactive materials. According to SRP 9.2.6, Section II, acceptance for meeting the relevant aspects of GDC 60 is based on meeting the guidance in RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."

In DCD Tier 2, Section 9.2.6.1, "Design Bases," the applicant states that "the condensate storage facilities handle non-radioactive fluid. Therefore RG 4.21 and GDC 60 are not applicable for the condensate storage facilities." The staff recognizes the lower potential for having significant radioactivity in the CSF for PWRs as opposed to BWRs; however, since the applicant indicates in both DCD Tier 2 Sections 10.4.1.5, "Instrumentation Requirements," and 10.4.7.2.1, "General Description," that the condensate level in the hotwell is maintained within proper limits by automatically transferring condensate to or from the condensate storage system, the staff felt under certain circumstances the fluids handled by the CFS could be radioactive. As indicated in the SRP, Section 9.2.6, "through its connections with the RCS (in boiling-water reactors) or secondary coolant system (in pressurized-water reactors), the CSF potentially contains radioactive material." Since the condensate storage facilities have the potential to become radioactive if primary to secondary leakage (i.e. steam generator tube leakage) occurs for a sustained duration, the staff requested in RAI 135-8001, Question 09.02.06-2, that the applicant provide information on how the design satisfies GDC 60 as it relates to control of radioactive release to the environment.

In its response to RAI 135-8001, Question 09.02.06-01, dated April 16, 2016 (ML16107A045), the applicant indicated that the CSF is not treated as potentially containing radioactive material due to the fact that there are no supply lines to the CST except the nitrogen and demineralized water lines. The response states that the condensate overflow from the hotwell is directed to the condensate overflow storage sump in the turbine generator building and is not returned to the CSF, and includes a markup to the DCD to provide clarification on how overflow from the

condenser hotwell is handled. The staff reviewed the CSF design shown in DCD Tier 2 Figures 9.2.6-2, “Condensate Storage and Transfer System Flow Diagram,” and 10.4.7-1, “Condensate and feedwater System Flow Diagram,” and confirmed that there were no potentially radioactive sources feeding the CSF. Therefore, the staff finds that GDC 60 is not directly applicable to the CSF, and that the provisions for handling condenser hotwell overflow without the use of the CSF satisfies GDC 60 as it relates to the control of radioactive release to the environment. RAI 135-8001, Question 09.02.06-01, is closed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD.

Based on the above evaluation, the staff finds that CSF design as described in the DCD complies with the requirements of GDC 60.

9.2.6.4.4 Conformance with 10 CFR 20.1406

The DCD does not discuss how the condensate storage facilities comply with 10 CFR 20.1406. As mentioned above, in DCD Tier 2, Section 9.2.6.1, the applicant states that RG 4.21, which provides regulatory guidance on how to comply with 10 CFR20.1406, is not applicable. However the staff felt that, since the condensate storage facilities interface with systems containing radioactive fluids, 10 CFR 20.1406 is applicable. The staff requested in RAI 135-8001, Question 09.02.06-03, that the applicant provide information on how condensate storage facilities design satisfies the requirements of 10 CFR 20.1406.

In its response to RAI 135-8001, Question 09.02.06-03, dated April 16, 2016 (ML16107A045), the applicant indicated that the CSF can only add condensate to the hotwell, and that there is not a return line for the control of condensate overflow. It also points out that the CSTs are located at ground level elevation (98’- 8”) which is much higher than the condenser located in the condenser pit (elevation 55’-0”). The applicant concludes that the location of the connection from the CST supply line to the condenser hotwell, along with the approximate 40’ elevation difference, will prevent back leakage from the condenser hotwells to the CSTs.

The staff has reviewed the applicants response and confirmed that the system design includes features that protect the system from becoming contaminated by not serving as a receiver for excess water generated by potentially radioactive systems (such as the condenser hotwell) and by including design features, such as having storage tanks being at a higher elevation than the condenser, so as to provide protection against back leakage of condensate into the CSF tanks. Therefore, the staff finds that the system design addresses 10 CFR 20.1406 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.

The staff also noticed in DCD Tier 2, Table 1.9-2, “APR1400 Conformance with the Standard Review Plan,” that the applicant indicated that SRP 9.2.6 is not applicable for the same reasons it states that GDC 60 and RG 4.21 are not applicable. The staff does not agree with applicant’s conclusion since GDC 2 and 60 are applicable as well as 10 CFR 20.1406. The staff issued RAI 135-8001, Question 09.02.6-04, to have the applicant correct Table 1.9-2 to show the correct applicability for SRP 9.2.6.

In its response to RAI 135-8001, Question 09.02.06-04, dated April 16, 2016 (ML16107A045), the applicant revised Table 1.9-2 as requested. The table now indicates that APR1400 conforms to SRP 9.2.6 with noted exceptions. The staff reviewed the applicant’s response and

found it acceptable since it shows the CSF to be in conformance with SRP 9.2.6, and the CSF design in compliance with GDC 2. RAI 135-8001, Question 09.02.06-04, is closed. The staff confirmed that the RAI response markup has been incorporated into revision 1 of the DCD.

Based on the above evaluation, the staff finds that CFS design as described in the DCD complies with the requirements of 10 CFR 20.1406.

9.2.6.4.5 ITAAC

There are no APR1400 ITAAC information for the CSF. The staff finds this aspect of the DCD acceptable.

9.2.6.4.6 Technical Specifications

There are no APR1400 TS sections for the CSF. The staff finds this aspect of the DCD acceptable.

9.2.6.5 Combined License Information Items

In accordance with DCD Tier 2, Table 1.8-2, and DCD Tier 2, Section 9.2.6, the applicant has not identified any COL information items that are directly applicable to the CFS. No additional COL information items were identified by the staff that should be in DCD Tier 2, Table 1.8-2.

9.2.6.6 Conclusion

The design of the CSF in DCD Tier 2, Section 9.2.6, is acceptable because, as set forth above, it meets appropriate regulatory requirements: GDC 2 on protection from natural phenomena; GDC 5 on sharing of structures, systems, and components; GDC 60 for control of release of radioactive material to the environment; and 10 CFR 20.1406 for minimization of contamination.

9.2.7 Chilled Water System

9.2.7.1 Introduction

The chilled water system consists of the essential chilled water system (ECWS) and plant chilled water system (PCWS). The ECWS provides chilled water to safety-related HVAC cooling loads such as the EDG rooms, and the control room, among others. The PCWS provides chilled water for nonsafety-related HVAC cooling loads such as the containment fan coolers and the reactor cavity air handling unit (AHU).

9.2.7.2 Summary of Application

DCD Tier 1: Specific design requirements of the ECWS are addressed in DCD Tier 1, Section 2.7.2.3, “Essential Chilled Water System.” The functional arrangement of the ECWS is shown in DCD Tier 1, Figure 2.7.2.3-1, “Essential Chilled Water System.” Mechanical design information is provided in DCD Tier 1, Table 2.7.2.3-1, “Essential Chilled Water System Equipment and Piping Location/Characteristics,” which provides physical locations, ASME Code Section III applicability, and seismic Category. In addition, instrumentation and controls including display locations, electrical design information, and safety function are identified in DCD Tier 1, Table 2.7.2.3-2, “Essential Chilled Water System Components List” and DCD

Tier 1, Table 2.7.2.3-3, "Essential Chilled Water System Instruments List." DCD Tier 1, Table 2.7.2.3-4, "Essential Chilled Water System ITAAC," lists the ECWS ITAAC.

Specific design requirements of the PCWS are addressed in DCD Tier 1, Section 2.7.2.4, "Plant Chilled Water System." DCD Tier 1, Table 2.7.2.4-1, "Plant Chilled Water System ITAAC," lists the PCWS ITAAC.

DCD Tier 2: The design basis and complete description of the ECWS and PCWS are described in DCD Tier 2, Section 9.2.7, "Chilled Water System." In addition, ECWS parameters are included in Table 9.2.7-1, "Essential Chilled Water System Component Data," and Table 9.2.7-2, "Essential Chilled Water Heat Load and Flow Rate," and flow diagrams for the ECWS and PCWS is included in Figure 9.2.7-1 and Figure 9.2.7-2, "Plant Chilled Water System Flow Diagram," respectively.

The DCD Tier 2, Section 9.2.7.2.1 provides design information for the ECWS. The ECWS consists of two independent, redundant divisions. Each division can provide 100 percent of the design-basis heat loads. The ECWS rejects heat via water cooled chiller refrigeration units. The chiller condensers are supplied with cooling water from the CCWS and are located in dedicated rooms within the auxiliary building. Each chiller operates on environmentally safe refrigerants and contains a condenser, compressors, evaporator, and associated piping and controls.

DCD Tier 2, Section 9.2.7.2.2 provides design information for the PCWS, which includes two subsystems: the central chilled water system, and the compound building chilled water system.

ITAAC: ITAAC for the ECWS and PCWS are included in DCD Tier 1, Table 2.7.2.3-4, and Table 2.7.2.4-1, respectively.

Initial Test Program: Initial plant testing for the chilled water system is described in DCD Tier 2, Section 14.2.12.1.74, "Chilled Water System Test."

Technical Specifications: The ECWS TSs associated with DCD Tier 2, Section 9.2.7 are given in DCD Tier 2, Chapter 16, TS 3.7.10, "Essential Chilled Water System (ECWS)."

9.2.7.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.2.2, Revision 4, and are summarized below. Review interfaces with other SRP sections can also be found in NUREG-0800, Section 9.2.2.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the capabilities of the structures housing the system and the system itself to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of safety-related functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to effects of missiles inside and outside containment, effects of pipe whip, jets, environmental conditions from high- and moderate-energy line-breaks, and dynamic effects of flow instabilities and attendant loads (e.g., water hammer) during normal plant operation, as well as upset or accident conditions.

3. GDC 5, "Sharing of structures, systems, and components," insofar as it requires that SSCs important to safety not be shared among nuclear power units unless it can be shown that sharing will not significantly impair their ability to perform their safety functions.

4. GDC 44, "Cooling water," as it relates to the capability to transfer heat from systems, SSCs important to safety to an UHS during both normal and accident conditions, with suitable redundancy, assuming a single active component failure coincident with either the loss of offsite power or loss of onsite power.

5. GDC 45, "Inspection of cooling water system," as it relates to design provisions for inservice inspection of safety-related components and equipment.

6. GDC 46, "Testing of cooling water system," as it relates to design provisions for pressure and operational functional testing of cooling water systems and components to assure:

   - Structural integrity and leak-tightness of its components;

   - Operability and performance of active system components; and

   - Capability of the integrated system to perform credited functions during normal, shutdown, and accident conditions.

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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA, and NRC regulations.

8. 10 CFR 20.1406, as it relates to the standard plant design certifications and how the design and procedures for operation will minimize contamination of the facility and the environment facilitate eventual decommissioning and minimize to the extent practicable, the generation of radioactive waste.

9.2.7.4 Technical Evaluation

The staff's evaluation of the chilled water system is based upon the information provided in the applicant's DCD, Revision 1, including Tier 1 and Tier 2.

9.2.7.4.1 GDC 2, Design bases for protection against natural phenomena

The staff reviewed the chilled water system for compliance with the requirements of GDC 2 with respect to its design for protection against the effect of natural phenomena such as earthquakes, tornados, hurricanes, and floods. Compliance with the requirements of GDC 2 is based on meeting the guidance of RG 1.29, Regulatory Position C.1, for the safety-related portions of the system, and RG 1.29, Regulatory Position C.2, for nonsafety-related portions of the system.

DCD Tier 2, Section 3.2 categorizes SSCs based on safety importance and other considerations. DCD Tier 2, Table 3.2-1, provides the component safety classifications, seismic Category, quality group, codes and standards, and locations of the SSCs. The staff finds that the safety classification, quality group, seismic Category, and location for the ECWS and PCWS are properly designated. All safety-related portions of the ECWS and PCWS are located inside the AB, which is designed to seismic Category I criteria, and to withstand extreme wind, missiles, and flooding.

The safety-related portions of the ECWS are designed to seismic Category I requirements. Additionally, to ensure that failure of any nonsafety-related portions of the ECWS do not compromise performance of any safety-related function of the system, nonsafety-related portions of the ECWS are designed to seismic Category II criteria.

The only portion of the PCWS that is safety-related and designed to seismic Category I criteria are those necessary for containment isolation. Nonsafety-related portions of the PCWS located in the auxiliary building are designed to seismic Category II requirements to ensure that failure of the PCWS will not compromise any safety-related components during an SSE. In RAI 269-8319, (ML15295A264) Question 09.02.02-11, Item a, the staff requested the applicant to clarify whether all nonsafety-related portions of the PCWS are designed as seismic Category II, due to some discrepancies between statements in the DCD. In a response dated November 25, 2015 (ML15329A380), the applicant stated that the nonsafety-related potions of the PCWS located in the turbine building and compound building are designed to seismic Category III criteria, and that DCD Tier 2, Section 9.2.7.1.2, "Plant Chilled Water System," will be revised to make the clarification. The staff finds the applicant's response acceptable because the portions of the PCWS in the turbine building and compound building do not perform any safety-related functions, nor would a failure in this portion of the system prevent an SSC from performing a safety function.

RAI 269-8319, Question 09.02.02-11, Item b, noted that the DCD used conflicting component names between the ECWS and PCWS and requested the applicant correct the inconsistencies. In its November 25, 2015, response the applicant stated the DCD will be revised in order to resolve the inconsistencies. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD.

Section 3.4, "Water Level (Flood) Design," of this report addresses the staff's evaluation of flood protection provided for SSCs important to safety.

Section 3.5, "Missile Protection," of this report addresses the staff's evaluation of protection provided for SSCs important to safety from missiles.

DCD Tier 2, Section 3.12.3.7, "Non-Seismic/Seismic Interaction (II/I)," states that the primary method to avoid potential adverse interactions is to isolated the non-seismic piping from the seismic Category I piping system. If that is not feasible or practical, the non-seismic piping system is classified as seismic Category II. Section 3.7, "Seismic Design," of this report further addresses the staff's evaluation of non-seismic interaction with seismic Category I SSCs.

As discussed above, the staff finds that the nonsafety-related and safety-related parts of the chilled water system are properly classified such that the analyses, design features, and provisions described in DCD Tier 2, Chapter 3, and evaluated by the staff in the corresponding sections of this report, will ensure that the chilled water system is capable of performing its

safety functions during the natural phenomena described in GDC 2. The design of these SSCs meets the guidance provided in RG 1.29, Regulatory Positions C.1 and C.2, for compliance with GDC 2 requirements. Therefore, the staff finds that the requirements of GDC 2 are met.

9.2.7.4.2 GDC 4, Environmental and dynamic effects design bases

The staff reviewed the chilled water system to determine if the design meets the relevant requirements of GDC 4 to remain functional during all postulated environmental conditions (or dynamic effects such as pipe breaks) associated with normal operations, maintenance, testing, and postulated accidents. The ECWS design temperature and pressure are such that the ECWS meets the staff definition of a moderate-energy system. Section 3.6.1, “Protection against Dynamic Effects Associated with the Postulated Rupture of Piping,” of this report addresses the staff’s evaluation of the design of structures, shields, and barriers necessary for SSCs to be protected against dynamic effects of high-energy and moderate-energy line breaks. Based on the staff’s evaluation discussed in Section 3.6.1 of this report, the staff finds that the design of the ECWS assures that it is protected against the effects of, and is able to perform its safety-related functions while exposed, to the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.

The ECWS consists of two independent divisions, and all safety-related components are physically separated. A single failure does not compromise the system’s safety function to provide chilled water to safety-related HVAC cooling loads. Each division of the ECWS contains two 100 percent capacity chillers and pumps. A failure modes and effects analysis (FMEA) is provided in DCD Tier 2, Table 9.2.7-3, “Essential Chilled Water System Failure Modes and Effect Analysis,” to demonstrate that failure of a single active component will not compromise the ability of the system to perform its safety function.

The piping of the PCWS within areas containing safety-related equipment (i.e., the auxiliary building) is designed as seismic Category II. Safety-related portions of the PCWS are located such that the adverse consequences of a pipe rupture or other component failure will not prevent the safety-related portions of the system from performing its safety function.

Compliance with GDC 4 is also based on meeting the guidance discussed in NUREG-0927 for water hammer prevention and mitigation. As described in DCD Tier 2, Section 9.2.7.2.1, “Essential Chilled Water System,” the ECWS design minimizes the potential for water hammer by:

- Containing a compression tank to keep the system filled and maintain required minimum pressure.
- Installing vents at high points and drains at low points.
- Selecting valve open and close times.

A COL information item is provided to assure that the COL applicant develops procedures for filling, venting, keeping the system full, and operating it to minimize the potential for water hammer.

Based on the preceding discussion, the staff finds that the safety-related and nonsafety-related chilled water systems comply with the requirements of GDC 4, regarding capability to continue

functioning to ensure safe shutdown during normal operations, anticipated operational occurrences, and accident conditions.

9.2.7.4.3 GDC 5, Sharing of structures, systems, and components

The staff finds that the design of the chilled water system as described in the DCD does not share safety-related SSCs with any other nuclear power units. Therefore, the chilled water system complies with the provisions of GDC 5.

9.2.7.4.4 GDC 44, Cooling water

As described in Section 9.2.7.2 of this report, the ECWS consists of two divisions. Each division is located in the auxiliary building and physically separated from each other. Each ECWS division is a closed loop system that supplies chilled cooling water to the HVAC cooling coils of the control room AHUs, EDG rooms, electrical and I&C rooms, auxiliary building (controlled area) ventilation, and safety-related pump and heat exchanger rooms. Each division consists of two essential chiller units, two essential chilled water pumps, one compression tank, one essential chilled water makeup pump, air separator, chemical addition tank, valves, user loads, and associated piping and controls. Each ECWS chiller and associated pump in each division is capable of providing 100 percent of the design-basis heat loads. Each ECWS division pump is sized to provide 8710 L/min (2300 gpm) and is designed with 10 percent margin for head and a minimum of 25 percent greater available NPSH than required NPSH. The condensers of the essential chiller refrigeration units are water cooled by the CCWS. CCWS is evaluated in Section 9.2.2, "Component Cooling Water System," of this report. The ECWS component data is given in DCD Tier 2, Table 9.2.7-1. In the event of a design basis accident concurrent with LOOP, one chiller and one pump per division start automatically from the EDG loading sequencer. If a pump or chiller fails to operate, the standby pump and chiller start automatically.

During normal operation, both divisions are considered operational. The chiller and pump that do not operate are kept in standby. The system design heat loads for normal and abnormal operating conditions are given in DCD Tier 2, Table 9.2.7-2, "Essential Chilled Water Heat Load and Flow Rate." The ECWS flow diagram is shown in DCD Tier 2, Figure 9.2.7-1. The staff reviewed the ECWS description, tables, and figures to confirm that the flow paths and components have been identified and described in sufficient detail to enable a full understanding of the system design and operation. The staff compared the capacity of the ECWS to the heat loads of the systems the ECWS is credited with cooling and concluded that the flow rates and heat removal capability provided in the tables provided adequate cooling for SSCs important to safety during both normal and accident conditions.

As discussed above, the ECWS pumps have a 10 percent margin for pump head. RAI 269-8319, Question 09.02.02-12, Item d requested the applicant to explain whether the design of the ECWS has additional design margin to account for uncertainties, component wear and aging effects, and fouling of heat exchangers. In a letter dated April 22, 2016 (ML16114A000), the applicant stated in response to RAI 269-8319, Question 09.02.02-12, item d, that the chilled water flow rate of the ECWS is calculated using a cooling load with 10 percent margin, and a fouling factor of 0.0005 $hr \cdot ft^2 \cdot {}^\circ F/BTU$ is applied to the ECWS chiller tubing. In addition, the ECWS system is filled with demineralized water and uses corrosion inhibitors to compensate for future fouling. The staff finds the applicant's response to RAI 269-8319, Question 09.02.02-12, item d, acceptable because it demonstrates that the ECWS has been designed with appropriate margins for adequate operation consistent with

SRP 9.2.2. In addition, operating experience has indicated the use of a fouling factor of 0.0005 hr·ft2·°F/BTU to be appropriate for a closed system utilizing demineralized water and corrosion inhibitors. The staff considers RAI 269-8319, Question 09.02.02-12, Item d, to be closed.

The applicant included an ECWS FMEA in DCD Tier 2, Table 9.2.7-3. The staff reviewed all potential single failures in the table to confirm that no single failure would prevent the ECWS from performing its safety function. Also, because each safety-related ECWS division has its own safety-related emergency power source which is protected from the effects of natural phenomena as described in DCD Tier 2, Chapter 3, and evaluated in the corresponding sections of this report, the staff finds that the LOOP as a result of natural phenomena will not adversely affect the capability of the ECWS to perform its safety functions.

The ECWS chillers are designed to use environmentally friendly refrigerants and the rooms are equipped with refrigerant leak detectors that alarm in the MCR and RSR. When actuated the chiller room supply fan and exhaust fan start automatically to remove refrigerant. In addition, the essential chiller relief valves are routed to outside the building to protect station personnel from refrigerant exposure in accordance with American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 15 requirements.

The ECWS safety-related air-operated flow control valves are discussed in DCD Tier 2, Section 9.2.7.2.1, and provide chilled water flow control through each set of safety-related cooling coils. RAI 269-8319, Question 09.02.02-12, item c, requested the applicant to provide additional information on the failure mode of the ECW air-operated control valves. In a letter dated December 16, 2015 (ML15350A366), and a revised response in a letter dated April 22, 2016 (ML16114A000), the applicant stated that the ECW control valves are air-operated and are designed to fail open upon a loss of instrument air. The staff finds the applicant's response to RAI 269-8319, Question 09.02.02-12, item c, regarding the ECW flow control valves acceptable because their fail-open design ensures the system can still perform its safety function in the event of a loss of instrument air. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 269-8319, Question 09.02.02-12, item c, to be resolved and closed.

In response to RAI 269-8319, Question 09.02.02-12, dated December 16, 2015 (ML15350A366), Items a and b, the applicant also stated that the system piping will be sized in order to limit water velocity, and that strainers will be installed in the construction phase and removed prior to operation. The applicant added that strainers are not necessary during normal operation because the chilled water system is a closed system and filled with demineralized water. The staff finds the applicant's responses to RAI 269-8319, Question 09.02.02-12, items a and b, related to pipe sizing and system filtration acceptable because the system design appropriately limits flow velocities and prevents foreign debris from entering the system during construction. The staff finds RAI 269-8319, Question 09.02.02-12, items a and b, to be resolved and closed.

Each ECWS division contains a compression tank with a nitrogen fill connection. The compression tank accommodates thermal expansion and contraction of the system, creates ECWS pump NPSH, maintains system pressure, and is designed in accordance with ASME B&PV Code, Section III, Class 3. In addition, the tanks are provided with relief valves to protect against system overpressure. The nitrogen overpressure in the compression tank maintains

ECWS pump suction pressure above the fluid vapor pressure to enhance available NPSH and prevents air leakage into the system.

The normal makeup water source to the ECWS is from the nonsafety-related demineralized water system. The safety-related makeup water source is from the AFWST via the essential chilled water makeup pump. Under seismic or post-accident conditions, when demineralized water may be unavailable for ECWS makeup, the essential chilled water makeup pump automatically starts on a compression tank low-level signal. In response to RAI 269-8319, Question 09.02.02-12, dated December 16, 2015 (ML15350A366), item e, the applicant stated that the leak rate of the ECWS is calculated as 80 gallons per day and is sized to accommodate at least 7 days of system operation without the need for makeup water. The staff finds the applicant's response to RAI 269-8319 Question 09.02.02-12, item e, related to the evaluation of system leakage acceptable because the essential chilled water makeup pumps are a seismically qualified makeup water source and the ECWS compression tank is designed to accommodate at least 7 days of system operation consistent with SRP 9.2.2 Section III.3.C. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 269-8319, Question 09.02.02-12, item e, to be resolved and closed.

The staff reviewed the description of all alarms, instrumentation, and control functions in DCD Tier 2, Section 9.2.7.5, "Instrumentation Requirements." The staff reviewed the adequacy of instrumentation to support required system testing, as well as the adequacy of alarms and instrumentation to notify operators of degraded conditions. The ECWS can be operated from the MCR, RSR, or on the local control panel. However, the DCD lacked information for instrumentation design and requirements. Therefore, the staff issued RAI 269-8319, Question 09.02.02-14 requesting the applicant to provide additional information regarding the instrumentation and controls associated with the ECWS. In letter dated May 10, 2016 (ML16131A883), the applicant stated in response to RAI 269-8319, Question 09.02.02-14, that local temperature, flow, and pressure indicators, and inlet and outlet pressure indicators of the evaporator will be added to DCD Tier 2, Figure 9.2.7-1. The applicant also stated that instrumentation for chiller protection is provided on the local control panel; this includes refrigerant pressure, refrigerant temperature, chilled water temperature, and chilled water flow. In addition, component status is indicated on the information flat panel displays as well as the safety consoles and local control panel. Alarms such as trouble/disable and ECW compression tank high/low alarms are indicated on the large display panel. The staff reviewed the applicant's response and finds it to be acceptable because the design of the ECWS includes adequate instrumentation to support required testing, and operator notification of degraded conditions. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 269-8319, Question 09.02.02-14, to be resolved and closed.

The staff finds that the ECWS has the heat removal capacity to transfer the design basis accident heat load to the safety-related chillers from SSCs important to safety and the required redundancy to address single failure scenarios. In addition, the ECWS has sufficient emergency power supplies, freeze protection, chemistry controls, and NPSH margin for the ECWS pump. The ECWS has safety-related makeup water for each division under accident conditions. Safety-related portions of the PCWS can be isolated from nonsafety-related portions of the system so that the system safety function (containment isolation) is not compromised. The entire ECWS system is safety-related and designed to the seismic Category I criteria, and has adequate division separation and redundancy in order to assure

capability to perform safety-related functions. On the basis of the above discussion, the staff finds that the ECWS complies with the requirements of GDC 44 for providing cooling water to the safety-related HVAC systems.

9.2.7.4.5 GDC 45, Inspection of cooling water system and GDC 46 Testing of cooling water system

The DCD Tier 2, Section 9.2.7.1.1.1, "Safety Design Bases," states that the ECWS is designed for periodic inspection and inservice testing to provide assurance of the integrity and capability of the system in accordance with GDC 45 and 46. In addition, the system is designed such that ECWS components are tested before, during and after construction, and per TS surveillances. RAI 269-8319, Question 09.02.02-13, item a, requested the applicant to verify whether the ECWS was accessible for periodic inspection and testing. In a letter dated November 25, 2015 (ML15329A380), the applicant stated in response to RAI 269-8319, Question 09.02.02-13, item a, that ECWS components are accessible for periodic inservice testing, inspections, and maintenance and the DCD will be updated to make that clarification. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 269-8319, Question 09.02.02-13, item a, to be resolved and closed.

RAI 269-8319, Question 09.02.02-13, item b, requested the applicant to discuss whether the ECWS design includes isolation valves for component maintenance. In a letter dated April 22, 2016 (ML16114A000), the applicant stated in response to RAI 269-8319, Question 09.02.02-13, item b, that isolation valves are provided at the inlet and outlet of components such as chillers and pumps, and that the current ECWS design utilizes globe valves for initial flow control and pump isolation . The applicant also stated that DCD Tier 2, Figure 9.2.7-1 will be revised to include the globe valves on the discharge side of the essential chilled water pumps. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 269-8319, Question 09.02.02-13, item b, to be resolved and closed.

Similarly, the staff verified the PCWS is designed such that the safety-related containment isolation valves and piping permit periodic inspections and pressure and functional tests to provide assurance of the integrity and capability of the system in accordance with GDC 45 and 46.

Based on the fact that the ECWS is designed for periodic inspection and testing and is accessible in the auxiliary building, and the PCWS containment isolation valves permit periodic inspection and testing, the staff concludes that the applicant has provided information to assure that the ECWS and PCWS comply with the requirements of GDC 45 and 46.

9.2.7.4.6 10 CFR 20.1406, Minimization of Contamination

10 CFR 20.1406 requires that applicants for standard plant design certifications 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 chilled water system is a closed loop cooling water system that removes heat from safety-related and nonsafety-related HVAC systems during normal operating, accident, and shutdown conditions. Because it is a closed loop system, there is no direct path for release of radioactive material from the ECWS to the environment. However, minimization of contamination is not discussed in the DCD. Therefore, the staff issued RAI 269-8319,

Question 09.02.02-15, to request the applicant to address the requirements of 10 CFR 20.1406 and the potential of radioactive contamination of the chilled water system. In a letter dated December 16, 2015 (ML15350A366), the applicant stated in response to RAI 269-8319, Question 09.02.02-15, that the cooling coils of the chilled water system are maintained at a higher pressure than the atmospheric pressure in the HVAC equipment areas, and there is no potential for radioactive contamination of the chilled water system from potentially contaminated HVAC systems. In addition, the staff notes that migration of radioactive material from potentially radioactive systems is prevented by a minimum of two heat exchanger barriers, so no radiation monitors are needed in the chilled water system. For example, radiation monitors located in the CCWS detect radioactive contamination entering and exiting the system such that detection and isolation would occur prior to potentially contaminating the chilled water system (either ECWS or PCWS, for both systems' chiller condensers are cooled by CCWS). The staff finds the applicant's response to RAI 269-8319, Question 09.02.02-15, acceptable because it addresses the potential for radioactive contamination of the chilled water system consistent with the guidance of RG 4.21. Based on the above evaluation, the staff concludes that the chilled water design as described in the DCD complies with the requirements of 10 CFR 20.1406.

9.2.7.4.7 Initial Test Program

Applicants for combined licenses must provide plans for pre-operational testing and initial operations in accordance with 10 CFR 52.79, "Contents of applications; technical information," paragraph (a)(28), requirements. DCD Tier 2, Section 14.2.12.1.74, describes the initial test program for the ECWS.

Section 14.2 of this report addresses the staff's evaluation of the initial test program for APR1400 chilled water system.

9.2.7.4.8 TAAC

DCD Tier 1, Section 2.7.2.3, "Essential Chilled Water System," provides APR 1400 design certification information and ITAAC for the ECWS. DCD Tier 1, Section 2.7.2.4, "Plant Chilled Water System," provides APR 1400 design certification information and ITAAC for the PCWS. The ITAAC related to the PCWS containment isolation valves and the piping between them is provided in DCD Tier 1 Section 2.11.3, "Containment Isolation System." DCD Tier 1 information for plant system SSCs is evaluated in Section 14.3.7 of this report, and evaluation of DCD Tier 1 information in this section is an extension of the evaluation provided in Section 14.3.7. This evaluation pertains to plant systems aspects of the proposed DCD Tier 1 information for ECWS and PCWS.

The staff reviewed the descriptive information, safety-related functions, arrangement, mechanical, I&C and electric power design features, environmental qualification, as well as system and equipment performance requirements provided in DCD Tier 1, Sections 2.7.2.3 and 2.7.2.4 to confirm completeness and consistency with the plant design basis as described in DCD Tier 2, Section 9.2.7. The staff also reviewed DCD Tier 1, Table 2.7.2.3-1, Table 2.7.2.3-2, Table 2.7.2.3-3, and Figure 2.7.2.3-1. Since the containment isolation valves and the piping between them is the only safety-related portion of the PCWS, the staff finds that the ITAAC as listed in DCD Tier 1 Table 2.7.2.4-1 and 2.11.3-2, "Containment Isolation System ITAAC," are acceptable because they are sufficient to demonstrate that the safety-related portion of the PCWS will be designed and operate in accordance with the design certification.

RAI 269-8319, Question 09.02.02-16, item a, requested the applicant to include conservative parameters for the ITAAC associated with ECW pump and ECW makeup pump net positive suction head. In a letter dated December 17, 2015 (ML15351A171), the applicant stated in response to RAI 269-8319, Question 09.02.02-16, item a, that Item 10 in DCD Tier 1, Table 2.7.2.3-4, will be revised to specify that the NPSH analyses will account for pressure losses of inlet piping and components and minimum operating level of the ECW compression tank. The staff finds the applicant's response to be acceptable because it ensures the ECW pump and makeup pump NPSH analyses will account for pressure losses and low ECW tank level when measuring the available NPSH. The staff considers RAI 269-8319, Question 09.02.02-16, item a, closed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD.

Based on its review, the staff finds that that the DCD Tier 1 information and ITAAC requirements adequately describe the design certification requirements for the ECWS and PCWS. Further the staff concludes that the ITAAC requirements are sufficient to demonstrate that the ECWS and PCWS will be designed and will operate in accordance with the design certification and that if the acceptance criteria is met that there is reasonable assurance that the design is built and will operate in accordance with the design certification, the provision of the AEA and NRC regulations which include 10 CFR 52.47(b)(1).

9.2.7.4.9 Technical Specifications

TS 3.7.10 provides the LCO and SRs for the ECWS. TS 3.7.10 requires entry into a 7-day LCO Action Statement if one of the ECWS divisions is inoperable.

SR 3.7.10.1 requires periodic verification that all valves that are not locked are in their correct positions. SR 3.7.10.2 requires periodic verification that each ECWS component properly actuates in response to an actual or simulated actuation signal.

Chapter 16 of this report includes the staff's evaluation of the ECWS TS to assure that the proposed TS and associated Bases adequately address and reflect system-specific design considerations as described in DCD Tier 2, Section 9.2.7 and that they meet the applicable regulations for inclusion in the TS.

9.2.7.5 Combined License Information Items

The following is a list of applicable COL Information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(37)	The COL applicant is to develop the following procedures for the water system: filling, venting, keeping it full, and operating it to minimize the potential for water hammer. The COL applicant is also to analyze the system for water hammer impacts, design the piping system to withstand potential water	9.2.7

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
	hammer forces, and analyze inadvertent water hammer events in the ECWS in accordance with NUREG-0927.	

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for the chilled water system.

9.2.7.6 Conclusion

The staff evaluated the chilled water system for the APR 1400 standard plant design in accordance with the guidance that is referred to in Section 9.2.7.3 of this report. The staff's review included information in the DCD as supplemented by the applicant's response to numerous RAIs.

The staff finds that the applicant appropriately identified minimum ECWS heat load and flow capabilities for individual safety-related components, as well as for the system as a whole in various relevant modes of operation. The staff finds that the APR 1400 design is capable of performing its safety functions and provides inherent tolerance to single failures.

The staff review also included the ECWS and PCWS ITAAC, pre-operational testing, and TSs and finds these sections provided reasonable assurance that the ECWS and PCWS will be inspected, tested, and operated in accordance with the ECWS and PCWS design bases.

Based on the review above the staff concludes that the relevant regulatory requirements for this area of review and the associated acceptance criteria that are given in NUREG-0800, Section 9.2.2, Revision 4, have been met.

9.2.8 Turbine Generator Building Closed Cooling Water System

9.2.8.1 Introduction

The turbine generator building closed cooling water system (TGBCCWS) is a nonsafety-related system that removes heat generated by the equipment located in the turbine generator building during plant operation and transfers the heat to the nonsafety-related turbine generator building open cooling water system (TGBOCWS) for rejection to the normal heat sink. A flow diagram and equipment cooled by the TGBCCWS is depicted in DCD Tier 2, Figure 9.2.8-1, "Turbine Generator Building Closed Cooling Water System Flow Diagram."

9.2.8.2 Summary of Application

Tier 1: DCD Tier 1, Section 2.7.2.7, "Turbine Generator Building Closed Cooling Water System," states that there are no entries for this area of review.

Tier 2: DCD Tier 2, Section 9.2.8, "Turbine Generator Building Closed Cooling Water System," provides information on the TGBCCWS. The system performs no safety-related function and is designed to meet the following functional criteria:

- Supply sufficient cooling water to the turbine generator building during normal plant operation.
- Rejects heat from turbine generator building equipment to the TGBOCWS through the TGBCCWS heat exchangers.
- Demineralized water with corrosion inhibitors is used for cooling water.
- The cold side of the equipment is protected from overpressure by thermal relief valves.
- The TGBCCWS includes an independent closed loop cooling water system that allows operation of one air compressor when the TGBCCWS is not available.

ITAAC: There are no ITAAC items for this area of review.

Technical Specifications: There are no TSs for this area of review.

9.2.8.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are not specified in NUREG-0800. While not directly applicable to the TGBCCWS, the staff used SRP guidance on other water systems such as NUREG-0800, SRP Section 9.2.2, "Reactor Auxiliary Cooling Water System," for evaluating the adequacy of the TGBCCWS. The acceptance criteria contained in the noted SRP Section which are of importance as related to the TGBCCWS include the following:

1. GDC 2, "Design bases for protection against natural phenomena," in that failure of a nonsafety-related system or component due to natural phenomena such as earthquakes, tornadoes, hurricanes, and floods should not adversely affect safety-related SSCs.
2. GDC 4, "Environmental and dynamic effects design bases," in that failure of the TGBCCWS due to pipe break or malfunction should not adversely affect any essential systems or components that are necessary for safe shutdown or accident mitigation of the plant.
3. 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 DC has been built and will operate in accordance with the DC, the provisions of the AEA and the NRC regulations.
4. 10 CFR 20.1406, which requires each design certification applicant to describe how the facility design will minimize, to the extent practicable, contamination of the facility and the environment, and the generation of radioactive waste; and facilitate eventual decommissioning.

9.2.8.4 Technical Evaluation

The TGBCCWS provides a continuous supply of cooling water to the turbine generator building equipment during normal plant operation. During normal operation, one TGBCCWS pump and two heat exchangers are in operation with one pump and one heat exchanger in standby. The standby pump automatically starts whenever the pump discharge header pressure falls below a preselected value. The standby heat exchanger is placed in service manually.

The TGBCCWS consists of two 100 percent pumps, three 50 percent heat exchangers, one surge tank, one chemical addition tank, associated piping, valves, instrumentation, and controls that are located in the turbine generator building. A flow diagram of the TGBCCWS is shown in DCD Tier 2, Figure 9.2.8-1, "Turbine Generator Building Closed Cooling Water System Flow Diagram," and major system components are described in DCD Tier 2, Table 9.2.8-1, "TGBCCW System Component Design Parameters." The equipment cooled by the TGBCCWS is identified in Figure 9.2.8-1, and includes:

1. ISO phases bus duct cooler.
2. Generator stator water cooler.
3. Generator hydrogen cooler.
4. Secondary local grab sample cooler racks.
5. Feedwater pump lube oil coolers.
6. Air compressor inter coolers, after coolers, and lube oil coolers.
7. Main turbine lube oil coolers.
8. Condenser Hotwell Sample Coolers.
9. Feedwater booster pumps, lube oil coolers and mechanical seal coolers.
10. Startup feedwater pump, lube oil cooler and mechanical seal cooler.
11. Condensate pumps motor bearing cooler.

The TGBCCWS flow to the main turbine lube oil coolers, generator hydrogen coolers, and feedwater pump lube oil coolers is regulated by automatic control valves located in the associated cooler outlet lines. The flow of cooling water to all other coolers is regulated manually by individual throttling valves located at each cooler outlet. A thermal relief valve is installed at the outlet of each cooler.

To prevent TGBCCWS contamination by the TGBOCWS, the design operating pressure of the TGBOCWS is lower than the design operating pressures of the TGBCCWS. Additionally, the system includes an independent closed loop cooling water system that allows operation of one plant air compressor when the TGBCCWS is not available. The closed loop cooling water system is normally isolated and is started manually to provide cooling water when the TGBCCWS is unavailable.

A surge tank provides a reservoir to compensate for leakage from the system, the expansion and contraction of the cooling fluid with changes in system temperature, and a constant suction head source for the TGBCCWS pumps. The surge tank is connected to the suction of the pumps. Makeup water to the surge tank is provided from the demineralized water makeup system and is automatically controlled by the surge tank water level. The surge tank is pressurized by the nitrogen system to prevent oxygen from entering the system. The corrosion inhibitor is added to the TGBCCWS via the chemical addition tank to control the pH of the system.

9.2.8.4.1 GDC 2, Design bases for protection against natural phenomena

The staff's review of the TGBCCWS compliance to GDC 2 criteria is based on adherence to Position C.2 of RG 1.29. Based on its review of the APR1400 DCD, the staff finds that the TGBCCWS is a nonsafety-related, non-seismically designed system located in the turbine generator building which does not contain any safety-related SSCs. Failure of the TGBCCWS or its components due to natural phenomena will then have no adverse effects on safety-related SSCs. Therefore, the staff finds that the TGBCCWS meets the requirements of GDC 2.

9.2.8.4.2 GDC 4, Environmental and dynamic effects design bases

The staff's review of the TGBCCWS compliance with the requirements of GDC 4 is based on the determination that failure of the TGBCCWS, due to pipe break or malfunction of the system, does not adversely affect any of the plant's essential systems or components (i.e., those necessary for safe shutdown or accident prevention or mitigation). The TGBCCWS is a nonsafety-related system, and located in the turbine generator building which does not contain any safety-related SSCs. Therefore, the staff determined that the TGBCCWS meets the requirements of GDC 4.

9.2.8.4.3 10 CFR 20.1406, Minimization of contamination

10 CFR 20.1406 requires in part that each design certification applicant describe how facility design will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

In DCD Tier 2, Section 9.2.8.2.3, "Design Features for Minimization of Contamination," the applicant states that the APR1400 is designed with specific features to meet the requirements of 10 CFR 20.1406 and RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning." Further, it states that the basic principles of RG 4.21, and the methods of control suggested in the regulations, are specifically delineated in design and operational objectives discussed in DCD Tier 2, Section 12.4.2, "Minimization of Contamination and Radioactive Waste Generation."

The applicant stated that the heat exchangers that the TGBCCWS supplies to are not expected to contain radioactive fluid, except the process sampling coolers, which may have a low level of contamination. Also due to the infrequent sampling activity, and because the sampling coolers are small, the risk and consequence for TGBCCWS contamination is considered low.

The TGBCCWS is designed to prevent contamination through leakage in the heat exchangers. The integrity of the TGBCCWS heat exchangers is expected to be well maintained, resulting in

no contamination or a very low level of contamination of the system. The TGBCCWS heat exchangers are plate type and constructed of titanium material, which minimizes pinhole leaks.

Leakage from the system to the facility and the environment is captured by the design. The heat exchanger seals are designed to leak outside the heat exchangers where the leakage is collected in the turbine generator building drainage system. A sump is provided for collection of leakage. The sump is designed with a stainless steel liner and is equipped with level indication that will initiate an alarm for operator actions. As described in Section 9.3.3, discharge from the turbine generator building sump pumps is monitored for radiation contamination. When the contamination level is detected at or exceeding a predetermined set point, the drains are routed to the LWMS for process and release via the condensate polishing area sump.

The TGBCCWS surge tank is located at a high elevation. Leakage from the tank is to be collected in the drain system inside the turbine generator building. The surge tank is a packaged unit for full service life and is fabricated as an individual assembly for easy removal. The TGBCCWS is designed with minimal embedded or buried piping, and is designed for automated operations. Adequate ingress and egress spaces are provided for assessments and response when needed.

Based on the TGBCCWS design features described in DCD Tier 2, Section 9.2.8.2.3, the staff finds that the TGBCCWS design and operation are in compliance with 10 CFR 20.1406 criteria.

COL 9.2(35) requires the applicant to address design modification and perform post licensing actions that cannot be completed prior to the issuance of a COL license. Since the TGBCCWS is presented in the DCD as part of the certified design and there is no conceptual design information, the staff is unclear as to what information the COL applicant needs to submit as part of its COL application regarding the TGBCCWS. The applicant was requested in RAI 246-8307, Question 09.02.02-2, to provide the basis for the COL information item and to discuss why post licensing aspects such as field changes and operations are included. In its response dated February 3, 2016 (ML16034A162), the applicant confirmed that the TGBCCWS is part of the design being certified, and also that conceptual design information is presented in the DCD as follows:

- System design and operation description in DCD Subsection 9.2.8,
- TGBCCWS component design parameters in Table 9.2.8-1, and
- TGBCCWS flow diagrams in DCD Figure 9.2.8-1.

The staff reviewed the DCD markups for Sections 9.2.8 and 9.2.9, “Turbine Generator Building Open Cooling Water System,” Figures 9.2.8-1 and 9.2.9-1, “Turbine Generator Building Open Cooling Water System Flow Diagram,” that were provided in the RAI response and found that the only components regarded as conceptual design are the three 50 percent heat exchangers. However, in the markup provided for Table 9.2.8-1, the staff found that portions of the TGBCCWS Pump requirements are also included as a conceptual design and that portions of the TGBCCWS Heat Exchangers are not included in the conceptual design. The staff issued RAI 462-8571 (ML16110A017), Question 09.02.02-17, requesting that the applicant reconcile the above noted discrepancies. In its response dated June 1, 2016 (ML16153A482), and supplemented on June 21, 2016 (ML16173A467), the applicant provided information and DCD markups that reconciled the discrepancies and the staff finds the response acceptable.

Therefore, the staff considers RAI 462-8571, Question 09.02.02-17, closed. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD.

9.2.8.4.4 Initial Test Program

Preoperational testing to demonstrate the ability of the TGBCCWS to supply cooling water under normal plant operations is described in DCD Tier 2, Section 14.2.12.1.78, "Turbine Generator Building Closed Cooling Water System Test." Section 14.2 of this report addresses the staff's evaluation of the Initial Test Program for the APR1400 TGBCCWS.

9.2.8.4.5 ITAAC

There are no ITAAC associated with the TGBCCWS. Based on a graded approach commensurate with the safety significance of the SSCs, the staff agrees that ITAAC are not required for the TGBCCWS since the TGBCCWS is a nonsafety-related system located in the turbine generator building, and no safety-related equipment is located in the turbine generator building.

9.2.8.4.6 Technical Specifications

DCD Tier 2 Chapter 16 is not applicable to the TGBCCWS because there are no TSs associated with the system.

9.2.8.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(38)	The COL applicant is to confirm that there are no departures and shall meet the interface requirements (i.e., cooling duties and temperature requirements, piping and control interface)	9.2.8.1, 9.2.10
9.2(39)	The COL applicant is to provide operational procedures and maintenance programs as related to leak detection and contamination control in accordance with RG 4.21.	9.2.8.2, 9.2.10

9.2(40)	The COL applicant is to include a site-wide radiological environmental monitoring program to monitor both the horizontal and vertical variability of the onsite hydrogeology and the potential effects of the construction and operation of the plant.	9.2.8.2, 9.2.10

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for this system.

9.2.8.6 Conclusion

Based on the review summarized above, the staff finds that the TGBCCWS design is consistent with the guidance of NUREG-0800, SRP 9.2.2 and that the information provided by the applicant adequately demonstrates compliance with the requirements of 10 CFR Part 50, Appendix A, GDC 2, GDC 4, 10 CFR 52.47(b)(1), and 10 CFR 20.1406. Further, the staff finds that this is a nonsafety-related system with minimal interface with systems that have radioactive effluents, and therefore will not adversely impact the plant safety-related operations.

Thus, the staff concludes that the design of the APR1400 TGBCCWS meets the Commission Regulations, and therefore is acceptable.

9.2.9 Turbine Generator Building Open Cooling Water System

9.2.9.1 Introduction

The TGBOCWS is a nonsafety-related system that removes heat generated by the TGBCCWS during plant operation. A flow diagram of the TGBOCWS is depicted in DCD Tier 2, Figure 9.2.9-1, "Turbine Generator Building Open Cooling Water System Flow Diagram."

9.2.9.2 Summary of Application

Tier 1: DCD Tier 1, Section 2.7.2.8, "Turbine Generator Building Open Cooling Water System," states that there are no entries for this area of review.

Tier 2: DCD Tier 2, Section 9.2.9, "Turbine Generator Building Open Cooling Water System," provides information on the TGBOCWS. The system performs no safety-related function and is designed to meet the following functional criteria:

- Supply sufficient cooling water to the TGBCCWS heat exchangers during all modes of plant operation.
- After cooling the TGBCCWS heat exchangers, the cooling water is branched off from the discharge header of the circulating water (CW) pump and is returned back to the CW discharge conduit. The TGBOCWS then discharges the heat to the CW cooling towers.

- Upon isolation or loss of one of two operating TGBCCWS heat exchangers or strainer, the remaining standby heat exchanger or strainer is still capable of heat removal.

ITAAC: There are no ITAAC items for this area of review.

Technical Specifications: There are no TSs for this area of review.

9.2.9.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are not specified in NUREG-0800. While not directly applicable to the TGBOCWS, the staff used SRP guidance on other water systems such as SRP 9.2.2, "Reactor Auxiliary Cooling Water System," for evaluating the adequacy of the TGBOCWS. The acceptance criteria contained in the noted SRP section which are of importance as related to the TGBOCWS include only the following:

1. GDC 2, "Design bases for protection against natural phenomena," in that failure of the nonsafety-related system or component due to natural phenomena such as earthquakes, tornadoes, hurricanes, and floods should not adversely affect the safety-related SSCs.

2. GDC 4, "Environmental and dynamic effects design bases," in that failure of the TGBOCWS due to pipe break or malfunction should not adversely affect any essential systems or components that are necessary for safe shutdown or accident mitigation of the plant.

3. 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 has been built and will operate in accordance with the DC, the provisions of the AEA and the NRC regulations.

4. 10 CFR 20.1406, which requires each design certification applicant to describe how the facility design will minimize, to the extent practicable, contamination of the facility and the environment, and the generation of radioactive waste; and facilitate eventual decommissioning.

9.2.9.4 Technical Evaluation

The TGBOCWS supplies cooling water to the cold side of the TGBCCWS heat exchangers in the turbine generator building. Water for the TGBOCWS is branched off from the circulating water (CW) pumps header. The heated cooling water, after passing the TGBCCWS heat exchangers, is discharged to the heat sink via the CW system. The TGBOCWS system consists of redundant strainers, valves, associated piping, and instrumentation and controls, which are located in the turbine generator building. To prevent TGBCCWS contamination by the TGBOCWS, the design operating pressure of the TGBOCWS is lower than the design operating pressures of the TGBCCWS. To minimize the potential for water hammer, the operating pressure at all location in the system remains higher than the saturated condition at the operating temperature.

9.2.9.4.1 GDC 2 Design bases for protection against natural phenomena

The staff's review of the TGBOCWS compliance to GDC 2 criteria is based on adherence to Position C.1 of RG 1.29, "Seismic Design Classification." Based on its review of the APR1400 DCD, the staff finds that the TGBOCWS is a non-safety, non-seismically designed system located in the turbine generator building which does not contain any safety-related SSCs. Failure of the TGBOCWS or its components due to natural phenomena will then have no adverse effects on safety-related SSCs. Therefore, the staff finds that the TGBOCWS meets the requirements of GDC 2.

9.2.9.4.2 GDC 4, Environmental and dynamic effects design bases

The staff's review of the TGBOCWS compliance with the requirements of GDC 4 is based on the determination that failure of the TGBOCWS, due to pipe break or malfunction of the system, does not adversely affect any of the plant's essential systems or components (i.e., those necessary for safe shutdown or accident prevention or mitigation). The TGBOCWS is a nonsafety-related system and located in the turbine generator building which does not contain any safety-related SSCs. Furthermore, flooding due to line break of this system is not adversely affecting any SSCs since it is bounded by Circulating Water System line-break. Therefore, the staff determined that the TGBOCWS meets the requirements of GDC 4.

9.2.9.4.3 10 CFR 20.1406, Minimization of contamination

10 CFR 20.1406 requires in part that each design certification applicant describe how facility design will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

In DCD Tier 2, Section 9.2.8.2.3, the applicant states that the APR1400 is designed with specific features to meet the requirements of 10 CFR 20.1406 and RG 4.21. Further, it states that the basic principles of RG 4.21, and the methods of control suggested in the regulations, are specifically delineated in design and operational objectives discussed in DCD Tier 2, Section 12.4.2.

The applicant described that the systems and equipment with which the TGBOCWS come in contact with are not normally expected to contain radioactive fluid. The only interface for the TGBOCW system is with TGBCCWS heat exchangers, which supply continuous cooling water to the turbine generator building equipment, which are not expected to contain radioactive fluid.

The TGBOCWS is designed to prevent contamination through leakage in the heat exchangers. The integrity of the TGBCCW heat exchangers is expected to be well maintained, resulting in no contamination or a very low level of contamination of the system. The TGBCCWS heat exchangers are plate type and constructed of titanium material, which minimizes pinhole leaks.

Leakage from the system to the facility and the environment is captured by the design. The heat exchanger seals are designed to leak outside the heat exchangers where the leakage is collected in the turbine generator building drainage system. A sump is provided for collection of leakage. The sump is designed with a stainless steel liner and is equipped with level indication that will initiate an alarm for operator actions. Any residual contamination of the hydrogeology is not likely to be distinguishable from other contamination sources. Hence, the TGBOCWS has

low risk and low radiological consequence, and radiological environmental monitoring for the TGBOCWS is not considered effective.

The TGBOCWS is designed with minimal embedded or buried piping, and is designed for automated operations. Adequate ingress and egress spaces are provided for assessments and response when needed.

Based on the TGBOCWS design features described in DCD Tier 2, Section 9.2.8.2.3, the staff finds that the TGBOCWS design and operation, are in compliance with 10 CFR 20.1406 criteria.

9.2.9.4.4 ITAAC

There are no ITAAC associated with the TGBOCWS. Based on a graded approach commensurate with the safety significance of the SSCs, the staff agrees that ITAAC are not required for the TGBOCWS since the TGBOCWS is a non-safety related system located in the turbine generator building, and no safety-related equipment is located in the turbine generator building.

Preoperational testing to demonstrate the ability of the TGBOCWS to supply cooling water under normal plant operations is described in DCD Tier 2, Section 14.2.12.1.45, "Turbine Generator Building Open Cooling Water System Test."

9.2.9.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.2(38)	The COL applicant is to confirm that there are no departures and shall meet the interface requirements (i.e., cooling duties and temperature requirements, piping and control interface)	9.2.8.1, 9.2.10
9.2(39)	The COL applicant is to provide operational procedures and maintenance programs as related to leak detection and contamination control in accordance with RG 4.21.	9.2.8.2, 9.2.10
9.2(40)	The COL applicant is to include a site-wide radiological environmental monitoring program to	9.2.8.2, 9.2.10

	monitor both the horizontal and vertical variability of the onsite hydrogeology and the potential effects of the construction and operation of the plant.	
COL 9.2(41)	The COL applicant is to maintain complete documentation of system design and any site specific design modifications during the COL application, for the features for contamination control, in accordance with RG 4.21, Subsection A-3 to facilitate decommissioning.	9.2.9.2, 9.2.10

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 DCD Tier 2, Table 1.8-2 for the TGBOCWS.

9.2.9.6 Conclusion

Based on the review summarized above, the staff finds that the TGBOCWS design is consistent with the guidance of NUREG-0800, SRP 9.2.2, and that the information provided by the applicant adequately demonstrates compliance with the requirements of 10 CFR Part 50, Appendix A, GDC 2, GDC 4, 10 CFR 52.47(b)(1), and 10 CFR 20.1406. Further, the staff finds that this is a nonsafety-related system with minimal interface with systems that have radioactive effluents, and therefore will not adversely impact the plant safety-related operations.

Thus, the staff concludes that the design of the APR1400 TGBOCWS meets the Commission Regulations, and therefore is acceptable.

9.3 Process Auxiliaries

9.3.1 Compressed Air and Gas Systems

9.3.1.1 Introduction

The compressed air and gas systems are composed of the compressed air system (CAS), the compressed gas system, and the breathing air system. In turn, the CAS includes two other systems: the instrument air system (IAS) and the service air system (SAS).

The IAS provides air for instrumentation and control air to safety-related and nonsafety-related components and systems. The SAS provides air for pneumatic equipment and other services during plant normal operation and for maintenance during the plant shutdown.

The compressed gas system is composed of the nitrogen subsystem, the hydrogen subsystem, and the carbon dioxide subsystem.

The breathing air system supplies emergency breathing air (grade D respiratory quality) for control room personnel.

9.3.1.2 Summary of Application

DCD Tier 1: The applicant has provided a system description in DCD Tier 1, Section 2.7.5.1, "Compressed Air and Gas Systems."

DCD Tier 2: The applicant has provided a system description in DCD Tier 2, Section 9.3.1, "Compressed Air and Gas Systems." The CAS consists of compressors, dryers, filters, receivers, and other equipment required for performing its nonsafety-related functions. DCD Tier 2, Figures 9.3.1-1, "Instrument Air System Flow Diagram," and 9.3.1-2, "Service Air System Flow Diagram," provide details about the IAS and SAS systems. DCD Table 9.3.1-2, "Component Design Data," provide design data for the major CAS components.

ITAAC: The applicant proposed ITAAC 2.7.5.1, "Compress Air and Gas System," to confirm that a failure on the CAS will not impact the functionality of safety-related SSCs located in the proximity of the CAS.

Technical Specifications: There are no TSs requirements associated with the CAS.

9.3.1.3 Regulatory Basis

The relevant requirements of the Commission regulations for this area of review, and the associated acceptance criteria, are given in SRP Section 9.3.1, Revision 2, March 2007, "Compressed Air Systems," and are summarized below.

1. GDC 1, "Quality standards and records," as to safety-related SSCs designed, fabricated, and tested to quality standards commensurate with the importance of the safety functions to be performed.
2. GDC 2, "Design bases for protection against natural phenomena," as it relates to system capability to withstand the effects of earthquakes.
3. GDC 5, "Sharing of structures, systems, and components," as it relates to capability of shared systems and components important to safety to perform required safety functions.
4. 10 CFR 50.63 as it relates to necessary support systems providing sufficient capacity and capability to ensure the capability to cope with a SBO event.

9.3.1.4 Technical Evaluation

In DCD Tier 2, Section 9.3.1, "Compressed Air and Gas System," the applicant identifies the following design bases for the CAS:

a. The CAS serves no safety function and therefore has no safety design basis, except for containment isolation, which is described in DCD Tier 2, Subsection 6.2.4.

b. The safety-related air-operated valves and air-operated control dampers served by the IAS do not require instrument air to perform their safety-related function, and these components fail in the safe position on loss of instrument air pressure following a SBO.

c. For the safety-related air-operated valves, each valve has an air accumulator with two cycles of minimum capacity as a backup compressed air to the IAS to perform its safety-related function on loss of instrument air pressure, if needed.

d. An independent closed loop cooling system allows operation of one air compressor when the air compressor cooling water is not available.

e. The CAS is designed for one unit and is not shared with other units.

f. The IAS meets the air quality requirements of ISA 7.0.01 to supply clean, dry, oil-free instrument air.

9.3.1.4.1 GDC 1, Quality standards and records

GDC 1 requires that safety-related SSCs be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions performed. The IAS provides air to several safety-related valves and dampers (not part of the CAS), as identified in DCD Tier 2, Table 9.3.1-1, "Safety-Related Air-Operated Valves and HVAC Control Dampers." These safety-related valves do not use air to perform their safety function and fail in a safe position on loss of air.

In accordance with SRP Section 9.3.1, the applicant should address Generic Issue 43, "Reliability of Air Systems," regarding the reliability of safety-related equipment actuated or controlled by compressed air to demonstrate conformance with GDC 1. SRP 9.3.1 specifically indicates that an air system designed to air quality standards of ANSI/ISA S7.3-R1981 helps ensure that the CAS and connected components will perform their safety-function.

Additionally, NUREG-1275, Volume 2, "Operating Experience Feedback Report - Air Systems Problems," and Generic Letter 88-14, "Instrument Air Supply System Problems Affecting Safety-Related Equipment," indicate compressed air contamination as a significant contributor to unreliability in safety-related air-actuated equipment. Finally, RG 1.68.3, "Preoperational Testing of Instrument and Control Air Systems," Position C.9, provides guidance on preoperational testing using compressed air supplies with less restrictive air quality requirements.

DCD Tier 2, Section 9.3.1.1, "Design Basis," indicates that the compressed air system is designed to meet the requirements of ANSI/ISA 7.0.01-1996, "Quality Standard for Instrument Air." Additionally, DCD Tier 2, Section 9.3.1.4, "Inspection and Testing Requirements," states

that IAS is analyzed for moisture, air, and particulate content consistent with the guidance of ISA 7.0.01.

The staff notes that ANSI/ISA 7.0.01-1996 quality requirements are not consistent with the air quality requirements of the endorsed guidance in ANSI/ISA-S7.3-R1981. In RAI 87-7993 (ML15197A271), Question 09.03.01-01, the staff requested the applicant to justify crediting the ANSI/ISA 7.0.01-1996 quality requirements instead of the NRC endorsed guidance provided in ANSI/ISA-S7.3-R1981, or to update the DCD to reference the endorsed guidance.

In its October 28, 2015, response to Question 09.03.01-01 (ML15301A857) the applicant stated that the current guidance ANSI/ISA 7.0.01-1996 supersedes and incorporates the NRC endorsed guidance provided in ANSI/ISA-S7.3-R1981. The staff evaluated the applicant's response and determined that the response was not acceptable since the NRC never endorsed the newer guidance. In follow-up RAI 477-8589 (ML16130A087), Question 09.03.01-06 the staff re-stated that the NRC endorsed guidance is ANSI/ISA-S7.3-R1981 and requested the applicant to update the DCD to reflect how the compressed air system design conforms with the staff's approved air quality standard.

In its response to RAI 477-8589, Question 09.03.01-06 (ML16162A056), the applicant proposed to modify the DCD in order to reference the NRC endorsed guidance as the staff requested in the RAI.

The staff evaluated the proposed DCD changes and determined that the proposed changes would remove the reference to non-endorsed guidance and replace them with references to the NRC endorse guidance. The staff also reviewed Revision 1 to the DCD and confirmed that the applicant included the above mention DCD changes.

In addition to specific design requirements identified above, Generic Issue 43 also stresses the importance of procedures, training and testing related to loss of air system pressure. In DCD Tier 2, Section 14.2.7, "Conformance of Test Programs with NRC Regulatory Guides," the applicant states that RG 1.68.3 is not applicable to APR1400 because the safety-related air instruments are supplied by the high quality air of the IAS. However, the staff identified that the SAS can supply backup air to the IAS; therefore, a low quality air system could provide air to the safety-related air instruments. Additionally the applicant has not proposed an ITAAC or a startup test to verify that the safety-related air-operated instruments are connected to the proper system. Therefore, in RAI 87-7993, Question 09.03.01-02, the staff requested the applicant to propose a startup test for the CAS consistent with the guidance provided in RG 1.68.3.

In its response to Question 09.03.01-02, dated December 31, 2015 (ML15365A304), the applicant proposed to update DCD Tier 2, Section 14.2.7.2, stating that the APR1400 will comply with RG 1.68.3. The applicant took exception with position C.7 and C.8 of RG 1.68.3, which require the testing of safety-related air-operated valve to fail in a safe position, since these valves are evaluated in the corresponding safety-related system and are not considered part of the IAS. The applicant also took exception with position C.9 which requires that testing demonstrate that the plant equipment designated by design to be supplied by the IAS is not being supplied by other compressed air supplies (such as the service air system), which may have less restrictive air quality requirements. The applicant described the system configuration that prevents the possibility of suppling low quality air to the safety related valves.

The staff evaluated the applicant's response and determined that the proposed test exceptions are adequate. Testing of the fail position on safety-related valves in their respective systems instead of testing them in this subsection is an acceptable alternative to positions C.7 and C.8. Also, the staff evaluated the system configuration and confirmed that the service air system connects upstream of the filters of the IAS precluding the incursion of low quality air into the safety-related SSCs. Therefore, the staff finds the applicant's response acceptable and the staff RAI 87-7993, Question 09.03.01-02 resolved. The staff also reviewed Revision 1 to the DCD and confirmed that the applicant included the above mention DCD changes.

The SAS provides makeup to the IAS, but the system connects upstream of the dryers and filters; therefore, all the air in the IAS is of high quality. The staff determined that this adequately addresses the Generic Issue 43 concern regarding air quality from backup sources.

DCD Tier 2, Figure 9.3.1-1, "Instrument Air System Flow Diagram," indicates that the instrument air system is used to provide air to components in possibly contaminated areas. A review of the system P&ID (DCD Tier 2, Figure 9.3.1-1) shows insufficient detail to determine if the CAS could be contaminated through interfaces with radioactive system or if provisions are provided for detection of activity and isolation of the system to prevent contamination or a release to the environment. In RAI 87-7993, Question 09.03.01-03 the staff requested the applicant to provide an evaluation of whether the compressed air system (IAS and the SAS) could become contaminated through interfaces with radioactive systems and, if so, the applicant should provide methods for detection, collection and control of system leakage to preclude contaminating other systems and preclude its release to the environment.

In its response to RAI 87-7993, Question 09.03.01-03, dated October 28, 2015 (ML15301A857), the applicant stated that the IAS and the SAS are pressurized systems that have no direct contact with any radioactive system; therefore, these systems are classified as non-radioactive.

The staff evaluated the applicant's response and determined that it is acceptable to conclude that the IAS and the SAS are not likely to be contaminated given their separation from any potentially contaminated system. The staff finds the concerns discussed in RAI 87-7993, Question 09.03.01-03, resolved.

Based on the above, the staff concludes that the design of the compressed air system satisfies GDC 1 regarding quality standards and records commensurate with the importance of the safety functions performed by the compressed air system.

9.3.1.4.2 GDC 2, Design bases for protection against natural phenomena

In order for the CAS to meet the requirements of GDC 2, as it relates to SSCs being capable of withstanding natural phenomena, RG 1.29, Positions C.1 and C.2 provide an acceptable method to meet this criterion. The IAS is not credited to remain operational following a seismic event except for the containment isolation function. DCD Tier 1, Table 2.11.3-1, "Containment Isolation System Components List," identifies the IAS valve as IA-V020, the SAS valve as SA-V001, and the nitrogen system valve as NT-V0004. All these valves are classified as seismic Category I valves exposed to harsh environment. DCD Tier 2, Table 3.9-4, "seismic Category I Active Valves," identifies the IAS valve as IA-0020 and the nitrogen system valve as NT-0004, but it does not mention the SAS system valve. DCD Tier 2, Table 3.9-11, "Inservice

Testing of Safety-Related Pumps and Valves," identifies the IAS valve as IA-0020, the SAS valve as SA-0001, and the nitrogen system valve as NT-0004. These isolation valves are also discussed in DCD Tier 2, Table 3.11-3, "Equipment Qualification Equipment List," where they are identified as IAS (valve IA-V0020), SAS (valve SA-V0001), and the nitrogen system valve (valve NT-V0004), and being exposed to mild environmental conditions.

In RAI 87-7993, Question 09.03.01-04, the staff requested the applicant to correct the inconsistency in the nomenclature of the valve names across the DCD, and to correct the inconsistency in the environmental qualification of the valves.

In its response to Question 09.03.01-4, dated October 28, 2015 (ML15301A857), the applicant clarified that the different tables have different purposes, therefore there is no inconsistency in nomenclature. The valve description in Table 2.11.3-1, "Containment Isolation System Components List," is to describe the item number of the valve instead of the valve number. The valve descriptions in Table 3.9-4, "Seismic Category I Active Valves," and Table 3.11-3, "Equipment Qualification Equipment List," are to describe the valve numbers and valve identification numbers, respectively, instead of item numbers. The applicant also proposed to correct the inconsistency in environmental qualification zones for the valves.

The staff evaluated the applicant's response and determined that, based on the clarification of the table nomenclature and the proposed DCD changes, the staff concerns presented in RAI 87-7993, Question 09.03.01-04, are resolved. The staff also reviewed Revision 1 of the DCD and confirmed that the applicant included the above mentioned DCD changes.

The DCD Tier 2, Section 9.3.1.1, states that each safety-related valve is provided with an accumulator with two cycles of minimum capacity, if needed. The non-seismic compressed air system piping is routed in areas with safety-related and seismic Category I and II components. During a seismic event, the non-seismic compressed air system piping could adversely affect seismic Category I and II components that are located nearby. It is not clear to the staff that the applicant has evaluated the impact of the failure of the non-seismic Category I SSCs on the seismic Category I SSCs.

In RAI 87-7993, Question 09.03.01-05, the staff requested the applicant to include in the DCD an evaluation of the impact of the failure of the non-seismic Category I SSCs on the seismic Category I SSCs, and to provide the seismic design of the accumulators provided for the safety-related valves.

In its response to Question 09.03.01-05, dated October 28, 2015 (ML15301A857), the applicant stated that non-nuclear safety (NNS) SSCs located on safety-related areas are designed as seismic Category II to protect the safety-related SSCs from the failure of the NNS SSC. The staff confirmed that DCD Tier 2, Table 3.2-1, Item 47 states that the Instrument Air piping located in safety-related areas are design as seismic Category II components. The applicant's response also clarified that the AFW pump turbine steam (TBN STM) supply valves include a seismic Category I compress air accumulator. These accumulators are a procured item provided by the valve manufacturer.

The staff evaluated the applicant's response and determined that crediting seismic Category II piping to protect the safety-related SSCs is the adequate method to ensure the operability of safety-related SSCs. The staff also finds adequate to design the accumulators to seismic

Category I standards; therefore, the staff determined that the concerns discussed in RAI 87-7993, Question 09.03.01-05, are resolved.

Based on the above discussion, the staff concludes the design of the compressed air system satisfies GDC 2 regarding protection from the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, and external missiles.

9.3.1.4.3 GDC 5 Sharing of structures, systems, and components

The APR1400 design is a single-unit design; therefore, the issue of sharing SSCs across different units doesn't apply. GDC 5 is inherently satisfied for the APR1400 application.

9.3.1.4.4 10 CFR 50.63, Loss of all alternating current power

The IAS and the SAS air compressors are non-1E powered and, in the event of a LOOP, they do not receive power from the EDG s. Similarly, during a SBO, the IAS compressors do not receive power from either one of the SBO generators.

The CAS is not required to operate during an SBO. Therefore, the staff finds that the design of the compressed air system satisfies the requirements of 10 CFR 50.63, regarding the capability for responding to a SBO.

9.3.1.4.5 Initial Test Program

As discussed previously in this Section, the applicant proposed a startup test for the CAS consistent with the guidance provided in RG 1.68.3. The staff's evaluation of the initial plant testing program is documented in Section 14.2 of this report.

9.3.1.4.6 ITAAC

Initially, the staff reviewed the CAS in accordance with SRP Section 14.3.2.7, "ITAAC for Plant Systems," and agreed with the applicant that no specific ITAAC is needed for verifying the CAS performance. However, in its review of the applicant's April 16, 2016, response (ML16107A007) to RAI 372-8461 (ML16022A218), Question 03.06.01-01, the staff noted that the applicant had created individual ITAAC for each high- and moderate-energy system in order to reconcile the pipe rupture hazards analyses report with the as-built layout of the plant. The staff requested additional information regarding a corresponding ITAAC requiring the reconciliation of the pipe rupture hazards analyses report.

In response to the staff RAI, the applicant proposed to create ITAAC 2.7.5.1 "Compress Air and Gas System." This ITAAC is related to the pipe rupture hazards analyses and therefore evaluated in Section 3.6.1 of this report.

9.3.1.4.7 Technical Specifications

There are no TSs applicable to the compressed air system. The staff reviewed the CAS against 10 CFR 50.34 and the STS and concluded that no TS are needed for the CAS.

9.3.1.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items		
Item No.	**Description**	**DCD Tier 2 Section**
9.3(1)	The COL applicant is to provide the supply systems of the nitrogen gas subsystem, the hydrogen subsystem, the carbon dioxide subsystem, and the breathing air systems.	9.3.1.2.1, 9.3.5

The staff evaluated the proposed COL 9.3(1) and determined that, since the compressed gas system has no safety-related function other than containment isolation, requiring the COL applicant to address the design details of the compressed gas system is acceptable.

9.3.1.6 Conclusion

Based on the review above, the staff concludes that the compressed air and gas systems are in compliance of GDC 1, 2, 5, and 10 CFR 50.63.

9.3.2 Process and Post-Accident Sampling Systems

9.3.2.1 Introduction

The Process and Post-Accident Sampling System (PPASS) allows the plant staff to obtain liquid and gaseous samples and determine their physical and chemical characteristics by measurement and analysis. Centralized and local facilities permit samples to be taken of primary and secondary coolant, containment atmosphere, liquid and gaseous waste treatment systems, and the IRWST. The system consists of the normal primary sampling system (NPSS), the post-accident sampling system (PASS), and the secondary sampling system (SSS).

9.3.2.2 Summary of Application

DCD Tier 1: In the DCD Tier 1, Section 2.7.2.6, “Process and Post-Accident Sampling Systems” the applicant describes the PPASS sampling functions and the safety-related containment isolation function. The Tier 1 information includes design information and ITAAC related to functional arrangement, ASME Code requirements, seismic design, instrumentation, controls, displays, and alarms.

DCD Tier 2: The applicant has described the sampling systems in DCD Section 9.3.2, “Process and Post-Accident Sampling Systems,” where it is asserted that the process sampling system

has no safety function apart from containment isolation. Detailed descriptions of all the sample points and the type of sampling done at each are contained in DCD Tables 9.3.2-1, "Normal Primary Sampling System (NPSS) Sample points," and 9.3.2-2, "Secondary Sampling System Sample Points." These descriptions include samples of the primary reactor coolant, gaseous samples from containment, sampling of containment sumps and tanks, and sampling of secondary side water.

ITAAC: The ITAAC related to the PPASS are listed in DCD Tier 1 Subsection 2.7.2.6.

Technical Specifications: There are no TS for this area of review.

9.3.2.3 Regulatory Basis

From NUREG-0800, SRP 9.3.2, "Process and Post-Accident Sampling Systems," acceptance criteria for chemistry and chemical-engineering issues in sampling systems are:

1. 10 CFR 20.1101(b), which relates engineering controls to achieve doses to workers and the public ALARA.
2. GDC 1, "Quality standards and records," as it relates to the design of the PPASS and components in accordance with standards commensurate with the importance of their safety functions.
3. GDC 2, "Design bases for protection against natural phenomena," as it relates to the ability of the PPASS to withstand the effects of natural phenomena.
4. GDC 13, "Instrumentation and control," as it relates to monitoring variables that can affect the fission process, the integrity of the reactor core, and the reactor coolant pressure boundary (RCPB).
5. GDC 14, "Reactor coolant pressure boundary," as it relates to reliability of the RCPB by sampling for chemical species that affect the RCPB.
6. GDC 26, "Reactivity control system redundancy and capability," as it relates to controlling reactivity by sampling boron concentration.
7. GDC 41, "Containment atmosphere cleanup," as it relates to limiting fission products released to the environment by sampling the chemical additive tanks so as to ensure adequate supply of chemicals that meet materials compatibility and iodine removal requirements.
8. GDC 60, "Control of releases of radioactive materials to the environment," as it relates to the capability of the PSS to control the release of radioactive materials to the environment.
9. GDC 63, "Monitoring fuel and waste storage," as it relates to detecting excessive radiation in the fuel storage and radioactive waste systems.
10. GDC 64, "Monitoring radioactivity releases," as it relates to monitoring the containment atmosphere and plant environs for radioactivity.

11. 10 CFR 50.34(f)(2)(xxvi) and its equivalent, Three Mile Island (TMI) Action Plan Item III.D.1.1 in NUREG-0737, which relate to leakage of radioactive material out of containment through sampling points.

12. 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, the facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA and NRC regulations.

The acceptance criteria are delineated in the SRP Section 9.3.2; in particular, the applicant should demonstrate sampling of the sites mentioned on page 9.3.2-6 of SRP 9.3.2. Also, sampling procedures should adhere to the guidelines of RG 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste,", Regulatory Positions C.2, C.6, and C.7, specifically, and the EPRI report, "PWR Primary Water Chemistry Guidelines."

9.3.2.4 Technical Evaluation

The staff reviewed the information provided in DCD Tier 2, Section 9.3.2, "Process and Post-accident Sampling System," Revision 1, against the guidance of SRP Section 9.3.2. SRP 9.3.2 contains a number of detailed acceptance criteria that should be met concerning sampling of many fluids and gasses.

9.3.2.4.1 Sampling Locations

SRP Section 9.3.2 requires a number of sample locations to be included in order to satisfy regulatory criteria; these are listed in a table on page 9.3.2-6 of SRP 9.3.2. The applicant has listed numerous sample locations in DCD Tables 9.3.2-1 and 9.3.2-2. The tables in the DCD also summarize the species that are to be measured at each sample point in accordance to the EPRI PWR Primary and Secondary Water Chemistry Guidelines. The tables in the DCD list many more locations in addition to those required by SRP 9.3.2, indicating a very extensive and thorough sampling system. The staff agrees that these features of the system design and operation are consistent with SRP guidance and, therefore, satisfy the requirements of GDC 13, 14, 26, 41, 60, 63, and 64, as they relate to sampling locations identified in SRP 9.3.2.

9.3.2.4.2 Sampling Procedures

Most samples (including all from the RCS) are collected manually (i.e., "grab samples"). Grab sample instruments are calibrated regularly with known standards. Liquid samples from the RCS are conducted through stainless steel pipe to a common sample room outside of containment. The sample lines from the RCS hot leg include extra length to delay arrival of the sample sufficiently to allow for decay of ^{16}N.

Shielded compartments are available in the sample room to minimize exposure to personnel from potentially radioactive samples. The sample panel is situated in a ventilated, hooded enclosure to further reduce the possibilities of exposure or contamination. Spilled or leaked water is routed to a waste holdup tank for processing. The DCD does not supply information regarding the actual handling of samples, especially those that might contain radioactive materials. The local grab sample ports do use quick-disconnect couplings, but there is no

information in the DCD on the time it takes for samples to be analyzed once they are drawn.

In RAI 392-8464 (ML16032A392), Question 09.03.02-01, the staff requested that the applicant provide more information on its sample procedures, specifically the handling of the samples and the timing of the analyses. By response dated March 21, 2016 (ML16081A212), the applicant clarified that the time needed to perform sampling and analysis will be estimated based on operating experience. During normal operation the analysis of the samples will be performed within one hour. This time is appropriate based on the experience of the operating fleet for protecting personnel from excessive radiation exposures and to minimize loss of short-lived radionuclides by decay. The staff finds this acceptable because the timing is well within the recommendations of RG 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste." As for post-accident conditions, the applicant stated that it will take approximately one hour to analyze the samples. This time includes preparing the sampling line, obtaining the post-accident sample, the transferring of the sample and diluting it. The staff finds this acceptable because it meets NUREG-0737, "Clarification of TMI Action Plan Requirements" as required by Generic Letter (GL)-80-90 "Post TMI Requirements, NUREG-0737."

Gaseous samples are drawn from several containment locations, as described in DCD Table 9.3.2-1 in fulfillment of requirements of GDC 64. As in the case of most liquid samples, these are "grab samples," and the sample lines must be purged before the sample is isolated. Heat tracing and insulation are used on high-temperature lines to limit plate-out and prevent dew condensation (these procedures help to ensure representative samples, as required by RG 1.21 (C.6)). The DCD mentions that dew condensation liquid collected in gas sample containers is routed to holdup tanks, as required by GDC 60. Together with heat tracing of sample lines, return of samples to the containment, and procedures to minimize radiation exposure to technicians, the plan should provide representative samples, even during accidents or in other situations where condensable gases are part of the sample stream.

The PASS draws liquid samples from the RCS hot leg, IRWST, and gas samples from the containment atmosphere. The liquid lines lead to a dedicated sample vessel with lead shielding, and a shielded sample hood. The hood has an extended handle to manually collect samples and protect personnel from radiation exposure, in accordance with NUREG-0737. The DCD states that the liquid sampling system has the capability to take a boron measurement and measurements of dissolved gasses, pH, and chloride in accordance with NUREG-0737, which the staff finds acceptable.

The secondary side system draws continuous samples through online analyzers, which measure for pH, conductivity, dissolved oxygen, oxygen scavenger, Si, Cl, Na, and SO_4. Continuous analyzers are also used by the steam generator blowdown system. Both of these systems are concerned with the purity of secondary water to ensure materials integrity in the RCPB, as required by GDC 13 and 14.

9.3.2.4.3 10 CFR 50.34(f)(2)(xxvi) and NUREG-0737, Three Mile Island (TMI) Action Item III.D.1.1

Three Mile Island Action Plan Item III.D.1.1 in NUREG-0737 and 10 CFR 50.34(f)(2)(xxvi) require a leakage control program to minimize the leakage from those portions of the PSS outside of the containment that contain or may contain radioactive material following an accident. Containment and primary coolant sampling is a system listed by Item III.D1.1 (among

others) as potentially in scope of the requirement. DCD Section 9.3.2, lists NUREG-0737, Item III.D.1.1 and 10 CFR 50.34(f)(2)(xxvi) among the design bases for the PSS and no further detail is provided in DCD Section 9.3.2 on how leakage control is ensured. Additionally, DCD Chapter 16, Technical Specification 5.5.2, “Primary Coolant Sources Outside Containment,” states the following:

> This program provides controls to minimize leakage from those portions of systems outside containment that could contain highly radioactive fluids during a serious transient or accident to levels as low as practicable. The systems include Containment Spray, Safety Injection, Chemical and Volume Control, and Sampling System. The program shall include the following:
>
> - Preventive maintenance and periodic visual inspection requirements, and
> - Integrated leak test requirements for each system at least once per 24 months.

This describes a program intended to fulfill the requirements of NUREG-0737, Item III.D.1.1. This program will be completed by the COL applicant under COL 9.3(1) and the initial and periodic tests would be performed by the COL holder. Based on the above, the staff finds the applicant has appropriately described the recommended program to meet NUREG-0737, Item III.D.1.1 as required by GL-80-90, “Post TMI Requirements, NUREG-0737” and 10 CFR 50.34(f)(2)(xxvi).

9.3.2.4.4 Seismic Design and Quality Group Classification

DCD Tier 1, Subsection 2.7.2.6, “Process and Post-Accident Sampling System,” and Tier 2, Subsection 9.3.2.1, “Design Bases,” discuss the design bases for the PPASS. Compliance with GDC 1 and GDC 2 is based on the seismic design and quality group classification of sampling lines, components, and instruments for the PPASS conforming to the classification of the system to which each sampling line and component is connected. This is based on conformance to RG 1.29, RG 1.26, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” and RG 1.97, “Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants,” as stated in SRP Section 9.3.2. In addition to DCD Tier 1, Subsection 2.7.2.6, and DCD Tier 2, Subsection 9.3.2, the staff reviewed DCD Tier 2, Subsection 3.2, “Classification of Structures, Systems, and Components,” as it relates to the PPASS. DCD Tier 2, Table 3.2-1 lists the seismic design and quality group classifications for the PPASS. By comparing the seismic and quality group classifications for the PPASS to the connected systems, the staff determined that the design of the PPASS conforms to the seismic and quality guidance in RG 1.26, RG 1.29, and RG 1.97.

For sampling from primary coolant systems, which are designated Class 1, the PPASS components are designated Class 2. This is based on using a sampling line flow-limiting orifice that serves as a boundary between Class 1 and Class 2. This is acceptable because the orifice design meets the shutdown and cooling capability exception to the RCPB standards requirement in 10 CFR 50.55a(c)(1). The staff audit of the orifice design is documented in an audit report (ML16298A330). The portion of the PPASS designed seismic Category I and Safety Class 2 extends up to and including the first isolation valve outside containment, which is acceptable because it conforms to the guidance in RG 1.26 and RG 1.29. Based on the PPASS

components having the same quality and seismic classifications as the systems to which they are connected, the staff concludes that the PPASS meets the requirements of GDC 1 and GDC 2 as they relate to seismic and quality classification.

9.3.2.4.5 Tier 1 and ITAAC

DCD Tier 1, Section 2.7.2.6, "Process and Post-Accident Sampling System," describes the PPASS, including equipment and piping location/characteristics (Table 2.7.2.6-1), system component list (Table 2.7.2.6-2), instruments list (Table 2.7.2.6-3), and system ITAAC (Table 2.7.2.6-4. Tier 1, Section 2.7.2.6 also includes Figure 2.7.2.6-1, "Process and Post-accident Sampling System," a schematic diagram showing the functional arrangement of the PPASS, including safety-related components addressed in the Tier 1 design description, the ASME Code class boundaries, the containment boundary, and the valves that perform safety functions.

The PPASS components covered by ITAAC in Table 2.7.2.6-4 match the safety significance of the system (i.e., the piping and components designed to ASME Code, Section III, and seismic Category I). With respect to the PPASS, the staff finds these ITAAC adequate to ensure future plants will be built in accordance with the DC because the ITAAC include the applicable items listed in SRP Section 14.3 for fluid systems.

9.3.2.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.3(1)	The COL applicant is to provide the supply systems of the nitrogen gas subsystem, the hydrogen subsystem, the carbon dioxide subsystem, and the breathing air systems.	9.3.1.2.1, 9.3.5
9.3(2)	The COL applicant is to provide operation procedures and maintenance programs as related to leak detection and contamination control.	9.3.2.2.4, 9.3.5

As described above in Section 9.3.2.4.3, COL 9.3(1) addresses operational procedures and programs to address Three Mile Island action items. The staff finds the COL information item acceptable because it is appropriate for COL applicants and holders to provide procedure and program details. The staff finds COL 9.3(2) acceptable because it addresses as-built plant information that cannot be provided in the design certification.

9.3.2.6 Conclusion

The applicant has described extensive sampling of liquid and gaseous systems, including concentrations of impurities and added chemicals in RCS and secondary water, and fission products in water and gas space. The sampling locations and procedures are consistent with SRP 9.3.2, RG 1.21, and EPRI Primary and Secondary Water Chemistry Guidelines. Hence, they satisfy the requirements of GDC 13, 14, 26, 41, 60, 63, 64, 10 CFR 20.1101(b), 10 CFR 50.34(f)(2), and 10 CFR 52.47(b)(1). The staff concludes that the criteria of NUREG-0737 (as amended by SECY-93-087) are met for the PSS. In addition, based on the PPASS components having the same quality and seismic classifications as the systems to which they are connected, the staff concludes that the PPASS meets the requirements of GDC 1 and GDC 2 as they relate to seismic and quality classification. Thus the staff concludes, based on information supplied by the applicant, that all regulatory criteria have been satisfied.

9.3.3 Equipment and Floor Drainage System

9.3.3.1 Introduction

The equipment and floor drainage system (EFDS) collects radioactive and non-radioactive liquid waste from equipment and floor drains within the containment, auxiliary, compound, and turbine generator buildings during all modes of operation. The liquid waste is then transferred to processing and disposal systems: the LWMS and the waste water treatment facility (WWTF). The EFDS consists of collection sumps, sump pumps, valves, piping, and instrumentation.

9.3.3.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Section 2.7.2.5, “Equipment and Floor Drainage System.”

DCD Tier 2: DCD Tier 2, Section 9.3.3, “Equipment and Floor Drainage Systems,” provides a description of the EFDS. The portions of the EFDS that are outside the scope of the design certification (DC) are presented as conceptual design information (CDI) in DCD Tier 2, and delineated by double brackets ([[ ]]). A future COL applicant shall provide all the necessary information related to the conceptual design portion of the EFDS, which will then be reviewed by the staff.

The EFDS consists of drainage subsystems for radioactive, potentially radioactive, as well as non-radioactive drainage. All radioactive and potentially radioactive liquid waste is transferred to the LWMS, addressed in Section 11.2 of this report, which is capable of processing such waste. A schematic of the radioactive portion of the system is depicted in DCD Tier 2, Figure 9.3.3-1, “Radioactive Drain System Flow Diagram.”

The non-radioactive drainage subsystem includes the turbine generator building drain and miscellaneous building drainage systems, non-radioactive equipment vent and drainage system, roof drainage system, and wastewater transfer system. Non-radioactive liquid waste is normally transferred to the conceptually designed WWTF. Non-radioactive subsystems are segregated and isolated from radioactive and potentially radioactive subsystems systems except for the turbine generator building sumps discharge piping. In addition, radioactive and potentially radioactive subsystems are segregated by division and quadrant within the auxiliary building.

The turbine generator building sumps are capable of diverting their contents to the LWMS if radiation levels are detected.

Initial Test Program: Preoperational testing involving the EFDS are described under DCD Tier 2, Subsection 14.2.12.1, "Preoperational Tests."

ITAAC: The ITAAC associated with the EFDS are given in DCD Tier 1, Section 2.7.2.5, and DCD Tier 1, Tables 2.7.2.5-4, "Equipment and Floor Drainage System ITAAC," and 2.11.3-2.

Technical Specifications: There are no TSs associated with the EFDS.

9.3.3.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800," Section 9.3.3, Revision 3, March 2007, and are summarized below.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to preventing adverse effects to important-to-safety SSCs due to the failure of the EFDS, a nonsafety-related system, from natural phenomena such as earthquakes, tornadoes, hurricanes, and floods.

2. GDC 4, "Environmental and dynamic effects design bases," 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 EFDS.

3. GDC 60, "Control of releases of radioactive material to the environment," as it relates to design provisions to control suitably the release of radioactive materials in liquid effluents during normal reactor operation, including anticipated operational occurrences (AOOs).

4. 10 CFR 20.1406, "Minimization of contamination," as it relates to the standard plant design certifications and how the design and procedures for operation will minimize contamination of the facility and the environment, facilitate eventual decommissioning, and minimize to the extent practicable, the generation of radioactive waste.

5. 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 facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA, and NRC regulations.

9.3.3.4 Technical Evaluation

The staff reviewed the EFDS described in the APR1400 DCD, Revision 1, in accordance with SRP Section 9.3.3, Revision 3. The staff's evaluation of the EFDS is based upon information provided in the applicant's DCD, Revision 1, including Tier 1 and Tier 2.

9.3.3.4.1 GDC 2, Design bases for protection against natural phenomena

GDC 2 acceptance is based on the safety-related portions of the system being able to withstand the effect of natural phenomena (such as seismic event, floods, etc.) without the loss of capability to perform safety functions. SRP Section 9.3.3 (III.1.B) states that if a portion of the EFDS can result in the inundation of safety-related areas due to drain backflow from malfunction of active components, blockage, or the probable maximum flood, then such portion is safety-related.

As a part of GDC 2 review, the staff reviewed the applicant's determination of the "safety-related" portions of the system. According to DCD Tier 2, Section 9.3.3.3, "Safety Evaluation," the engineering safety feature (ESF) pump rooms are designed to prevent potential EFDS backflow flooding through the use of check valves in the discharge lines of the ESF pump room sump pumps. The ESF pump rooms contain the safety-related ESF pumps, the safety-related ESF pump room flood level instrumentation, and the non-safety-related ESF pump room sumps. The staff reviewed DCD Tier 2, Figure 9.3.3-1 and Table 3.2-1 but could not verify whether the EFDS is capable of preventing flooding after a seismic event because there was no safety classification or seismic classification information provided for these check valves. Therefore, RAI 244-8326 (ML15296A013), Question 09.03.03-01, requested the applicant to: (1) provide additional information in the DCD to indicate that the EFDS design is capable of preventing flooding from backflow utilizing the check valves, and (2) provide appropriate safety-related classification designation for these systems and components.

In letter dated December 17, 2015 (ML15351A159), the applicant responded that although the check valves are not designed as safety-related, the flood source from the floor drain sump area is blocked by the drain routing height differential and therefore flood conditions in the ESF pump room is not expected. The RAI response contains a reference schematic drawing visually depicting the elevations of the floor drain sump, ESF pump room sump, maximum flood height for the floor drain sump room, and the top piping height for the pipe discharging from the ESF pump room sump pump and supplying the floor drain sump. The schematic drawing also states the maximum flood height in the floor drain sump room is EL 64'-0" while the top piping height is EL 68'-9". Therefore, even if the passive check-valves were to fail, a flood in the floor drain sump rooms cannot flood backwards into the ESF sumps and will not adversely impact the ESF pumps. Therefore, the staff agrees that these check valves are not required to be safety-related and finds the RAI response acceptable. The staff considers RAI 244-8326, Question 09.03.03-01, closed.

Furthermore, SRP Section 9.3.3(III.3.A) states that the failure of any nonsafety-related or nonseismic Category I portions of the system should not preclude the safe operation of the safety-related seismic Category I EFDS portions. DCD Tier 2, Subsection 9.3.3.1.2, "Power Generation Design Bases," indicates that the ESF pump room flood level instrumentation and EFDS containment isolation valves are the only components that are safety-related and therefore designed to seismic Category I. This is verified in DCD Tier 2, Table 3.2-1, and Figure 9.3.3-1. The EFDS portions surrounding these seismic Category I portions are labeled as seismic Category II, which means their failure will not prevent the safety-related function of the containment isolation valves nor ESF room floor drain alarms.

The GDC 2 acceptance is based on the safety-related portions of the system being able to withstand the effect of natural phenomena such as flooding or a seismic event. Based on the

above review, the staff finds that the safety-related components of the EFDS are adequately defined and the system meets GDC 2.

9.3.3.4.2 GDC 4, Environmental and dynamic effects design bases

The GDC 4 acceptance is based on the system being able to prevent flooding that could adversely affect SSCs important to safety. SRP Section 9.3.3 Subsection II, "Acceptance Criteria," clarifies the acceptance of GDC 4 for the EFDS. It states that, for the EFDS, the purpose of GDC 4 is to assure the capability to provide the required drainage capability necessary to accommodate unanticipated flooding from pipe breaks, tank leaks, discharge from fire suppression systems, and other potential flooding sources. Therefore, the staff determined that the drainage capability of the EFDS for the flood protection should be addressed in DCD Tier 2, Section 9.3.3 for the EFDS to meet GDC 4 criterion. DCD Section 3.4.1, "Flood Protection," Section 3.4.1.3, "Flood Protection from Internal Sources," and Section 3.4.1.5, "Evaluation of Internal Flood Protection," discuss the flood protection design to withstand the effects of and to be compatible with the internal flooding of normal operation, maintenance, testing, and postulated accidents (e.g., pipe break, tank ruptures, etc.). The staff reviewed DCD Section 9.3.3, as it relates to Sections 3.4.1, 3.4.1.3, and 3.4.1.5, and determined that the EFDS is accounted for in the flood protection design as described in the above DCD sections. However, the staff could not find the information related to the required drainage capability necessary to accommodate unanticipated flooding from pipe breaks, tank leaks, discharge from fire suppression systems, and other potential flooding sources.

Based on the above review, staff issued RAI 114-8041 (ML15208A282), Question 03.04.01-06, in which the applicant was requested, in part, to: (1) clarify what drainage capability is assumed in the flood analysis, and to substantiate the assumption by supporting flood analysis calculations, which are not available in the DCD; (2) revise DCD Tier 2, Section 9.3.3 to address GDC 4 compliance in accordance with SRP Section 9.3.3 regarding drainage capability; and (3) components needed for flood protection may need to be identified as being safety-related and subject to GDC 2 requirements. Section 3.4.1 of this report provides the staff's evaluation of the applicant's response to RAI 114-8041, Question 03.04.01-06, in letter dated June 27, 2016 (ML16179A429).

GDC 4 requires, in part, that SSCs important to safety be "appropriately protected against dynamic effects, including…the effects of discharging fluids." As stipulated in item III.1.D of SRP Section 9.3.3, "Equipment and Floor Drainage System," if a failure or malfunction in a portion of the system could affect safety-related (including accident mitigation) SSCs adversely, it is safety-related in this area. DCD Tier 2, Section 9.3.3.2.5, "System Operation," and Figure 9.3.3-1, indicate that the ESF pump room sump contains one sump pump each, while the rest of the EFDS sumps contain redundant sump pumps. Upon review, the staff noted no further information regarding the failure or malfunction of an ESF pump room sump pump and the effects that could compromise the safety-related SSCs in that ESF pump room. Therefore, the staff issued RAI 244-8326, Question 09.03.03-02, requesting additional information as to how the EFDS design meets GDC 4 given a single failure of the only sump pump in any one of the ESF pump rooms.

In a letter dated December 17, 2015 (ML15351A159), the applicant responded that a single failure of the sump pump will not affect the ESF function because the drainage system is designed in accordance with the divisional and quadrant separation concept which includes the use of flood barriers to prevent propagation of flood water from one quadrant to any other.

Furthermore, the response states that the sumps have enough capacity to hold flood water within a single quadrant without pumping to the liquid treatment systems. The staff finds that the other safety train with ESF pump function would be unaffected and therefore be available because a flooding event in one quadrant would not leak in to any of the other quadrants thus leaving three quadrants unaffected. A safety train consists of two quadrants and thus one safety train remains unaffected. The applicant notes the ESF pumps are not required for safe shutdown. The staff finds this RAI response acceptable because it provides a clarification for the protection of the affected safety-related function. Therefore, RAI 244-8326, Question 09.03.03-02, is considered to be closed.

DCD Tier 2, Section 9.3.3, states that safety-related equipment is protected from flooding effects by concrete walls and water-tight doors with individual drainage paths. In addition, the drains for these rooms are separated from outside floor drains which are reviewed in Section 3.6.1 of this report. Therefore, water flooding the surrounding area should not impact safeguard components located inside the concrete walls. In addition, DCD Tier 2, Subsection 9.3.3.1.2, "Power Generation Design Basis," states that the EFDS is capable of preventing a backflow of water that may exist from maximum flood levels resulting from external or system leakage to areas of the plant containing safety-related equipment. The staff issued RAI 244-8326, Question 09.03.03-01, which requested the applicant to provide additional information in the DCD to demonstrate that the EFDS design is capable of preventing flooding from backflow utilizing the check valves. As stated above in Subsection 9.3.3.4.1 of this report, the staff found the applicant's response in letter dated December 17, 2015, acceptable.

GDC 4 acceptance is based on a system's ability to prevent flooding that could adversely affect SSCs important to safety, as a result of pipe breaks, tank ruptures, and other postulated accidents. The applicant has shown that the ESF equipment is protected from flooding by watertight concrete rooms equipped with individual floor drains and drainage paths with isolation valves and backflow prevention, as described in DCD Tier 2, Sections 3.4 and 9.3.3. Based on the above review, the staff concludes that the EFDS meets GDC 4.

9.3.3.4.3 GDC 60, Control of releases of radioactive materials to the environment

In order to meet GDC 60, the EFDS must be designed to control the release of radioactive material in liquid effluent, including operational occurrences, by preventing the inadvertent transfer of contaminated fluids to a non-contaminated drainage system for disposal. Since the EFDS usually consists of both radioactive and nonradioactive subsystems, this criterion applies. The inadvertent transfer of radioactive wastes to the nonradioactive portion of the system could result in radioactive releases to the environment. The APR1400 EFDS maintains the radioactive and potentially radioactive subsystems separate from the nonradioactive subsystems. In addition, the radioactive and potentially radioactive subsystems within the auxiliary building are separated by division and building quadrant. This further controls any unintended leakage by containing to one division and building quadrant. All floor and equipment drains within the auxiliary and containment buildings (areas with systems that handle radioactive liquids) are part of the radioactive subsystem. Therefore, any unintended leakage from any of these system locations would be properly controlled.

DCD Tier 2, Figure 9.3.3-1, shows the schematics for the various radioactive and potentially radioactive EFDS subsystems. This figure also shows the flow path connection to the LWMS, sumps, sump pumps, isolation valves, check valves, and SSC classifications. However, the staff found such information insufficient since it did not include the turbine generator building

EFDS. The turbine generator building EFDS is not expected to contain radioactive effluents during normal operation; however, there are systems located within the turbine generator building that may inadvertently leak and cause radioactive effluents into the EFDS. The turbine generator building EFDS normally connects to the waste water treatment facility which is a facility not equipped to handle radioactive liquid waste. Therefore, the staff the issued RAI 244-8326, Question 09.03.03-03, requesting the applicant to provide in the DCD a turbine generator building EFDS flow diagram schematic, including the interconnection to the LWMS and WWTF and SSC classification.

In letter dated January 11, 2016 (ML16011A193), the applicant responded with a reference schematic depicting the turbine generator building sumps, their interconnection, and the interconnection to the LWMS and WWTF systems. The schematic shows how the turbine generator building EFDS is normally aligned to the WWTF, but can be switched over to the LWMS upon detection of radiation by the radiation monitoring system (RMS). The staff noted that this reference schematic was not included in a DCD mark-up. Instead, the applicant proposed a COL information item to have the COL applicant provide the turbine generator building EFDS flow diagram. In addition, the applicant proposed another COL information item (COL 3.2(3)) for the COL applicant to provide the classification for the turbine generator building EFDS. The applicant reiterated that, for the other EFDS subsystems, the safety-related portions are identified in Figure 9.3.3-1 by means of seismic Category and quality group in accordance with DCD Tier 2, Table 3.2-1.

The staff finds these COL information items unacceptable because the turbine generator building is within the scope of the DCD certification. During a subsequent meeting, the staff asked the applicant to provide the turbine generator building EFDS reference schematic provided in the RAI response and the appropriate SSC classifications into the DCD as this is about the level of detail the staff requires. After two RAI rounds and two teleconferences, the applicant has not provided the TGB EFDS schematic nor the turbine generator building EFDS SSC classification in the DCD. Therefore, the staff will rely on the schematic docketed under the applicant’s response to RAI 244-8326, Question 09.03.03-03, dated January 11, 2016 (ML16011A193). The staff finds this acceptable because this system is not safety-related, the applicant has provided a basic COL information item (COL 9.3(4)) to have the COL applicant provide the site-specific TGB flowpath schematic for the EFDS and its interconnections, and has provided another COL information item (COL 3.2(3)) to have the COL applicant provide the classification of SSCs for the turbine generator building EFDS. The above COL information items will ensure the TGB EFDS will be provided for review and approval and, therefore, are acceptable.

According to SRP Section 9.3.3, Section III.1.C, “Review Procedures,” an EFDS portion is considered safety-related if it is connected in such a way that inadvertent contamination of non-radioactive portions of the EFDS can occur. The applicant stated that under normal operating conditions the turbine generator building sump’s non-radioactive contents are routed to the conceptual design waste water treatment facility and, if the turbine generator building sump contents become contaminated, the contaminated fluid can be detected by radiation monitors and diverted to the LWMS. During the review, the staff found that an inadvertent transfer of radioactive effluent is possible if the turbine generator building discharge valve fails to close. Also, if the radiation monitors fail, the turbine generator building sump discharge valve may not receive the proper signal to close. The staff issued RAI 244-8326, Question 09.03.03-04, requesting the applicant to provide additional information on how this valve changes the flow path and will operate to prevent inadvertent contamination.

In letter dated December 8, 2015 (ML15342A496), the applicant responded that the turbine generator building drain system consists of condenser pit sumps (north/south) and a condensate polishing area sump. All turbine generator building EFDS sump pumps discharge into the WWTF as long as no contamination fluid is present. The discharges from the condenser pit sumps and condensate polishing area sump are monitored for process radiation. Upon detection of radioactivity, the operating condenser pit sump pumps are stopped automatically by the RMS signal. The discharge valve to the WWTF is then closed and the discharge valve to condensate polishing area sump is opened simultaneously. Then, the sump pump is manually started. The flow is then diverted to the condensate polishing area sump.

Similar to the condenser pit sumps, the operating condensate polishing area sump pump is stopped automatically by the RMS signal upon detection of radioactivity. The discharge valve to WWTF is closed, and the discharge valve to LWMS is opened simultaneously. Then, the sump pump is manually started and the flow is then diverted to the LWMS. Thus, all radioactive liquid from any of the turbine generator building sumps will be diverted to the LWMS, a system equipped to handle radioactive effluents. The staff finds the response acceptable because tripping of the sump pump prevents further contamination of the WWTF regardless if valve fails to close. Additionally, by manually starting the sump pump after valve alignment to the appropriate LWMS facility, the operators would have the ability to ensure proper closure of the valve supplying the WWTF before starting sump pump, thereby preventing inadvertent flow back to the WWTF.

GDC 60 requires the EFDS to be designed to control the release of radioactive material in liquid effluent, including operational occurrences by preventing the inadvertent transfer of contaminated fluids to a non-contaminated drainage system for disposal. The applicant has shown that the EFDS adequately provided the means to control for radioactive, as described in DCD Tier 2, Sections 3.2 and 9.3.3, to include proper routing of effluents, SSC classification, and sump pump controls to prevent overflow or incorrect effluent routing. Based on the above review, the staff concludes that the EFDS meets GDC 60.

9.3.3.4.4 Conformance with 10 CFR 20.1406

DCD Tier 2, Subsection 9.3.3.2.6, “Design Features for Minimization of Contamination,” provides details of the EFDS design features to meet the requirements of 10 CFR 20.1406, “Radiological Criteria for Unrestricted Use,” and guidance of RG 4.21.

The EFDS is a nonsafety-related system that includes subsystems which may contain radioactive fluids from pipe leakage and equipment drainage. The DCD states the EFDS incorporates methods of leak identification and leakage control for the prompt assessment and response to manage collected fluids. The EFDS provides the following design features to minimize contamination:

1. removable sump liners made of stainless steel and encased in concrete,
2. sump liners are coated for cleaning and installed with rim seals to prevent infiltration of contaminated drainage,
3. flanged drain pipe connections to sumps permit removal of liners,
4. minimal use of embedded or buried piping through the use of pipe chases,

5. piping sleeves used between buildings with leakage directed back to originating facility,

6. sump levels are monitored in MCR and automatically start sump pumps to minimize overflow potential,

7. sumps/subsystems segregated for different handling and processing requirements,

8. RDS sumps contain sampling points to facilitate routine sampling and analyses,

9. utility connections, such as water and air, have a minimum of two barriers to prevent cross-contamination, and

10. turbine generator building sumps monitored for radiation and automatically stop flow to WWTF upon detection.

The staff reviewed DCD Tier 2, Section 9.3.3.2.6, as related to prevention and minimization of contamination from the EFDS. Consistent with RG 4.21, the EFDS design incorporates adequate measures, such as those listed above, to allow for sampling, leak detection, and contamination controls. Therefore, the staff concludes that the EFDS, as described in the DCD, meets the requirements of 10 CFR 20.1406 with regards to design features. The staff notes that DCD Tier 2, Chapter 12 contains the site-wide master program and procedures for all systems required to satisfy 10 CFR 20.1406.

9.3.3.4.5 Initial Test Program

Applicants for standard plant design approval must provide plans for preoperational testing and initial operations in accordance with 10 CFR 50.34(b)(6)(iii) requirements. Preoperational test requirements applicable to the equipment and floor drainage systems are described in DCD Tier 2, Subsection 9.3.3.4, “Inspection and Testing Requirements.” The preoperational initial plant tests identified in DCD Tier 2, Section 14.2, containing acceptance criteria involving the equipment and floor drainage systems include:

- Subsection 14.2.12.1.9, “Reactor Drain Tank Subsystem Test”[1].
- Subsection 14.2.12.1.10, “Equipment Drain Tank Subsystem Test”[1].
- Subsection 14.2.12.1.135, “Leakage Control and Detection of outside Containment System.”

The initial plant test program for APR1400 is evaluated in Section 14.2, of this report.

The staff reviewing DCD Tier 2, Section 3.4.1, “Flood Protection and Evaluation,” issued RAI 114-8041, Question 03.04.01-6, item f, requesting the applicant provide additional information regarding the require0ment for testing and maintenance throughout the life of the plant for the functional capability of the EFDS to drain the flooded water to the sump located in the lowest elevation of the building. This RAI requested the DCD include information on initial

1 The reactor drain tank and the equipment drain tank are part of the chemical volume and control system. However, these tanks do play a role in the equipment and floor drainage system. The acceptance criteria for the initial plant preoperational testing for these tanks reference descriptions found in DCD Tier 2, Section 9.3.3.

plant testing and programmatic control for this system function.

In a letter dated June 27, 2016, the applicant responded that they are not required to perform an initial plant test to verify the functional capability of drain paths due to the passive component feature of the embedded piping. The applicant did provide an indication that, to ensure adequate drainage after construction, system flushing will be performed as part of the system turnover to the operating licensee. To ensure that the functional capability and availability of the drainage system is maintained throughout the life of the plant, the COL applicant is to establish procedures and programmatic controls. The applicant proposed a revision to the DCD to incorporate COL 3.4(3) to address this availability of the floor drains. With regards to the review of DCD Tier 2, Section 9.3.3, the staff agrees with the rationale provided by the applicant that an initial plant test is not required for the passive features because they have no moving parts and their embedment reduces probability of damage. The staff further agrees with the applicant's performance of system flushing at system turnover to the licensee. The staff finds this acceptable as this testing will occur after construction but prior to fuel load and will assess the ability of all parts of the system to adequately drain liquids to the LWMS and WWTF. Therefore, the staff agrees that the proposed COL information item will help ensure the system is functional for its operating lifetime. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 114-8041, Question 03.04.01-06, item f, to be resolved and closed. The closure of this RAI can be found in Section 3.4.1 of this report.

9.3.3.4.6 ITAAC

DCD Tier 1, Section 2.7.2.5, "Equipment and Floor Drainage System," contains a description of the EFDS and includes ITAAC in DCD Tier 1, Table 2.7.2.5-4, "Equipment and Floor Drainage System ITAAC." The equipment and floor drainage systems are nonsafety-related systems with the exception of the containment isolation valves in the drainage piping from ESF equipment rooms and the flood alarms for the ESF pump room sumps. Table 2.7.2.5-4 contains design commitments to ensure the safety-related containment isolation valves are built according to ASME Code standards with corresponding ITAAC.

The staff finds that appropriate ITAAC are specified for the EFDS and consistent with the approach that is described in Tier 2, DCD Section 14.3. The staff concludes that, if the ITAACs for EFDS are performed and the acceptance criteria is met, there is reasonable assurance that the plant is built and will operate in conformity with the design certification, the provisions of the AEA, and the Commission's rules and regulations.

9.3.3.4.7 Technical Specifications

There are no TS sections for the EFDS. The system is not safety-related and is not required for safe shutdown; therefore the staff finds this acceptable.

9.3.3.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
3.2(3)	The COL applicant is to provide the classification of structures, systems, and components for the turbine generator building drain system.	9.3.3.1.2
3.4(3)	The COL applicant is to establish procedures and programmatic controls to ensure the availability of the floor drainage.	3.4.1.3
9.3(2)	The COL applicant is to prepare operational procedures and maintenance programs as related to leak detection and contamination control.	9.3.3.2.6
9.3(3)	The COL applicant is to maintain complete documentation of system design, construction, design modifications, field changes, and operations.	9.3.3.2.6
9.3(4)	The COL applicant is to provide the flow diagram of turbine generator building drain system and the interconnection from the auxiliary boiler building sump, and the flow diagram of CCW heat exchanger building drain system to LWMS or turbine generator building (TGB) sump.	9.3.3.2

9.3(6)	The COL applicant is to prepare the site radiological environmental monitoring program.	9.3.3.2.6

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for this system.

9.3.3.6 Conclusion

Based on the review above, the staff concludes that the APR1400 equipment and floor drainage system design is acceptable because it meets applicable regulatory requirements of GDC 2 regarding protection from natural phenomena, GDC 4 regarding protection against missiles and effects of pipe breaks, GDC 60 regarding control of release radioactive materials, 10 CFR 20.1406 regarding minimizing contamination, and 10 CFR 52.47(b)(1) regarding ITAAC.

9.3.4 Chemical and Volume Control System

9.3.4.1 Introduction

The CVCS is designed to maintain the required water inventory, chemistry, and purity in the RCS through its charging and letdown functions, provide flow to the reactor coolant pump seals, and control the boron neutron absorber concentration in the reactor coolant. Section 9.3.4.4 of this report summarizes the CVCS, which performs both safety and non-safety-related functions.

9.3.4.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in Tier 1 Section 2.4.6, “Chemical and Volume Control System.”

DCD Tier 2: The applicant provided a Tier 2 system description in Section 9.3.4, “Chemical and Volume Control System (Including Boron Recovery System),” summarized here, in part, as follows.

The DCD provides information regarding the CVCS design as a whole and on a component basis. The CVCS performs the following functions: (1) maintains the coolant inventory in the RCS for all modes of operation; (2) provides seal water flow to the RCS pumps; (3) provides makeup capability for small RCS leaks; (4) regulates the boron concentration in the reactor coolant during normal operation; (5) controls the reactor coolant water chemistry; (6) performs purification by removal of the fission and activation products in the reactor coolant; (7) borates the RCS for cold shutdown; and (8) provides pressurizer auxiliary spray water for depressurization of the RCS when none of the RCS pumps are operating.

The CVCS performs the following safety functions: (1) maintains the integrity of the RCPB; and (2) provides containment isolation of CVCS lines penetrating containment.

In general, the CVCS consists of charging pumps, a regenerative heat exchanger, a letdown heat exchanger, ion exchangers, filters, pumps, tanks, and associated valves, piping, and

instrumentation. The system parameters are given in DCD Tier 2, Table 9.3.4-2, "Chemical and Volume Control System Parameters."

The DCD also provides information regarding the system operation during plant startup, normal operation, plant shutdown, and accident operation. Furthermore, the DCD presents information on the availability and reliability, accident response, provisions for leakage detection and control, and a radiological evaluation of the CVCS.

ITAAC: The ITAAC associated with DCD Tier 2, Section 9.3.4 are given in DCD Tier 1, Section 2.4.6, Table 2.4.6-4, "Chemical and Volume Control System ITAAC."

Technical Specifications: The TS associated with DCD Tier 2, Section 9.3.4 are given in DCD Tier 2, Chapter 16, and evaluated in Chapter 16 of this report. These include Section 3.1.8, "Charging Flow," Section 3.3.14, "Boron Dilution Alarms," Section 3.9.1, "Boron Concentration," and chemistry-related requirements of DCD Tier 2, Section 3.4.15, "RCS Specific Activity."

9.3.4.3 Regulatory Basis

The relevant requirements of the NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.3.4, "Chemical and Volume Control System (PWR) (Including Boron Recovery System)," and are summarized below. NUREG-0800, Section 9.3.4 also provides review interfaces with other SRP sections.

1. GDC 1, "Quality standards and records," as it relates to system components being assigned quality group classifications and application of quality standards in accordance with the importance of the safety function to be performed.

2. GDC 2, "Design bases for protection against natural phenomena," as it relates to structures housing the facility and the system itself being capable of withstanding the effects of earthquakes.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to shared systems and components important to safety being capable of performing required safety functions.

4. GDC 14, "Reactor coolant pressure boundary," as it relates to assuring RCPB material integrity by means of the CVCS being capable of maintaining RCS water chemistry necessary to meet PWR RCS water chemistry TSs.

5. GDC 29, "Protection against anticipated operational occurrences," as it relates to the reliability of the CVCS to provide negative reactivity to the reactor by supplying borated water to the RCS in the event of anticipated operational occurrences, if the plant design relies on the CVCS to perform the safety function of boration for mitigation of design-basis events.

6. GDC 33, "Reactor coolant makeup," as it relates to the CVCS capability to supply reactor coolant makeup in the event of small breaks or leaks in the RCPB, to function as part of ECCS assuming a single active failure coincident with the loss of offsite power, and to meet ECCS TSs, if the plant design relies on the CVCS to perform the safety function of safety injection as part of ECCS.

7. GDC 55, “Reactor coolant pressure boundary penetrating containment,” as it relates to the CVCS capability of isolating containment.

8. GDC 60, “Control of releases of radioactive materials to the environment,” and GDC 61, “Fuel storage and handling and radioactivity control,” as they relate to CVCS components having provisions for venting and draining through closed systems.

9. 10 CFR 50.34(f)(2)(xxvi), as it relates to the provisions for a leakage detection and control program to minimize the leakage from those portions of the CVCS outside of the containment that contain or may contain radioactive material following an accident.

10. 10 CFR 50.63(a)(2), as it relates to the ability of the CVCS to provide sufficient capacity and capability to ensure that the core is cooled in the event of a SBO.

11. 10 CFR 52.47(b)(1), as it relates to 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 AEA, and NRC regulations.

Acceptance criteria adequate to meet the above requirements are given in SRP Section 9.3.4.

9.3.4.4 Technical Evaluation

The staff reviewed the DCD in accordance with the SRP, NUREG-0800, Section 9.3.4, the guidance provided in applicable RGs, and the NRC’s regulations.

The applicant designed the CVCS to provide a flow path for the continuous letdown and charging of the RCS in order to maintain water inventory based on the pressurizer level control system, provide RCP seal injection, provide auxiliary pressurizer spray, and maintain purity and chemistry of the RCS. The system accomplishes both safety-related and non-safety related functions. The staff reviewed the applicant’s DCD Tier 1 and Tier 2 information related to the CVCS in accordance with the guidance of SRP Section 9.3.4. The staff compared the applicant’s DCD information to the acceptance criteria in Section 9.3.4 of the SRP, as described in this evaluation. Staff acceptance of the design is based on meeting the requirements of GDCs 1, 2, 5, 14, 29, 33, 55, 60, and 61. Compliance with 10 CFR 50.34(f)(2) (xxvi), 10 CFR 50.63(a)(2), and 10 CFR 52.47(b)(1) is also required.

9.3.4.4.1 Normal Operation

The staff reviewed the CVCS’s design functions and confirmed that the applicant designed the CVCS to maintain integrity of the RCPB and provide containment isolation of CVCS lines to confine the release of any radioactivity from the containment following a postulated design basis accident.

The staff also confirmed that the applicant designed the CVCS to control boron concentration in the RCS to obtain optimum control element assembly positioning, compensate for reactivity changes associated with major changes in reactor coolant temperature, core burnup, and xenon variations, and provide shutdown margin for maintenance and refueling operations.

Furthermore, the CVCS will also maintain RCS water inventory, thereby compensating for reactor coolant contraction or expansion resulting from changes in reactor coolant temperature and for other coolant losses or additions.

The staff further noted that the CVCS provides injection water at the proper temperature, pressure, and purity for the reactor coolant pump seals and collects the controlled bleedoff from the reactor coolant pump seals, maintains the chemistry and purity of the reactor coolant during normal and shutdown operations, and provides auxiliary pressurizer spray for (1) control of pressurizer pressure during the final stages of shutdown, and (2) pressurizer cooling.

The staff's review of the DCD concludes that the major CVCS components include a regenerative heat exchanger, a letdown heat exchanger, purification and deborating ion exchangers, a volume control tank (VCT), two multi-stage centrifugal charging pumps, an auxiliary charging positive displacement pump (ACP), a boric acid batching tank, a boric acid storage tank, two boric acid makeup pumps, a holdup tank, a gas stripper, two holdup pumps, a boric acid concentrator, a reactor makeup water tank, two reactor makeup water pumps, and associated piping and valves. The applicant provided flow diagrams and CVCS piping and instrumentation diagrams (P&ID) in DCD Tier 1, Figure 2.4.6-1, "Chemical and Volume Control System," and DCD Tier 2, Figure 9.3.4-1, "Chemical and Volume Control System Flow Diagram." The staff reviewed the drawings and confirmed that they provide equipment locations along with system interconnections, pressure and temperature ratings, and safety or seismic classifications. The applicant provided the principal component data summary of the CVCS in DCD Tier 2, Table 9.3.4-1, "Principal Component data Summary." The staff reviewed the component data summary, including design pressures and materials, and confirms that the applicant used materials appropriate for the chemical environment of the CVCS.

The staff noted that during normal operation, letdown flow from the RCS passes through the tube side of the regenerative heat exchanger and the letdown heat exchanger. The temperature reduction occurs to cool the letdown water to purification subsystem operating conditions. The applicant stated that it reduced the letdown fluid pressure from RCS pressure to purification subsystem operating conditions in two stages. The first stage occurs at the letdown orifices, and the second occurs at the letdown control valves downstream of the orifices. The letdown flow is then filtered, monitored via a process radiation monitor and a boronometer, purified via the purification ion exchanger, and sprayed into the VCT through the hydrogen overpressure gas. The VCT water is then sucked into the inlet of the charging pumps. From there, the water passes through charging restricting orifices and the charging flow control valves. Finally, a portion of the charging flow is diverted to the RCP seal injection system through one of two RCP seal injection filters. The shell side of the regenerative heat exchanger injects the un-diverted charging fluid back into the RCS.

The staff confirmed that the design includes a pressurizer level setpoint program that varies as a function of the RCS average temperature, and the pressurizer level control system maintains the reactor coolant inventory. If the VCT level gets to a high-level setpoint, the pre-holdup ion exchanger and gas stripper will divert letdown flow to the holdup tank. If the VCT level gets to a low-level setpoint, normally with the makeup system set for automatic, the BAST and reactor makeup water tank (RMWT) will provide a preset blend of boric acid and demineralized water to the VCT, respectively. A low-low VCT level signal will switch the charging pump suction to the BAST, and then cause the VCT outlet valves to close.

The staff noted that the design provides two centrifugal charging pumps with minimum flow protection to preclude pump damage under dead-heading conditions. The charging pumps are not safety-related; thus, the staff concluded that the applicant's minimum flow protection for the charging pumps is adequate commensurate with the pump's importance to safety. Additionally, the applicant's CVCS design provides an auxiliary charging pump parallel to the two centrifugal pumps to maintain RCP seal injection if the two centrifugal pumps are unavailable.

The staff noted that the CVCS will remove oxygen from the coolant via hydrazine when the reactor coolant temperature is below 150 °F, and when the reactor is at normal operating power, the hydrogen cover gas in the VCT provides oxygen scavenging. Lithium-7 hydroxide (LiOH, enriched in Lithium-7) maintains the coolant's pH.

The staff noted that the operators normally control the boron concentration via feed and bleed. To change the boron concentration, the makeup system supplies either reactor makeup water or boric acid to the VCT, and the pre-holdup ion exchanger and the gas stripper divert the letdown stream to the holdup tank. At the end of a fuel cycle, with low boric acid concentrations in the coolant, the operators use the deborating ion exchanger to remove boron from the reactor coolant because the feed-and-bleed method becomes inefficient.

The staff confirmed that the applicant designed the APR1400 with the capability of boron recycling. The boron recovery subsystem of the CVCS accepts letdown flow diverted from the VCT as a result of feed-and-bleed operations for shutdowns, startups, and boron dilution over core life. The diverted letdown flow passes through the purification filter, the purification ion exchanger, as well as the pre-holdup ion exchanger and the gas stripper, ultimately making its way to the holdup tank. After a sufficient volume accumulates in the holdup tank, the holdup pump forces the fluid into the boric acid concentrator, where the fluid is concentrated with boron from 4,000 ppm to 4,400 ppm. From there, the concentrated boric acid is discharged, normally, to the BAST.

The staff determined that the makeup subsystem of the CVCS provides a means of changing the RCS boron concentration. The boric acid batching tank (BABT) initially introduces boron into to the CVCS. There, reactor makeup water is added to the BABT and heated by immersion heaters. Boric acid powder is then added to the heated fluid in the BABT where a mixer agitates the fluid. Boric acid concentrations of up to 12 wt% can be prepared. Due to these high concentrations of boric acid in the BABT, electric immersion heaters maintain the temperature of the solution high enough to preclude precipitation. From the BABT, the concentrated boric acid solution is drawn into the boric acid batching eductor and diluted by fluid being circulated from the BAST or the IRWST via the boric acid makeup pump. The reactor makeup water pump can take suction from the reactor makeup water tank and pump the water through the eductor. The boric acid makeup pump normally supplies boric acid stored in the BAST to the RCS, while the reactor makeup water pump supplies the reactor makeup water stored in the RMWT to the RCS.

The four operational modes of the CVCS are dilute, borate, manual, and automatic. The dilute mode introduces a preset quantity of reactor makeup water into the VCT or directly into the charging pump suction header via the VCT bypass valve, at a preset rate. Similarly, the borate mode introduces a preset quantity of boric acid into the VCT or directly into the charging pump suction header via the VCT bypass valve, at a preset rate. The manual mode allows for operator control of reactor makeup water and boric acid flow rates to give any blended boric acid solution between 0 and 4,400 ppm. The automatic mode takes a preset blended boric acid

solution and introduces it into the VCT based on the VCT level controller. The operators have the capability of adjusting the preset solution concentration in the automatic mode to match the boric acid concentration of the RCS.

The staff noted that the applicant claimed that heat tracing is not required for the majority of the CVCS because boron concentrations will not exceed 2.5 wt% (4,400 ppm). However, for portions of the system that can contain higher concentrations (e.g. the BABT discharge lines, which can contain up to 12 wt% boron) and for lines that are located in the yard (where external temperatures can get low), heat tracing is provided. The staff confirmed that solubility limits of boron in water are higher than what the applicant designed for non-heat traced lines of the CVCS. Therefore, the staff accepts the applicant's design related to heat tracing of CVCS lines that can contain high concentrations of boric acid and lines which are located in the yard.

The staff confirmed that the applicant designed the CVCS with a seal injection subsystem to provide cooling to the RCP seals. A portion of the charging flow is diverted downstream of the charging flow control valves and directed to the seal injection filters and seal injection flow control valves. The filters remove insoluble particulates that may otherwise damage the RCP seals. The seal injection flow control valves maintain the desired flow to each pump. The auxiliary charging pump can be aligned to accomplish seal injection if both charging pumps are incapable of providing seal injection flow.

The staff confirmed the design of the gas stripper subsystem to remove hydrogen and fission gases from the RCS. This helps in precluding the buildup of explosive gas mixtures in the holdup tank, as well as minimizing the release of radioactive fission product gases in aerated vents or liquid discharges.

The applicant included provisions in the CVCS design to isolate the purification and deborating ion exchangers, as well as the process radiation monitor and boronometer, when the letdown fluid temperature exceeds the allowable resin temperature.

The staff confirmed that there are two purification ion exchangers in the CVCS, each containing a mixed-bed resin with the necessary connections to replace the resin by sluicing where screens prevent the release of resin though vent and effluent nozzles. The applicant designed each ion exchanger to pass the maximum letdown flow and be mechanically identical to each other. The staff noted that one purification ion exchanger has the volume of resin necessary to continuously remove impurities and radionuclides from the RCS over core life, and the other ion exchanger is used intermittently to control lithium concentration in the reactor coolant.

The staff noted that during APR1400 plant startup, prior to establishing a pressurizer steam bubble, the RCS is in a water-solid condition with one charging pump, one letdown control valve, and one charging control valve in operation. All letdown orifice isolation valves and the orifice bypass valve are fully opened. The operators adjust the charging control valve manually to allow minimum charging flow. The operators form a pressurizer steam bubble by adjusting RCS pressure via the letdown control valve and then increasing the pressurizer temperature until it is at a saturation condition. Subsequently removing reactor coolant from the RCS causes flashing in the pressurizer steam space. Following the establishment of the pressurizer steam bubble, the operators place the pressurizer level and pressurizer pressure controllers in automatic mode after manual control of the letdown control valve and letdown orifice bypass flow control valve has allowed the pressurizer level and pressure to become within some specified band.

During plant shutdown, the staff noted that the applicant designed the CVCS to be used to maintain pressurizer level, reduce fission gas activity and hydrogen concentration, increase boron concentration, and aid in cooling/depressurizing the pressurizer while maintaining its boron content. The CVCS interfaces with the shutdown cooling system (SCS), so that when the SCS is operational, shutdown cooling flow can be purified as well.

Consistent with the SRP, the staff's review of the CVCS during normal operation, component descriptions, and piping and instrumentation diagrams confirmed:

1. Isolation exists in portions of piping requiring it (e.g. containment isolation, pump isolation, etc.);
2. Safety-related components of the CVCS (e.g. isolation valves) are not shared between units and GDC 5 is met;
3. Boration is accomplished with a designated boric acid source containing the boric acid concentration necessary to shutdown the reactor;
4. Minimum flow protection is provided for the CVCS pumps and is adequate;
5. Heat tracing is provided on pipes and tanks, where appropriate, to preclude boric acid precipitation;
6. Over-temperature protection is provided for the purification and deborating ion exchangers and is adequate;
7. A means for monitoring filter/ion exchanger differential pressures is available;
8. Equipment is provided capable of maintaining the reactor coolant purity;
9. Material is compatible to reduce corrosion and thus reduce the probability for abnormal leakage, rapid propagating failure, or gross rupture of the RCPB; and
10. The CVCS is designed to control releases of radioactive materials to the environment by venting and draining through closed systems and meets GDC 60 and 61.

9.3.4.4.2 Accident Operation

The staff notes that the APR1400 CVCS is not required to perform any accident mitigation or safe shutdown function other than its containment isolation function and function to maintain the RCPB integrity. The applicant assigned the safety functions regarding accident mitigation and safe shutdown to dedicated safety systems. For example, the applicant credited the Safety Injection System (SIS), reviewed in Section 6.3, "Safety Injection System," of this report, for RCS inventory control and boration in the Chapter 15 accident analyses.

While the CVCS is not required to perform any accident mitigation or safe shutdown function, the CVCS is important to safety for the normal day-to-day operation of the plant. The staff reviewed DCD Tier 2, Section 9.3.4, with this in mind, and confirmed that the applicant designed the CVCS with a degree of reliability and redundancy commensurate with its level of importance to the safety of the plant and accepted industry standards.

In accordance with GDC 33 the design shall contain a system to supply reactor coolant makeup for protection against small breaks in the RCPB. The system shall be designed to assure that the system safety function can be accomplished, assuming only offsite power is available or only onsite power is available, using the piping, pumps, and valves which are used to maintain coolant inventory during normal reactor operation. The staff reviewed the applicant's design and confirmed that the CVCS has the capacity to replace flow lost to containment due to small RCS leaks (anything beyond the capacity of the CVCS makeup is considered a small-break LOCA and is reviewed in Chapter 15.6.5, "Loss-of-Coolant Accidents Resulting from the Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary," of this report) and has the provisions for being powered from either onsite or offsite power sources. The staff also confirmed that the CVCS is not required to supply reactor coolant makeup to mitigate small breaks in the RCPB; the applicant relied upon the safety injection system as the safety-related system to accomplish this function (GDC 35). Nevertheless, the staff noted that the CVCS is important-to-safety and that the operators can operate the charging pumps in an accident scenario to reduce challenges to the SIS for certain sized small breaks. In accordance with SRP 9.3.4, Acceptance Criteria II.6, the staff determined that while the APR1400 CVCS is not a part of the SIS, nor is it safety-related, the applicant's design of having a separate, important-to-safety, system for normal operation inventory control and a safety-related system for accident operation inventory control meets the intent of the SRP Acceptance Criteria relating to GDC 33.

Similarly, in accordance with GDC 29, the staff noted that the APR1400 does not rely upon the CVCS to provide negative reactivity to the reactor in the event of AOOs; the APR1400 relies upon the safety-related SIS to perform the safety function of boration for AOOs. Therefore, GDC 29 as called out by SRP 9.3.4 does not apply to the APR1400 CVCS because the APR1400 CVCS is not credited in Chapter 15 for AOO mitigation. However, the staff further noted that the CVCS is important-to-safety, and can help reduce challenges to the SIS during an AOO.

The APR1400 design includes an onsite alternate AC (AAC) power source to cope with a SBO. The AAC power source provides power to the auxiliary charging pump which provides RCP seal injection. Chapter 8 of this report contains the staff's evaluation of the SBO analysis. The staff reviewed and confirmed that the CVCS design employs an ACP which provides RCP seal injection during a SBO as accepted by the SRP.

The staff reviewed the CVCS's safety function of containment isolation to confirm that the applicant has an adequate containment isolation scheme in accordance with GDC 55. GDC 55 requires the applicant to provide containment isolation valves in lines that are a part of the reactor coolant pressure boundary and penetrate primary reactor containment. The staff looked at several CVCS containment isolation valves which included CV-524 (charging containment isolation), CV-505 and CV-506 (RCP controlled bleedoff containment isolation), CV-509 (IRWST makeup line containment isolation), and CV-255 (RCP seal injection containment isolation). The following paragraphs document the staff's evaluation of the CVCS containment isolation function.

Regarding CV-524 and CV-255, the applicant stated in DCD Tier 2, Section 9.3.4.3.2, "Accident Response," that neither a containment isolation actuation signal (CIAS) nor a safety injection actuation signal (SIAS) isolates the charging line nor the RCP seal injection line. The staff noted that CV-524 and CV-255, according to DCD Tier 1, Table 2.4.6-2, "Chemical and Volume Control System Components List," and Figure 2.4.6-1, are normally open and fail as-is on a loss

of motive power. However, DCD Tier 1, Table 2.4.6-2 indicates that the active safety function of CV-524 and CV-255 is to close. The staff could not determine if the applicant's isolation scheme for the charging line and seal injection line penetrating containment complies with GDC 55 because the automatic isolation valve provided outside of containment could fail in the open position during an accident. Therefore, on August 20, 2015, the staff issued RAI160-8174 (ML15235A002), Question 09.03.04-02, to address this issue. By response dated October 29, 2015, (ML15303A440), and supplemented by an additional response dated April 22, 2016 response (ML16113A455), the applicant clarified with the staff that, as allowed by GDC 55, a containment isolation valve should be designed to take the position of greater safety. In the case of CV-524 and CV-255, that position is open. This allows for the charging system to continue to provide coolant to the reactor and RCP seals which helps reduce the challenges to the safety-related SIS. Furthermore, CV-524 and CV-255 are powered from a Class 1E power source, which would allow the operators to remote-manually close the valve if necessary during an accident. Based on the above, the staff considers RAI 160-8174, Question 09.03.04-02 resolved and closed.

Similarly for CV-509, the IRWST makeup line containment isolation valve, the staff noted that according to DCD Tier 1, Table 2.4.6-2 and Figure 2.4.6-1, CV-509 fails as-is on a loss of motive power; however, the active safety function of this valve is to close. Following the guidance provided in SRP 9.3.4, the staff was unable to determine if the applicant’s design contains adequate provisions for isolating the IRWST makeup line during accident scenarios. Therefore, on August 20, 2015, the staff issued RAI 160-8174, Question 09.03.04-05, to address this issue. In their letter of October 29, 2015 (ML15303A440), the applicant provided a response addressing the staff’s concern. The applicant responded by clarifying that the IRWST makeup line containment isolation valve (CV-509) is normally closed and rarely used during normal plant operation. CV-509 is only opened when makeup to the IRWST is necessary. The applicant stated that if the IRWST level is lowered, having the CVCS makeup capability provides for greater safety. The staff confirmed that this meets the intent of GDC 55, which allows automatic isolation valves to take the position which “provides greater safety.” Furthermore, the staff confirmed that CV-509 has Class 1E backup power, as presented in DCD Tier 1, Table 2.4.6-2, which would allow the operators to manipulate the valve during an accident if necessary. The staff considers RAI 160-8174, Question 09.03.04-5 resolved and closed.

In addition, the applicant stated in DCD Tier 2, Section 9.3.4.2, “System Description,” that neither a CIAS nor a SIAS isolates the RCP controlled bleedoff (CBO) line isolation valves (CV-505 and CV-506); however, a CSAS does isolate the CBO isolation valves. In accordance with GDC 55 and following Section 9.3.4 of the SRP, the staff was unable to determine if the applicant’s design contains adequate provisions for isolating the RCP CBO line during accident scenarios. Therefore, on August 20, 2015, the staff issued RAI 160-8174, Question 09.03.04-04 to address this issue. On October 29, 2015, the applicant provided a response (ML15303A440) addressing the staff’s concern. The applicant responded by stating for accident mitigation the RCP CBO line remains open because it is advantageous to provide seal injection flow to the RCPs during an accident to prevent the seals from failing. The staff confirmed that this meets the intent of GDC 55, which allows automatic isolation valves to take the position which “provides greater safety.” The staff considers RAI 160-8174, Question 09.03.04-04 resolved and closed.

Consistent with the SRP, the staff's review of the CVCS during accident operation confirmed:

1. Essential portions of the CVCS are isolable from the nonessential portions of the system as verified by the piping and instrumentation diagrams and system descriptions;

2. The safety function of the CVCS (i.e. containment isolation) will be maintained as required in the event of adverse environmental phenomena;

3. The CVCS is not required to perform emergency safety injection; however, can help reduce the challenges to the safety injection system for a certain range of break sizes;

4. The CVCS safety-related components (e.g. isolation valves) will accomplish the safety-related function of containment isolation in the event of a single failure; and

5. The CVCS is designed to operate during a SBO.

9.3.4.4.3 Vacuum Conditions Mitigation

The staff reviewed the CVCS design regarding wall inward buckling of tanks that can contain primary system water. In DCD Tier 2, Section 9.3.4.3.4, "Prevention for Wall Inward Buckling and Failure in Tanks," the applicant stated that "the VCT is designed to withstand vacuum conditions to prevent wall inward buckling and failure." The staff noted that the applicant provided no other information regarding vacuum condition mitigation for the VCT. Following the guidance provided in SRP Section 9.3.4, the staff was unable to determine if the applicant provided adequate wall inward buckling protection for the VCT. Therefore, on August 20, 2015, the staff issued RAI 160-8174, Question 09.03.04-01 to address this issue. On October 29, 03-012015, the applicant provided a response (ML15303A440) addressing the staff's concern. The applicant responded by stating that the VCT is designed and fabricated to assure structural integrity in accordance with the ASME Boiler and Pressure Vessel Code, Section III, ND-3133 and ND-3324 by considering the external and internal design pressures. The staff confirmed that the design provides adequate assurance for the prevention of wall inward buckling because ASME Boiler and Pressure Vessel Code Section 3 and its addenda are endorsed by the NRC. The staff considers RAI 160-8174, Question 09.03.04-01 resolved and closed.

9.3.4.4.4 Materials and Chemistry Aspects

The staff reviewed DCD Tier 2, Section 9.3.4 using the guidance of NUREG-0800, SRP Section 9.3.4. This SRP Section references the EPRI PWR Primary Water Chemistry Guidelines (hereafter referred to as the "EPRI Guidelines") as the standard by which water chemistry should be judged. Although the staff does not formally review or issue a safety evaluation of the various EPRI water chemistry guidelines, the staff recognizes the EPRI Guidelines as representing industry best practices in water chemistry control. Extensive experience in operating reactors demonstrates that following the EPRI Guidelines minimizes the occurrence of corrosion-related failures. Further, EPRI periodically revises the EPRI Guidelines to reflect evolving knowledge with respect to best practices in chemistry control. During the review, the staff noted that the applicant cited a specific revision of the EPRI Guidelines in the DCD. The staff could not conclude that a COL applicant, incorporating this design by reference, would be required to meet the latest revision of the EPRI Guidelines. Therefore, on December 15, 2015, the staff issued RAI 336-8367 (ML15349A760), Question 05.02.03-15 to

request the applicant to explain how COL applicants will meet the latest revision of the EPRI Guidelines at the time of submittal of any APR1400 COL application. On January 25, 2016, the applicant provided a response to this question addressing the staff's concern (ML16025A241). The applicant agreed to include two COL information items in DCD Tier 2, Section 5.2.3, "Reactor Coolant Pressure Boundary Materials," and DCD Tier 2 Section 9.3.4 to ensure the COL applicant references the latest edition of the EPRI Guidelines and provides threshold values and operator actions for primary water chemistry that are in compliance with the latest version of the EPRI Guidelines. The staff determined that these COL information items ensure the APR1400 primary water chemistry will conform to the latest EPRI Guidelines and thus will follow industry best practices. The two COL information items were incorporated into DCD Tier 2, Chapters 5 and 9, of Revision 1 to the DCD as proposed. The staff; therefore, finds the APR1400 RCS primary water chemistry control acceptable in accordance with GDC 14 as it relates to primary water chemistry, and RAI 336-8367, Question 05.02.03-15 is resolved and closed.

RCS Coolant Chemistry

The CVCS accomplishes purification of RCS water via letdown flow through purification ion exchangers and filters. DCD Tier 2, Section 9.3.4.2, describes this system in detail. The system contains two mixed bed resin ion exchangers; however, the design requires only one to be used during normal operation. The operators can hold one in reserve in case performance of the first diminishes. The applicant designed each purification ion exchanger to contain sufficient resin to last for an entire core life. The specified flow rate through a single ion exchanger is 80 gpm (0.0114 m^3/s), which implies that, on average, the entire RCS volume flows through the purification system in less than 24 hours. The staff finds the CVCS purification system adequate to control concentrations of impurities and additives in RCS water.

SRP Section 5.2.3 also covers reactor coolant chemistry, where the primary concern is the compatibility of RCS materials with the coolant. This staff reviewed this subject in greater detail in Section 5.2.3 of this report, where it is established that materials are compatible with primary system coolant and the RCS water doesn't negatively affect the performance of these materials, provided that adequate chemistry control occurs. For that reason, primary water chemistry control is the subject of both this section and Section 5.2.3.

In Revision 0 of the DCD, Tier 2, Tables 9.3.4-1A, "Reactor Coolant Plant Shutdown Operation Specifications," 9.3.4-1B, "Reactor Coolant Detailed Plant Startup Operation Specifications," and 9.3.4-1C, "Reactor Coolant Detailed Power Operation Specifications," show the limits for constituents in coolant. During the review, the staff noted that the applicant did not provide a detailed discussion of dissolved oxygen, ammonia, lithium, dissolved hydrogen, fluoride, nor sulfate. Therefore, on December 15, 2015, the staff issued RAI 336-8367, Question 05.02.03-16, to request that the applicant provide a more detailed explanation of the chemical specification in the tables as to be consistent with the EPRI Guidelines. On January 25, 2016, the applicant provided a response to this question addressing the staff's concern. In the response, the applicant provided an explanation on how its limiting values are equal to, or more stringent than, the Action Level 2 values from the EPRI Guidelines. The staff reviewed the applicant's values and response and confirmed that the provided limits for the RCS water chemistry control parameters are the same, or more stringent than the limits recommended by the EPRI Guidelines. The response included deletion of Tables 9.3.4-1A, -1B, and -1C, and relocation of the primary water chemistry specifications to a revised Table 5.2-5, and new Tables 5.2-6, -7, and -8, in Tier 2 Section 5.2.3.2.1. The changes

to DCD Tier 2, Chapters 5 and 9, were incorporated into Revision 1 of the DCD as proposed in the January 25, 2016, letter. Therefore, the staff finds the description of primary water chemistry acceptable with respect to chemistry control parameters, and RAI 336-8367, Question 05.02.03-16 is resolved and closed. Additional discussion on this topic can be found in Section 5.2.3 of this report.

The CVCS controls the pH by regulating the inventory of LiOH. The operators prepare a concentrated solution in a chemical mixing tank, from which they arrange direct addition to RCS water. LiOH is widely used throughout the industry for primary system pH control in operating reactors. During the review, the staff noted that the DCD did not provide detail on what pH control program the applicant will use, nor how that program will meet the EPRI Guidelines. Therefore, on December 15, 2015, the staff issued RAI 336-8367, Question 05.02.03-18, to request that the applicant provide a description of how it will control the pH in the RCS and how this pH control program will meet the EPRI Guidelines. On January 25, 2016, the applicant provided a response to this question that included a description of its pH control program that complies with the EPRI Guidelines. The applicant also stated that prior to initial criticality, the boron will range from near zero to 4,400 ppm, and lithium from 0 to 3.5 ppm. This will give a pH range of 4.2 to 10.7. Furthermore, the applicant stated that during operation, boron will range from near zero at the end of cycle to 4,400 ppm at refueling. Lithium, which the applicant uses as the alkalizing additive, will vary from 0.2 to 3.5 ppm. The applicant also agreed to add a graphic representation of the expected pH range during operation. The staff confirmed that the applicant's pH control program meets the EPRI Guidelines and is, therefore, acceptable. In addition, the staff confirmed that the pH graph was incorporated into Revision 1 of the DCD as proposed. Therefore, RAI 336-8367, Question 05.02.03-18 is resolved and closed.

At plant startup, the operators inject hydrazine into the RCS to scavenge oxygen. However, during normal operation, the operators control free oxygen by supplying hydrogen gas, which reacts with oxygen to form water. Radiolysis products catalyze this reaction in the coolant as it passes through the core. The staff noted that radiation also catalyzes the reverse reaction (i.e., the separation of water into hydrogen and oxygen molecules). Thus, the success of this method in reducing free oxygen depends on providing an excess amount of hydrogen. The CVCS supplies hydrogen to the coolant by maintaining a gas space of hydrogen in the VCT, which is downstream of the ion exchangers. The charging system then injects this water into the RCS directly from this tank. By maintaining hydrogen concentrations, as specified in DCD Tier 2, Table 5.2-8, the concentration of oxygen in the RCS is sufficiently low to protect materials from oxidative degradation in accordance with GDC 14. Additional discussion of scavenging oxygen in the RCS can be found in Section 5.2.3 of this report.

Borated Water Chemistry

Boric acid is initially present in the RCS for reactivity control, and its concentration can be gradually altered over the course of an operating cycle. The operators monitor inventory of boric acid and maintain it via the CVCS. To change concentration, the makeup part of the CVCS provides either reactor makeup water or boric acid to the VCT, and the operators can divert letdown to the holdup tank.

The operators mix concentrated boric acid solution (of up to 12.0 wgt% H_3BO_3) in the boric acid batching tank. To avoid precipitation, electric immersion heaters maintain the solution agitated and at a temperature high enough to preclude precipitation. In addition, the CVCS design equips this tank and the necessary discharge lines with heat tracing to further avoid precipitation

in the lines. The rest of the system operates at a lower boric acid concentration (maximum 2.5 wgt% H_3BO_3) and does not require heat tracing as stated earlier. The staff finds that this plan will preclude precipitation, ensure adequate mixing, and limit impurity concentrations of boric acid solutions.

Borated water discharged from various sources within the RCS is sent to a holdup tank to await reprocessing. Water first passes through the pre-holdup ion exchanger (to remove lithium and other radioactive ions), then to a gas stripper to remove hydrogen and fission gasses before arriving to the holdup tank. The boric acid concentrator works as a batch process. When the holdup tank has a sufficient volume, the operators will pump the water to the concentrator where the operators monitor it for proper boron concentration. If the concentration is too high, the volume passes through a boric acid condensate ion exchanger where boric acid is removed. The staff finds that applicant's plan for recycling boric acid solution ensures that the boric acid concentration is as intended and impurity concentrations are within specified limits in accordance with GDC 14.

9.3.4.4.5 Indications and Alarms

The applicant stated that the CVCS is normally operated from the MCR. System instruments provide input signals to monitor parameters and generate alarms in the MCR and RSR. The applicant provided in the design indications and alarms for temperature, pressure, level, flow, radiation, and boron. The staff reviewed system monitoring and control provisions described in DCD Tier 2, Section 9.3.4.5, "Instrumentation Requirements," to verify the adequacy of system instrumentation, indication, and alarm.

The staff's review confirmed adequate letdown heat exchanger temperature control as well as adequate purification and deborating ion exchanger protection. The design provides temperature measurements and temperature alarms at several points in the letdown line. The operators are able to measure the temperature at the letdown heat exchanger inlet and the letdown heat exchanger outlet. The temperature instrumentation provided at the letdown heat exchanger outlet controls the component cooling water flow through the letdown to maintain proper letdown temperature for purification system operation. This temperature instrument provides a close signal for the letdown isolation valve (CV-515) on high-high temperature, which has to be manually reset to restore normal letdown flow. The applicant also provided temperature instrumentation upstream of the letdown control valves. These instruments actuate valves which divert letdown flow around the purification and deborating ion exchangers, the process radiation monitor, and the boronometer on high temperature. In addition, letdown flow is restricted through the letdown flow orifices on high temperature.

The staff's review also confirmed that the applicant provided differential pressure instruments to protect filters and ion exchangers from high differential pressures, level instrumentation is provided to protect the charging pumps from cavitation and mitigate overfilling of the VCT, a boron dilution alarm is provided to alert the operators of an inadvertent dilution event, and pressure instrumentation is provided to control letdown pressure and start and stop pumps when necessary. In addition to the instrumentation discussed above, the staff reviewed additional instrumentation, indication, and alarms to assure adequate system operation, control, and monitoring abilities by the reactor operators. Consistent with SRP Section 9.3.4, Section III, Subsection 1.f, the staff determined that the applicant designed the CVCS with adequate system instrumentation, indication, and alarms.

9.3.4.4.6 Seismic and ASME Code Classification

The applicant identified quality group classifications for the CVCS in DCD Tier 2, Figure 9.3.4-1, and DCD Tier 2, Table 3.2-1. Furthermore, the applicant identified seismic classifications for the CVCS in DCD Tier 1, Table 2.4.6-1, "Chemical and Volume Control System Equipment and Piping Characteristics," Table 2.4.6-2. The staff reviewed these drawings and tables as related to the quality group and seismic categories for the safety related portions of the system. The staff confirmed that the safety related containment isolation valves in the CVCS are seismic Category I along with the piping between the valves, according to DCD Tier 1, Table 2.4.6-1. The following is a summary of the reviewed containment isolation valves:

- ASME Code Section III Class 2 IRWST Makeup Line Containment Isolation Check Valve located inside containment (CV-189);
- ASME Code Section III Class 2 IRWST Makeup Line Containment Isolation Motor Operated Valve located outside containment (CV-509);
- ASME Code Section III Class 2 Resin Sluice Supply Header to Reactor Drain Header Containment Isolation Check Valve located inside containment (CV-494);
- ASME Code Section III Class 2 Resin Sluice Supply Header to Reactor Drain Header Containment Isolation Air Operated Valve located outside containment (CV-580);
- ASME Code Section III Class 2 RDT Effluent Containment Isolation Air Operated Valves located inside and outside containment (CV-560, CV-561), respectively;
- ASME Code Section III Class 2 RCP Controlled Bleedoff Line Containment Isolation Air Operated Valves located inside and outside containment (CV-506, CV-505), respectively;
- ASME Code Section III Class 2 Seal Injection Containment Isolation Check Valve located inside containment (CV-835);
- ASME Code Section III Class 2 Seal Injection Containment Isolation Motor Operated Valve located outside containment (CV-255);
- ASME Code Section III Class 2 Charging Line Containment Isolation Check Valve located inside containment (CV-747);
- ASME Code Section III Class 2 Charging Line Containment Isolation Motor Operated Valve located outside containment (CV-524);
- ASME Code Section III Class 2 SCS Purification Line Containment Isolation Check Valve located inside containment (CV-363);
- ASME Code Section III Class 2 SCS Purification Line Containment Isolation Check Valve located outside containment (CV-362); and
- ASME Code Section III Class 2 Letdown Line Containment Isolation Air Operated Valves located inside and outside containment (CV-522, CV-523), respectively.

The staff confirmed that safety-related portions of the CVCS are located in the reactor containment building or the auxiliary building. The applicant designed both structures to withstand the effects of earthquakes, tornados, hurricanes, and other natural phenomena. DCD Tier 2 Sections 3.3, 3.4, 3.5, 3.7, and 3.11 identify the bases for the adequacy of the designs of these buildings. The staff also confirmed that the applicant designed the safety-related portions of the CVCS to remain functional during and after a safe-shutdown earthquake, with design loadings identified in DCD Tier 2 Sections 3.7 and 3.9. Based on the information found in these sections, and the fire protection information in DCD Tier 2 Section 9.5.1, the staff finds that the safety-related portions of the CVCS are adequately protected from the effects of natural phenomena and that the system design meets the requirements of GDC 1 and 2.

9.3.4.4.7 Leakage Monitoring and Prevention

In DCD Tier 2, Section 9.3.4.3.3, "Leakage Detection and Control," and Section 9.3.4.2.10, "Design Features for Minimization of Contamination," the applicant described the design provisions of the CVCS in regards to leakage detection and control, and features for minimization of contamination. The staff noted that components in the CVCS are provided with welded connections wherever possible and that all valves larger than 2 in. (5.1 cm) and all actuator-operated valves are provided with double-packing, lantern rings, and leak-off connections unless the valves are diaphragm valves. The applicant mentioned that the design uses diaphragm valves around the VCT gas space and boron recovery system to minimize activity release due to valve leakage. The staff also noted that the applicant designed for typical operation techniques to monitor and detect RCS primary leakage. For example, level in the VCT will remain constant during steady state operation when there is no RCS or CVCS leakage. In addition, the applicant designed the sumps in cubicles in which the CVCS tanks are located with leak detection instruments to initiate alarms in the event of leakage or overflow. In accordance with 10 CFR 50.34(f)(2)(xxvi), the staff finds the summary description for the CVCS leakage detection and control design features to be adequate.

9.3.4.4.8 Initial Plant Testing

The applicant prescribed the initial plant testing in DCD Tier 2, Section 14.2. Numerous startup tests are associated with the CVCS as follows:

- 14.2.12.1.5 – Chemical and Volume Control System Letdown Subsystem Test
- 14.2.12.1.6 – Volume Control Tank Subsystem Test
- 14.2.12.1.7 – Chemical and Volume Control System Charging Subsystem Test
- 14.2.12.1.8 – Chemical Addition Subsystem Test
- 14.2.12.1.9 – Reactor Drain Tank Subsystem Test
- 14.2.12.1.10 – Equipment Drain Tank Subsystem Test
- 14.2.12.1.11 – Boric Acid Batching Tank Subsystem Test
- 14.2.12.1.12 – Concentrated Boric Acid Subsystem Test
- 14.2.12.1.13 – Reactor Makeup Subsystem Test

- 14.2.12.1.14 – Holdup Subsystem Test
- 14.2.12.1.15 – Boric Acid Concentrator Subsystem Test
- 14.2.12.1.16 – Gas Stripper Subsystem Test
- 14.2.12.1.17 – Boronometer Subsystem Test
- 14.2.12.1.18 – Process Radiation Monitor Subsystem Test
- 14.2.12.1.19 – Gas Stripper Effluent Radiation Monitor Subsystem Test
- 14.2.12.1.57 – Pre-Core RCS Leak Rate Measurement
- 14.2.12.1.58 – Pre-Core Chemical and Volume Control System Integrated Test
- 14.2.12.1.60 – Pre-Core Boration / Dilution Measurements
- 14.2.12.1.84 – Heat Tracing System Test

In each of the above tests, the acceptance criteria involve satisfying the functional design requirements of DCD Tier 2, Section 9.3.4. The tests typically record system parameters, alarm settings, interlocks, and numerous other system features. The staff reviewed these test requirements, along with the planned ITAAC testing of DCD Tier 1, Table 2.4.6-4 and found this testing to be sufficient and adequate to demonstrate proper operation of the CVCS in accordance with its functional design requirements. Additional discussion of the staff's evaluation of the preoperational test plan is located in Chapter 14.2 of this review

9.3.4.4.9 ITAAC

The applicant described in DCD Tier 1, Section 2.4.6 the Tier 1 attributes of the CVCS. The applicant listed Tier 1 equipment, piping, alarm, display, and control functions in DCD Tier 1, Tables 2.4.6-1, 2.4.6-2, and 2.4.6-3, "Chemical and Volume Control System Instruments List." The applicant presented ITAAC requirements in Table 2.4.6-4, which the staff noted are written to verify the following:

1. The CVCS is built according to Tier 1 Subsection 2.4.6.1, "Deign Description," of the DCD.
2. ASME Code components and piping are designed and constructed in accordance with ASME Section III requirements.
3. Pressure boundary welds in ASME Code components and piping meet ASME Code Section III requirements for non-destructive examination.
4. Pressure boundary integrity of ASME Code components and piping is retained in accordance with ASME Section III requirements.
5. Seismic Category I components and piping can withstand seismic design basis loads without loss of safety function.

6. Class 1E components and instruments are qualified for a harsh environment that would exist before, during, and following a design basis accident.

7. Class 1E components and instruments are powered from their own respective Class 1E division, and separation is provided between Class 1E divisions and between Class 1E divisions and non-Class 1E divisions.

8. Motor-operated valves, air-operated valves (AOVs), and check valves perform their active safety function

9. Motor operated valves, AOVs, and solenoid-operated valves (SOVs) assume indicated loss of motive power position.

10. Displays, Alarms, and Controls required by the design exist in the MCR and RSR to start and stop the charging pump, auxiliary charging pump, and to open and close motor operated valves, AOVs, and SOVs as required.

11. CVCS provides makeup capability to maintain RCS volume.

12. CVCS supplies seal water to the RCP seals.

13. CVCS provides pressurizer auxiliary spray water for depressurization.

14. High energy piping systems are reconciled with pipe rupture hazards analyses report to ensure that safety-related SSCs are protected against or qualified to withstand dynamic effects associated with failures of these piping systems.

The staff finds the Tier 1 entries associated with the CVCS, including the ITAAC requirements, design description, and DCD Tier 1, Figure 2.4.6-1, to be adequate, except for the issues discussed below.

As part of the review of Section 14.3.4 "Reactor Systems – Inspections, Tests, Analyses, and Acceptance Criteria," of this report, the staff identified two general issues regarding the design description of the CVCS and ITAAC item 6.c in DCD Tier 1, Section 2.4.6, and Table 2.4.6-4, respectively. On July 16, 2015, the staff issued RAI 83-7962 (ML15197A267), Question 14.03.04-4, requesting the applicant provide a more detailed description of the CVCS design, particularly the system's safety-related functions, and RAI 83-7962, Question 14.03.04-5, requesting the applicant address ITAAC Item 6.c in Table 2.4.6-4 inaccurately reflecting the regulatory guide which it calls out. Section 14.3.4 of this report is tracking the resolution of these questions.

The staff reviewed DCD Tier 1, Figure 2.4.6-1, and DCD Tier 2, Figure 9.3.4-1 for consistency. The staff noted several discrepancies between the Tier 1 and Tier 2 figures involving valves (CV-362, CV-340, and CV-507) regarding the valves' indicated position and locking status. In order to ensure that the DCD Tier 1 information is consistent with and derived from DCD Tier 2 information, the staff, on August 20, 2015, issued RAI 160-8174, Question 09.03.04-06 to address this issue. By response dated October 29, 2015 (ML15330A440), supplemented by an additional response dated April 22, 2016 (ML16113A455), the applicant addressed the inconsistencies between DCD Tiers 1 and 2. The applicant responded by stating that DCD Tier 1, Figure 2.4.6-1 and DCD Tier 2, Figure 9.3.4-1 will be revised to maintain consistency between Tier 1 and Tier 2. The applicant also provided in the response DCD Tier 1,

Figure 2.4.6-1, and DCD Tier 2, Figure 9.3.4-1 markups. The staff reviewed the response and confirmed that the DCD markups adequately correct the inconsistencies and are acceptable. RAI 160-8174, Question 09.03.04-06 is being tracked as a **Confirmatory Item** pending the incorporation of the proposed changes into the appropriate DCD Tier 1 and DCD Tier 2 sections.

Following the resolution of the above issues, the staff determined that the APR1400 CVCS ITAAC are necessary and sufficient and meet the requirements of 10 CFR 52.47(b)(1).

9.3.4.4.10 Technical Specifications

DCD Tier 2, Chapter 16, Section 3.1.9, "Charging Flow," Section 3.3.14, "Boron Dilution Alarms," Section 3.9.1, "Boron Concentration," and other sections relating to leakage and leakage detection, RCS specific activity, and containment isolation present the TSs relating to the CVCS. The staff noted that the applicant provided a program for primary coolant sources outside containment which addresses the CVCS. The program includes preventive maintenance and periodic visual inspection requirements as well as integrated leak rate test requirements for the CVCS at least once per 18 months.

The staff reviewed the required actions and surveillance requirements together with the completion times allotted for corrective action and surveillance frequencies and found that the applicant's proposed TSs are acceptable.

9.3.4.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.3(2)	The COL applicant is to provide operational procedures and maintenance programs as related to leak detection and contamination control.	9.3.2.2.4, 9.3.3.2.6, 9.3.4.2.10, 9.3.4.5.6, 9.3.5
9.3(3)	The COL applicant is to maintain complete documentation of system design, construction, design modifications, field changes, and operations .	9.3.2.2.4, 9.3.3.2.6, 9.3.4.2.10, 9.3.5
9.3(6)	The COL applicant is to prepare the site radiological environmental monitoring program.	9.3.3.2.6, 9.3.4.2.10, 9.3.5

The staff identified an additional COL information item that the applicant should add to Table 1.8-2 for the CVCS, as discussed in RAI 336-8367 (ML15349A760), Question 05.02.03-15.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.3(7)	The COL applicant is to provide primary side water chemistry threshold values and recommended operator actions for chemistry excursions in compliance with the latest version of the EPRI PWR Primary Water Chemistry Guidelines in effect at the time of COLA Submittal. The COL applicant is to establish the operation water chemistry program six months before fuel load.	9.3.4.2.7, 9.3.5

The applicant agreed to add COL 9.3(7) to ensure the COL applicant references the latest edition of the EPRI Guidelines and provides threshold values and operator actions for primary water chemistry that are in compliance with the latest version of the EPRI Guidelines. The staff finds this acceptable and verified that this COL information item was incorporated as COL 9.3(7) in Revision 1 of the DCD; therefore, RAI 336-8367, Question 05.02.03-15 is resolved and closed.

9.3.4.6 Conclusion

The staff finds that the design of the CVCS is acceptable and meets the intent of the SRP Acceptance criteria regarding to GDC 1, 2, 5, 33, 55, 60, 61, 10 CFR 50.34(f)(2)(xxvi), 10 CFR 50.63(a)(2), and 10 CFR 52.47(b)(1). Specifically, with respect to safety functions of the CVCS, the staff concludes that the safety-related system components have appropriate ASME Code Section III classifications. The staff also concludes that the applicant assures the RCPB integrity by designing parts of the CVCS which interact with the RCS to withstand full RCS pressure. In addition, the staff concludes that the APR1400 design includes a containment isolation signal that causes containment isolation valves in the CVCS to close when required by the design. Furthermore, the staff concludes that providing an alternate AC source of power to power the auxiliary charging pump, which maintains RCP seal integrity during a SBO, meets the requirements of 10 CFR 50.63(a)(2) regarding the CVCS. The staff confirms that the CVCS is designed to prevent wall inward buckling and failure in tanks.

In regards to normal operation, the staff finds the overall design of the CVCS to be acceptable. In particular, the staff confirms that the design's letdown and charging functions are appropriate to accommodate normal changes in RCS inventory, the applicant provided in the design adequate seal injection to maintain RCP seal integrity (and thus RCPB integrity), the applicant's design of the CVCS meets the chemistry and purity standards, and the applicant adequately addressed boron concentration control.

In regards to the chemistry aspects of the CVCS, the applicant demonstrated that concentrations of impurities and added chemicals in RCS water are controlled consistent with the EPRI Guidelines, and hence, satisfy the requirements of GDC 14. In addition, the staff notes that borated water is regulated in the RCS and auxiliary systems consistent with EPRI Guidelines and with good engineering practice, thereby satisfying the requirements of GDC 14.

The staff reviewed all CVCS-related ITAAC in DCD Tier 1, Section 2.4.6, and finds them to be acceptable in accordance with 10 CFR 52.47(b)(1).

9.4 Heating, Ventilation, and Air Conditioning Systems

The HVAC evaluation for each major building or area is provided in the following subsections.

9.4.1 Auxiliary Building Clean Area and Compound Building HVAC System

9.4.1.1 Introduction

This section evaluates DCD Tier 2, Sections 9.4.3, "Auxiliary Building Clean Area HVAC System," and 9.4.7, "Compound Building HVAC System."

The auxiliary building clean area HVAC serves the auxiliary building clean area except for the control room envelope and electrical and I&C equipment areas in the auxiliary building.

The compound building HVAC system is to maintain the airborne radioactivity levels in the compound building controlled area below the derived air concentration values specified in 10 CFR Part 20, Appendix B, by supplying and exhausting sufficient airflow. The system is also designed to control the gaseous effluent release less than the dose and concentration criteria specified in 10 CFR Part 50, Appendix I, and 10 CFR Part 20, Appendix B.

9.4.1.2 **Summary of Application**

DCD Tier 1: DCD Tier 1, Section 2.7.3.3, "Auxiliary Building Clean Area HVAC System," provides the functional arrangement as shown in DCD Tier 1, Figure 2.7.3.3-1. The auxiliary building clean area HVAC system is a non-safety-related system except for safety-related cubicle coolers for motor-driven AFW pump rooms and essential chiller rooms. These cubicle coolers are cooled by the essential chilled water system.

As stated in DCD Tier 1, Section 2.7.3.7, "Compound Building HVAC System," there are no DCD Tier 1 entries for this system.

DCD Tier 2: The applicant has provided a system description in DCD Tier 2, Sections 9.4.3, "Auxiliary and Radwaste Area Ventilation System," and 9.4.7 summarized here, in part, as follows.

9.4.1.2.1 Auxiliary Building Clean Area HVAC System

In DCD Tier 2, Section 9.4.3.1, "Design Bases," and Section 9.4.3.2, "System Description," the applicant states that the system is designed to:

1. Provide a suitable environment for the operation of equipment and personnel access to the clean area of the auxiliary building.

2. Provide ventilation for the chiller rooms in accordance with the American Society for HVAC Refrigeration and Air Conditioning Engineers (ASHRAE) 15, "Safety Code for Mechanical Refrigeration."

3. Remove smoke from the area where the potential exists for heavy smoke conditions in the auxiliary building.

The auxiliary building clean area HVAC system is classified as non-safety-related except for the safety-related cubicle coolers. The safety-related cubicle coolers are connected to the Class 1E and SBO power. The safety-related portion of this system is designed in accordance with the requirements of 10 CFR Part 50 Appendix A, GDC 2 and 4, and NRC Seismic Design Classification RG 1.29.

The auxiliary building clean area HVAC system consists of four subsystems: auxiliary building clean area I and II HVAC, main steam valve room HVAC, main steam enclosure HVAC, and auxiliary building smoke removal HVAC.

Auxiliary Building Clean Area I and II HVAC Subsystem

During normal operation, the auxiliary building clean area I and II supply AHUs, exhaust fans, and cubicle coolers operate to maintain the suitable temperature and ventilation condition in the auxiliary building clean area. During abnormal and accident conditions, the motor-driven AFW pump room cubicle coolers and the essential chiller room cubicle coolers operate automatically according to the room temperature.

One chiller room supply fan and exhaust fan are provided per division to ventilate the chiller room in accordance with ASHRAE 15. The chiller room supply fan and exhaust fan are not required to operate during abnormal and accident conditions.

Main Steam Valve Room HVAC Subsystem

During normal operation, the main steam valve room supply AHUs operate to maintain the suitable temperature and ventilation condition in the main steam valve room. The air from the main steam valve room is released to the atmosphere through the removal blowout panel. The main steam valve HVAC subsystem is not required to operate during abnormal and accident conditions.

Main Steam Enclosure HVAC Subsystem

During normal operation, the main steam enclosure supply fans operate to maintain the suitable temperature and ventilation condition in the main steam enclosure. The air from the Main

Steam Enclosure HVAC Subsystem is not required to operate during abnormal and accident conditions.

Auxiliary Building Smoke Removal HVAC Subsystem

When a fire occurs in a division of the auxiliary building, the corresponding auxiliary building smoke removal fan is started manually to remove smoke after the fire has been suppressed.

9.4.1.2.2 Compound Building HVAC System

In DCD Tier 2, Sections 9.4.7.1, “Design Bases,” and 9.4.7.2, “System Description,” the applicant states that the system is designed to maintain a suitable environment for all equipment and personnel and the radiation zone of the compound building under a slightly negative pressure with respect to atmospheric pressure during normal operation.

The compound building HVAC system is classified as non-safety related and is designed in accordance with the requirements of 10 CFR Part 50 Appendix A, GDC 60, and RGs 1.140 and 4.21.

The compound building HVAC system consists of two subsystems: compound building clean area HVAC and compound building controlled area HVAC.

Compound Building Clean Area HVAC Subsystem

The Compound Building Clean Area HVAC Subsystem is designed to maintain an environment suitable for all equipment and personnel in the clean area of the compound building, and maintain clean areas, such as compound building control room and health physics areas, at a positive pressure with respect to surrounding areas.

The air is recirculated from the served areas, except for the battery room and chiller room, and is mixed with outside air to be used as supply air. The mixed air is filtered and cooled (or heated) through the supply AHU, and distributed to the compound building clean area subsystem boundary to maintain a suitable environment.

The air in the battery room is continuously exhausted to limit hydrogen accumulation to less than one percent of the total volume of the battery room based on RG 1.128, “Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants.”

Compound Building Controlled Area HVAC Subsystem

The Compound Building Controlled Area HVAC Subsystem is designed to maintain an environment that is suitable for all equipment and personnel in the potential radioactive area of the compound building. This subsystem also prevents the spreading of airborne radioactivity to surrounding areas by maintaining laboratory and sample counting rooms at a negative pressure with respect to surrounding areas.

Ducts carrying radioactive contaminated air are sized for minimum air velocity of 2,500 ft/min (12.7 m/sec) to avoid the settling of radioactive contaminated particles and becoming a radiation source.

9.4.1.3 Regulatory Basis

The relevant requirements of the NRC regulations for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.4.3, "Auxiliary and Radwaste Area Ventilation System," and are summarized below. Review interfaces with other SRP sections can be found in NUREG-0800, Section 9.4.3.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the capability of a system to withstand the effects of earthquakes.

2. GDC 5, "Sharing of structures, systems, and components," as it relates to the sharing of structures, systems, or components between multiple units.

3. GDC 60, "Control of releases of radioactive materials to the environment," as it relates to controlling the release of gaseous radioactive effluents to the environment.

4. 10 CFR 52.47(b)(1) 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 is met, a plant that incorporates the design certification and is constructed will operate in compliance with the design certification, the provisions of the AEA, and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, the auxiliary building clean area HVAC system and the compound building HVAC system should meet the guidance of RG 1.29, "Seismic Design Classification," Revision 4, March 2007, Regulatory Position C.1, for safety-related portions and Regulatory Position C.2 for non-safety-related portions.

2. For GDC 5, acceptance is based on the determination that sharing of the auxiliary building clean area HVAC system and the compound building HVAC system structures systems and components in multiple-unit plants does not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

3. For GDC 60, the auxiliary building clean area HVAC system and the compound building HVAC system should meet the guidance of RG 1.52, "Design, Testing, and Inspection Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants," Revision 4, September 2012, Regulatory Position C.3, and RG 1.140, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants," Revision 2, June 2001, Regulatory Positions C.2 and C.3.

4. For 10 CFR 52.47(b)(1), the auxiliary building clean area HVAC system and the compound building HVAC system should meet the guidance contained in SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria," and 14.3.7.

9.4.1.4 Technical Evaluation

The staff reviewed the auxiliary building clean area HVAC system (DCD Tier 2, Section 9.4.3) and the compound building HVAC system (DCD Tier 2, Section 9.4.7) for conformance with the requirements and acceptance criteria defined in SRP Section 9.4.3.

9.4.1.4.1 GDC 2, Design bases for protection against natural phenomena

The guidance for GDC 2 is based on RG 1.29, Regulatory Positions C.1 for safety-related SSCs and C.2 for non-safety-related SSCs if its failure could reduce the functioning of safety-related SSCs. Any SSCs not falling into the Regulatory Positions C.1 and C.2 are considered seismic Category III. DCD Tier 2, Sections 9.4.3.1, states that the auxiliary building clean area HVAC system components are non-safety-related except the safety-related cubicle coolers. The safety-related cubicle coolers are seismic Category I. The non-safety-related components and ductwork are seismic Category II. DCD Tier 2, Section 9.4.7, states that the compound building HVAC system components are non-safety-related and seismic Category III.

The staff reviewed the safety classification of SSCs serviced by these two HVAC systems and finds that DCD Tier 2, Sections 9.4.3 and 9.4.7, are consistent with regard to the safety and seismic classifications – all safety-related components are seismic Category I and all non-safety-related portions of the system in areas containing safety-related equipment are seismic Category II. Because the applicant appropriately classified SSCs in conformance with RG 1.29, the staff finds these classifications acceptable.

9.4.1.4.2 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the auxiliary building clean area HVAC system and the compound building HVAC system to ensure that the relevant requirements of GDC 5 are met.

GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design certification is only for a single-unit, and the requirements of GDC 5 are satisfied.

9.4.1.4.3 GDC 60, Control of releases of radioactive materials to the environment

GDC 60 requires that the nuclear power unit design include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

Since the auxiliary building clean area served by the auxiliary building clean area HVAC system does not contain any gaseous and liquid effluents, and the auxiliary building clean area HVAC system does not have air filtration and adsorption units, GDC 60 is not applicable.

For the compound building HVAC system, the staff reviewed DCD Tier 2, Section 9.4.7. The applicant stated that the design and construction of ACUs HEPA exhaust ACU and carbon adsorber exhaust ACU conform to recommendations of RGs 1.140 and 4.21. The staff reviewed the applicant's description of the control of radioactive contamination in DCD Tier 2, Section 9.4.7.1.2, "Compound Building Controlled Area HVAC Subsystem." Areas of higher potential for radioactive contamination are maintained under slightly negative pressure with

respect to surrounding areas of low potential radioactive contamination in the compound building controlled area.

The staff finds that RG 1.140, Regulatory Positions C.2 and C.3 are applicable to the compound building HVAC system since portions of the Compound Building HVAC System perform normal atmosphere cleanup functions for the compound building in the APR1400 design. The staff finds that this system is not required to function to mitigate the consequences of a design basis accident.

The staff reviewed compliance with RG 1.140 for the compound building HVAC system against Regulatory Positions C.2 and C.3 as discussed below.

RG 1.140, Regulatory Position C.2

Per RG 1.140, Regulatory Position C.2.1, the design of a normal atmosphere cleanup system should be based on the anticipated operating ranges for temperature, pressure, relative humidity, and radiation levels during normal plant operations and anticipated operational occurrences. In DCD Tier 2, Section 9.4.7, the applicant states that the design and construction of the ACUs (HEPA exhaust ACU and carbon adsorber exhaust ACU) conform to ASMEAG-1-2009 and ASME N509. The staff reviewed ASME AG-1, to determine if the operating ranges for temperature, relative humidity, pressure, and radiation levels were identified for normal plant operations and anticipated operational occurrences.

ASME AG-1, indicates that design requirements shall be specified for temperature, relative humidity, pressure, and radiation levels. ASME AG-1, does not provide the actual operating ranges. The use of both RG 1.140 and ASME AG-1, by the applicant provides assurance that the final design will consider both pressures and radiation levels for normal plant operations and anticipated operational occurrences. Therefore, the staff finds that compound building HVAC system conforms to RG 1.140, Regulatory Position C.2.1.

In accordance with RG 1.140, Regulatory Position C.2.2, if the normal atmosphere cleanup system is located in an area with high radiation during normal plant operation, then adequate shielding of components and personnel from the radiation source should be provided.

This section identifies the sources of radiation within the plant that form the basis for shielding design calculations and the sources of airborne radioactivity used for the design of personnel protection measures and dose assessment.

Per DCD Tier 2, Section 12.2.1.4, “Compound Building,” radioactive sources in the radwaste system components include fission and activation radionuclides produced in the core and in the reactor coolant. This section identifies the sources of radiation within the compound building that form the basis for shielding design calculations and the sources of airborne radioactivity used for the design of personnel protection measures and dose assessment. Therefore, the staff finds that the system conforms to RG 1.140, Regulatory Position C.2.2.

In accordance with RG 1.140, Regulatory Position C.2.3, the operation of any normal atmosphere cleanup system should not degrade the expected operation of any engineering safety feature (ESF) system that is required to operate after a design-basis accident. The staff concludes that the applicant has conformed to this guidance with regard to the compound building HVAC System, because this system does not perform any ESF function and is not connected to any ESF system per DCD Tier 2, Sections 9.4.7.3, “Safety Evaluation.”

In accordance with RG 1.140, Regulatory Position C.2.4, the design of a normal atmosphere cleanup system should consider any significant contaminants such as dust, chemicals, excessive moisture, or other particulate matter that could degrade the cleanup system's operation. Materials of construction and components shall be selected and tested to limit the generation of combustibles and contaminants per ASME N509, Section 4.4, "Environmental Design Condition," and various ASME AG-1 sections. The staff noted that the applicant has committed to RG 1.140 for the system design, as stated in DCD Tier 2, Sections 9.4.7. Leak testing of system ductwork in accordance with ASME N511 and ASME AG-1 is addressed in DCD Tier 2, Sections 9.4.7.4, "Inspection and Testing Requirements," for the system. The staff concludes that the applicant has conformed to the guidance in RG 1.140, Regulatory Position C.2.4.

RG 1.140, Regulatory Position C.3

RG 1.140, Regulatory Position C.3.1, states that a normal atmosphere cleanup system need not be redundant nor designed to seismic Category I classification; but at a minimum, a system should consist of the following components in the specified order:

1. HEPA filters before the adsorbers,
2. Iodine adsorbers (impregnated activated carbon),
3. Fans, and
4. Interspersed ducts, dampers, and related instrumentation.

RG 1.140 recommends that prefilters be installed upstream of the HEPA filters to increase their service life, and that HEPA filters be installed downstream of carbon adsorbers to retain carbon fines.

RG 1.140 does not call for an iodine adsorption component if the atmosphere cleanup system removes only particulate matter.

The staff reviewed the P&IDs for the compound building HVAC system and concluded that this system conforms to the guidance in RG 1.140, Regulatory Position C.3.1 because it contains the components specified above and follows the specified order.

To ensure reliable in-place testing, the volumetric air-flow rate of a single cleanup unit should be limited to approximately 849.51 m^3/min (30,000 CFM). If a total system air flow in excess of this rate is necessary, multiple units should be used per RG 1.140, Regulatory Position C.3.2.

The applicant did not indicate whether multiple-units for the compound building HVAC system would be used or provide the maximum air-flow rate for each unit. Therefore, to conform to the guidance in RG 1.140, Regulatory Position C.3.2, in RAI 97-8049 (ML15225A445), Question 09.04.03-01 the staff requested that the applicant provide data regarding the air flow rates for the carbon absorber exhaust ACU and HEPA Filter Exhaust ACU.

In an August 28, 2015, response (ML15240A429) to Part 1 of RA 97-8049, Question 09.04.03-01, the applicant states that:

> In the APR1400 standard design, the compound building HVAC system uses 1,500~2,000 cfm HEPA filters and the compound building HVAC system ACUs can allow at least a 45,000 cfm airflow rate without increasing the physical size and changing the filter layout of 3 HEPA filters high and 10 HEPA filters wide. In-place test equipment, such as aerosol generators, has been developed that provides the capability to perform reliable in-place testing for ACUs up to 65,000 cfm. Therefore, the compound building HEPA filter exhaust ACUs and carbon adsorber exhaust ACUs, which have 34,220 cfm airflow rate per single ACU, can ensure convenient maintenance and reliable in-place testing, and the compound building HVAC system is not required to limit airflow rate of a single ACU to 30,000 cfm in accordance with RG 1.140, Regulatory Position C.3.2.

The staff reviewed DOE HDBK-1169-2003, “DOE Handbook, Nuclear Air Cleaning Handbook,” Section 4.4.11, where higher than the traditional 1,500 cfm HEPA filters are described. Since APR 1400 is using 1,500 – 2,000 cfm HEPA filters and in-place test equipment up to 65,000 cfm, the staff considers Part 1 of RAI 97-8049, resolved.

In accordance with RG 1.140, Regulatory Position C.3.3, each normal atmosphere cleanup system should be instrumented to monitor and alarm for pertinent pressure drops and flow rates. The P&IDs, Figure 9.4.7-1, “Compound Building HVAC System Flow Diagram,” for the Compound Building HVAC System indicates that differential pressure across filters and the outlet airflow rate are being monitored. The P&IDs for the system also indicate that differential pressure across filters and system pressure are being monitored. The staff concluded that this system conforms to the guidance in RG 1.140, Regulatory Position C.3.3.

Per RG 1.140, Regulatory Position C.3.4, to maintain the radiation exposure to operating and maintenance personnel ALARA, normal atmosphere cleanup systems and components should be designed to control leakage and facilitate maintenance, inspection, and testing.

Per DCD Tier 2, Section 12.1.1, the design policy of the APR1400 is to maintain occupational radiation exposure ALARA to operating and construction personnel and to the public. The COL applicant is to provide the organizational structure to effectively implement the radiation protection policy, training, and reviews consistent with operational and maintenance requirements, while satisfying the applicable regulations and regulatory guides including RG 1.8, “Qualification and Training for Personnel for Nuclear Power Plants,” RG 1.33, “Quality Assurance Program Requirements,” RG 8.8, “Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable,” and RG 8.10, “Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable.” The ALARA policy is applied to the total exposures (person-Sv) received by all operation and construction personnel, and to individual exposures. The proper approach and awareness of potential problems related to radiation protection are addressed through the proper training of all plant personnel as provided in RG 1.8.

The staff reviewed DCD Tier 2, Sections 12.1.1, “Policy Considerations,” and finds the information acceptable because the information in the DCD clarifies the requirements to follow ALARA principles of RG 8.8 for the design of normal atmosphere cleanup systems. The staff concluded that this system conforms to the guidance in RG 1.140, Regulatory Position C.3.4.

Outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash and other contaminants on the operation of the system, in accordance with the guidance in RG 1.140, Regulatory Position C.3.5. In Part 2 of RAI 97-8049, Question 09.04.03-01, the staff requested that the applicant provide information on the use of louvers, grills, or screens for the Compound Building Controlled Area HVAC Subsystem to conform to RG 1.140, Regulatory Position C.3.5.

In an August 28, 2015 (ML15240A429), response to Part 2 of RAI 97-8049, Question 09.04.03-01, the applicant states that:

> Louvers with screens are used for outside air intake and discharge of the compound building controlled area HVAC subsystem to minimize snow, rain, and trash entrance. The louvers for supply air are installed in the wall of the air intake penthouse and the louvers for exhaust air are installed in the wall of the air exhaust penthouse. For air intake, the air intake louver openings are based on 400 fpm. For exhaust louvers, 500 fpm is used. These air face velocities for louvers are based on Chapter 21 of American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbook Fundamentals, 2009. The screens mounted on the interior faces of louvers are 3/4-inch mesh.

The staff considers Part 2 of RAI 97-8049 resolved. The staff does not see that the louvers with screens design for compound building described in any DCD sections. A follow-up RAI, RAI 382-8484, Question 09.04.03-02 (ML16032A102), was issued to request the applicant to document these louvers with screens design into the related DCD sections.

In its February 19, 2016, response (ML16050A033) to RAI 382-8484, the applicant agreed to revise DCD Subsection 9.4.7 to include use of louvers with screens for the outside air intake and discharge of the compound building HVAC system. The staff confirmed that the DCD has been revised and considers RAI 382-8484 resolved.

Normal atmosphere cleanup system housings and ductwork should be designed to exhibit, on test, a maximum total leakage rate as defined in Article SA-4500 of ASME AG-1-1997.

Per DCD Tier 2, Section 9.4.7.4, leak testing of the system ductwork is performed in accordance with ASME N511 and ASME AG-1. In addition, the applicant states that the design and construction of HEPA exhaust ACU and carbon adsorber exhaust ACU conform to ASME AG-1. The housing and ductwork are required to be tested according to Section TA of ASME AG-1. Therefore, the staff finds that the cited test standards conform to RG 1.140, Regulatory Position C.3.6.

9.4.1.4.4 ITAAC

The staff reviewed the proposed ITAAC for the auxiliary building clean area HVAC system and its associated safety-related features. The applicant's proposed ITAAC requirements in DCD Tier 1, Tables 2.7.3.3-3, "Auxiliary Building Clean Area HVAC System ITAAC," and DCD Tier 2, Section 14.3.2.7. The staff finds that sufficient information has been provided in conformance with SRP Sections 14.3 and 14.3.7.

Acceptance criteria are based on meeting the relevant requirements of 10 CFR 52.47(b)(1), which requires that the KHNP DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance a COL applicant will meet the provisions of the

AEA and NRC regulations; specifically, in accordance with the guidance found in RGs 1.29 and 1.40. The staff finds that the DCD Tier 1 ITAAC tables adequately address verification of the functional arrangement, physical separation, and seismic qualification of the auxiliary building clean area HVAC system. The staff also concludes that ITAAC tables verify the minimum inventory of system alarms displays and controls and the ITAAC verify required safety-related functions of the system. Based on this review, the staff has concluded that the auxiliary building clean area HVAC system of a plant that incorporates the design certification will be built and will operate in accordance with the DC, the AEA, and NRC regulations.

The staff notes that ITAAC information is not provided for the compound building HVAC system. The staff finds it acceptable because this system is non-safety-related, and service areas do not contain safety-related SSCs. The staff finds that adequate inspections and tests for these systems are performed in the Initial Plant Test Program.

9.4.1.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related air handling units and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.3, 9.4.7

The staff determined the above listing to be complete. Also, the list adequately describes actions necessary for the COL applicant or holder.

9.4.1.6 Conclusion

The staff reviewed the APR1400 standard design Auxiliary Building Clean Area HVAC System and Compound Building HVAC System using the acceptance criteria guidance defined in NUREG-0800, Section 9.4.3. The staff concludes that these systems comply with the requirements of GDC 2, GDC 5, and GDC 60. The ITAAC requirements were judged by the staff to be appropriate for these systems based on their performance requirements and, therefore, the staff concludes that the Auxiliary Building Clean Area HVAC System and Compound Building HVAC System designs comply with 10 CFR 52.47(b)(1).

9.4.2 Control Room HVAC System

9.4.2.1 Introduction

The Control Room HVAC System (CRHS) serves the areas enclosed in the Control Room Envelope (CRE). The CRHS consists of two divisions of control room emergency makeup air cleaning system (CREACS) and two divisions of control room supply and return system (CRSRS).

9.4.2.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Revision 1, Section 2.7.3.1, "Control Room HVAC System."

DCD Tier 2: The applicant has provided a system description in DCD Tier 2, Revision 1, Section 9.4.1, "Control Room HVAC System," summarized here, in part, as follows:

The CRHS is designed to maintain suitable environment conditions for personnel comfort, health, safety, and proper function of equipment and controls located in the CRE. The MCR habitability system, including the definition of the CRE is addressed in Section 6.4, "Habitability Systems," of this report. DCD Tier 2, Section 6.4, Figures 6.4-1, "Control Room Envelope Flow Diagram," shows the CRE area. DCD Tier 2, Section 6.4.2.1 includes the Technical Support Center (TSC) as part of the CRE. The staff evaluation of the TSC habitability is addressed in Section 6.4 of this report.

ITAAC: The ITAAC associated with DCD Tier 2, Section 9.4.1 are given in DCD Tier 1, Section 2.7.3.1.

Technical Specifications: The TSs associated with DCD Tier 2, Section 9.4.1 are given in DCD Tier 2, Chapter 16, Sections 3.7.11, "Control Room HVAC System."

9.4.2.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Revision 3, Section 9.4.1, "Control Room Area Ventilation System," and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.4.1.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to system capability to withstand the effects of earthquakes.
2. GDC 4, "Environmental and dynamic effects design bases," as it relates to the CRHS being appropriately protected against dynamic effects and being designed to accommodate the effects of, and to be compatible with, the environmental conditions of normal operation, maintenance, testing, and postulated accidents.
3. GDC 5, "Sharing of structures, systems, and components," indicates that sharing an SSC between multiple units will not significantly impair the SSC's ability to perform its safety function in the event one unit experiences an accident condition.

4. GDC 19, "Control room," as it relates to providing adequate protection to permit access to and occupancy of the control room under accident conditions.

5. GDC 60, "Control of releases of radioactive materials to the environment," as it relates to system capability to suitably control release of gaseous radioactive effluents to the environment.

6. 10 CFR 50.63, as it relates to necessary support systems providing sufficient capacity and capability to ensure the capability for coping with a SBO event.

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 AEA, and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, the CRHS should be consistent with the guidance of RG 1.29, Regulatory Position C.1, for safety-related portions and Regulatory Position C.2 for non-safety-related portions.

2. For GDC 4, the CRHS should be consistent with the acceptance criteria of NUREG-0800, Sections 3.5.1.1, "Internally Generated Missiles (Outside Containment)"; 3.5.1.4, "Missiles Generated by Tornadoes and Extreme Winds"; 3.5.2, "Structures, Systems, and Components to be Protected from Externally-Generated Missiles"; and 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment."

3. For GDC 5, acceptance is based on the determination that sharing of CRHS structures, systems and components in multiple-unit plants does not significantly impair their ability to perform their safety functions including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

4. For GDC 19, the CRHS should be consistent with the guidance of RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release."

5. For GDC 60, the CRHS should be consistent with the guidance of RG 1.52, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants," and RG 1.140, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants."

6. For 10 CFR 50.63, the CRHS should be consistent with the guidance of RG 1.155, "Station Blackout," including Regulatory Position C.3.2.4.

7. For 10 CFR 52.47(b)(1), the CRHS should be consistent with the guidance of RG 1.206, Section C.II.1, "Inspections, Tests, Analyses, and Acceptance Criteria,"

and that contained in SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria," and 14.3.7, "Plant Systems – Inspections, Tests, Analyses, and Acceptance Criteria."

9.4.2.4 Technical Evaluation

The staff reviewed the DCD and supporting Tier 2 information in accordance with NUREG-0800, Section 9.4.1, Section III, and Review Procedures. The staff's review results and conclusions reached are as follows:

As provided in the DCD the CRHS consists of two outside air intakes, dampers, two air cleaning units (ACU), four AHU, four humidifiers, one common kitchen and toilet exhaust fan, one smoke removal fan, and two computer room packaged air conditioning units (PACU).

The MCR is designed to maintain the following temperature ranges:

Room	Temperature	Humidity
MCR	20.1 °C to 25 °C (70 °F to 77 °F)	40-60%
HVAC Equipment Rooms	10 °C to 40 °C (50 °F to 104 °F)	(not defined)
Other Areas of CRE (TSC, etc.)	18.3 °C to 26.7 °C (65 °F to 80 °F)	40-60%

During normal operation, the mixed air is filtered, cooled, or heated through the supply AHU and distributed to the CRE to maintain suitable environmental conditions and to maintain a minimum 3.175 mm (0.125 in) water gauge of positive pressure with respect to the surrounding areas. Two computer room PACUs are provided for the computer room complex to maintain the suitable environmental conditions.

Upon receipt of an engineered safety feature actuation signal – safety injection actuation signal (ESFAS-SIAS) or an engineered safety feature actuation signal – control room emergency ventilation signal (ESFAS-CREVAS), all AHU inlet isolation dampers in the outside normal makeup air duct to the AHUs are automatically closed. Additionally, one of the two sets of outside air intake isolation dampers closes to isolate the higher radioactivity air supply from the two available outside air intakes. Then the kitchen and toilet exhaust fan stops automatically. The emergency makeup ACU of the operating division starts automatically to filter the outside makeup air and part of the recirculated air. The two isolation dampers in the exhaust duct to the outside of the smoke removal fan remain closed or automatically close to maintain CRE boundary integrity. The control room is maintained at a minimum of 3.175 mm (0.125 in) water gauge positive pressure with respect to the surrounding areas.

In DCD Tier 2, Section 9.4.1.1, "Design Bases," the applicant states that the control room HVAC system is safety-related and meets seismic Category I requirements with the exception of the humidifiers, kitchen and toilet exhaust fan, smoke removal fan, and related ductwork, which are non-safety-related and seismic Category II. The PACUs for the computer room complex are classified as non-safety-related and seismic Category III.

All the ACUs are designed and tested to ASME AG-1-2009, "Code on Nuclear Air and Gas Treatment," as shown in DCD Tier 2, Table 3.2-1 Sheet 82. The staff finds this follows the guidance of RG 1.52, and is therefore acceptable.

9.4.2.4.1 GDC 2, Design bases for protection against natural phenomena

In DCD Tier 2, Section 9.4.1.1, the applicant stated that all safety-related HVAC equipment, ductwork, and supports are designed to withstand the SSE.

As shown in DCD Tier 2, Table 3.2-1, Sheets 82-83, the staff finds that all safety-related portions of the system meet seismic Category I requirements and all non-safety-related portions of the system meet seismic Category II requirements with the exception of the PACUs for the computer room complex which are seismic Category III.

The staff finds the seismic design classification of SSC served by CRHS complies with the guidance in RG 1.29, Regulatory Positions C.1 and C.2; specifically, the staff has verified that all safety-related SSCs are classified as seismic Category I and all nonsafety-related SSCs that may affect safety-related functions are classified as seismic Category II. Therefore, staff finds that this system, for the purposes of the review in this chapter of the report, complies with the requirements of GDC 2. A more detailed seismic analysis of this system is contained in Chapter 3 of this report

9.4.2.4.2 GDC 4, Environmental and dynamic effects design bases

The GDC 4 requires that SSCs important to safety are designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.

In DCD Tier 2, Section 9.4.1.1, the applicant stated that all safety-related components are located in a missile-protected structure that is designed to withstand the effects of natural phenomena such as tornadoes, hurricanes, and floods. In addition, these components are protected from the effects of internally generated missiles, pipe breaks, and water spray.

The environmental and dynamic effects of internal and external missiles and postulated piping failures on the CRHS are addressed in DCD Tier 2, Section 3.5.1.1, "Internally Generated Missiles (Outside the Containment)," Section 3.6.1 and Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping."

The equipment is not located in an area with high-energy lines, therefore, is not subject to environmental qualification. According to DCD Tier 2, Section 3.11, "Environmental Qualification of Mechanical and Electrical Equipment," and Table 3.11-3, "Equipment Qualification Equipment List," Sheets 37-38, CRHS is designed and qualified in conformance with the requirements of GDC 4 as a mild environmental condition.

The staff concludes the design of the safety-related portions of the CRHS complies with the requirements of GDC 4 regarding potential dynamic effects, such as pipe whip, jet impingement, and missile impacts caused by equipment failure or events outside the plant. Based on the above, the staff finds that the CRHS complies with the requirements of GDC 4.

9.4.2.4.3 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the CRHS to ensure that the relevant requirements of GDC 5 are met.

The GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design is a single-unit station, and the requirements of GDC 5 are satisfied.

9.4.2.4.4 GDC 19, Control room

According to DCD Tier 2, Section 9.4.1, the CRHS meets the guidance of RG 1.78 which the staff has determined, for the purposes of this system, is the appropriate guidance. The staff has determined that the CRHS will provide an atmosphere in which a nuclear power plant can be safely operated under normal and non-design basis accident conditions. The performance of the CRHS under design basis accident conditions is evaluated in Section 6.4 of this report.

The staff finds that the CRHS complies with the requirements of GDC 19.

9.4.2.4.5 GDC 60, Control of releases of radioactive materials to the environment

GDC 60 requires that the nuclear power unit design include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

RG 1.140, “Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup systems in Light-Water-Cooled Nuclear Power Plants,” is not applicable to the CRHS because the system does not provide any normal atmospheric cleanup function.

In DCD Tier 2, Section 9.4.1.1, the applicant states that the CRHS meets the guidance in RG 1.52. The staff finds that control room emergency makeup ACUs (AU01A, AU01B) need to satisfy RG 1.52, Regulatory Position C.3, because these ACUs are required to function to mitigate the consequences of a design basis accident.

Section 6.5.1, “Engineered Safety Feature Filter Systems,” of this report documents the staff evaluation of the Control Room Emergency Makeup Air System (CREACS) against RG 1.52. As stated in this section, the staff finds that the CREACS conforms to the acceptance criteria of SRP Section 6.5.1 for ESF filter systems and conforms to the guidance of RG 1.52.

During normal operation, both iodine filtration trains (AU01A, AU01B) are secured and fully bypassed with the dampers. If high radiation is detected at the air intake, the fresh air supply is automatically redirected through the iodine filtration trains, and the trains are placed in operation. Additionally, recirculation flow is directed through the iodine filtration train. As stated in DCD Tier 2, Chapter 16, Technical Specifications, Section B 3.7.11, when one iodine filtration train operates, the outside fresh airflow rate is 6,268 m^3/hr. (3,700 cfm), and the CRE recirculation airflow rate is 7,305 m^3/hr (4,300 cfm), a total flow rate of 13,592 m^3/hr (8,000 cfm). The operation of CRHS creates an overpressure of 3.175 mm (0.125 in) water gauge as a minimum inside the CRE area to limit unfiltered incoming air leakage.

The staff believes that the automatic actuation feature of iodine filtration trains and the overpressurization of the CRE during a high-radiation event provide adequate protection to operators in the control room. Therefore, because the CRHS is designed to conform to the guidance of RG 1.52, including Regulatory Position C.3, the staff finds the design of the safety-related portions of

the CRHS complies with GDC 60 regarding provisions to suitably control the release of gaseous and liquid radioactive effluents to the environment.

9.4.2.4.6 10 CFR 50.63 Loss of all alternating current power

In DCD Tier 2, Section 8.4.1.1, "Description" [of SBO], the applicant states that, during a SBO, a non-Class 1E AAC gas turbine generator (GTG) with sufficient capacity, capability, and reliability provides power for the set of required loads (non-design-basis accident) to bring the plant to safe shutdown. The AAC GTG is started and manually connected to the set of required shutdown equipment within 10 minutes in accordance with Position C.3.2.5 of RG 1.155.

In DCD Tier 2, Section 9.4.1.1, the applicant states that during an SBO the safety-related equipment of the control room HVAC system is powered from the AAC source. The control room HVAC system is unavailable for 10 minutes until the AAC generator restores power after an SBO occurs. However, all safety-related electrical and I&C equipment in the MCR are designed to keep their integrity during loss of the control room HVAC system.

Based on the above DCD statements, the staff finds the design of the CRHS complies with 10 CFR 50.63 regarding the capability for responding to a SBO, specifically maintaining acceptable environmental conditions to support operator access/egress and equipment functionality during the SBO and recovery period because the safety-related portion of the system is consistent with the guidance of RG 1.155, Regulatory Position C.3.2.4 and remains operational. Therefore, the CRE room temperature would be expected to be maintained, and would not challenge equipment operability or operator performance. Any elevated CRE temperature would be sustained for a relatively short coping period before the expected restoration of safety-related AC power sources.

9.4.2.4.7 ITAAC

The staff reviewed the ITAAC requirements in DCD Tier 1, Tables 2.7.3.1-3, "Control Room HVAC System ITAAC," and DCD Tier 2, Section 14.3.2.7, "ITAAC for Plant Systems."

The staff noticed that in DCD Tier 1, Table 2.7.3.1-3 "Control Room HVAC System Components List," Item 7, the acceptance criteria requires the CRHS to be "capable of providing the conditioned air to maintain the room temperature within design limits for the CRE during plant normal, abnormal and accidents conditions." However, the parameters were not specified in regards to "design limits." The staff also noted that, in Item 8.b, the acceptance criteria requires the CRHS to "maintain positive pressure in the CRE during the emergency mode," but fails to define "positive pressure." Finally, in Item 11, the staff noted that the unfiltered inleakage test method is not specified. In order to remedy these omissions, RAI 236-8293 (ML15296A007), Question 09.04.01-01, was generated to request the applicant to (1) specify the parameters to define "design limits;" (2) more clearly define positive pressure; and (3) recommend that the applicant specify ASTM E741 as the required test method in the ITAAC.

In a November 12, 2015, response (ML15316A478) to RAI 236-8293, Question 09.04.01-01, the applicant states that:

1. The specific design room temperature limits for the CRE are described in the DCD Tier 2, Section 9.4.1.1 and they vary with the areas in the CRE such as 21.1 °C to 25 °C (70 °F to 77 °F) for MCR, 18.3 °C to 26.7 °C (65 °F to 80 °F) for other support areas, 10°C to 40°C (50 °F to 104 °F) for HVAC equipment rooms. KHNP believes

that specifying all the design room temperature limits in the acceptance criteria is excessive, and maintaining current term, “design limits” is adequate.

2. The text, “positive pressure in the CRE” in the DCD Tier 1, Table 2.7.3.1-3, Acceptance Criteria 8.b will be revised to “minimum 3.175 mm (0.125 in) water gauge of positive pressure in the CRE with respect to adjacent areas.”
3. The DCD Tier 1, Table 2.7.3.1-3, Inspection, Tests, Analyses 11 will be revised to include ASTM E741-2000 as the unfiltered inleakage test method.

The staff determined that, with the exception of providing design room temperature limits in the ITAAC, the applicant provided the information requested in RAI 236-8293. The staff concluded that, because design room temperature limits are addressed elsewhere in the DCD, it is acceptable that they not be specified in the ITAAC. The staff considers RAI 236-8293, Question 09.04.01-1, resolved.

The staff finds the ITAAC acceptance criteria conform to RG 1.206 for CRHS and therefore, finds the ITAAC requirements acceptable in complying with the requirements of 10 CFR 52.47(b)(1).

9.4.2.4.8 Technical Specifications

Technical specification and surveillance requirements for CRHS are addressed in DCD Tier 2, Section 16, Technical Specifications 3.7.11, “Control Room HVAC System (CHRS),” and B 3.7.11 (the associated basis).

The staff finds the TSs acceptable because the design bases were correctly translated into the specifications. CRHS must be operable in Modes 1, 2, 3, 4, 5 and 6. The Limiting Conditions on Operation for the CRHS conform to the guidance for standard TSs for Combustion Engineering Plants, NUREG-1432, which performs the equivalent function as the APR1400 CRHS system. Therefore, the staff finds the CRHS TSs and bases acceptable.

9.4.2.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related AHUs and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.1.2
9.4(2)	The COL applicant is to provide the interval of	9.4.1.2

	reopening the closed outside air intake isolation dampers by considering the durability of the isolation dampers and the site-specific meteorological data from radiological aspects.	

The staff determined the list adequately describes actions necessary for the COL applicant or holder. No additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for control room habitability considerations.

9.4.2.6 Conclusion

The staff reviewed information presented in the DCD on the design and operation of the CRHS. The staff concluded that the system can provide a controlled environment for the comfort and safety of control room personnel and can perform its safety functions under normal operating, anticipated operational transient, and design-basis accident conditions including a postulated single active failure.

The staff concludes that the design of the CRHS complies with the requirements of GDC 2, GDC 4, GDC5, GDC 19, GDC 60, and 10 CFR 50.63. The ITAAC and TS requirements will ensure that the CRHS can be properly inspected, tested, and operated in accordance with the design basis as described in the DCD and, therefore, the CRHS design complies with 10 CFR 52.47(b)(1).

9.4.3 Fuel Handling Area HVAC System

9.4.3.1 Introduction

This section evaluates DCD Tier 2, Section 9.4.2, “Fuel Handling Area HVAC System.”

The Fuel Handling Area HVAC System serves the fuel handling area including fuel pool area in the auxiliary building.

9.4.3.2 Summary of Application

DCD Tier 1: DCD Tier 1, Section 2.7.3.2 “Fuel Handling Area HVAC System,” provides the functional arrangement as shown in DCD Tier 1, Figure 2.7.3.2-1, “Fuel Handling Area HVAC System.” The normal HVAC subsystem is non safety-related and has a supply AHU, a normal exhaust air cleaning unit (ACU), ductwork, instrumentation, and controls. The emergency HVAC subsystem is safety-related and has two emergency exhaust ACUs, two cubicle coolers, ductwork, instrumentation, and controls.

DCD Tier 2: In DCD Tier 2, Section 9.4.2.1, “Design Bases,” and Section 9.4.2.2, “System Description,” the applicant states that, in part, as follows:

The system is designed to:

1. Maintain a suitable environment for the operation, maintenance, and testing of equipment.

2. Maintain a suitable access and working environment for personnel.

3. Maintain the fuel handling and storage area at a negative pressure relative to the atmosphere to prevent outleakage.

The Fuel Handling Area HVAC system conforms to RGs 1.13, 1.29, 1.52, 1.140, and 4.21.

The Fuel Handling Area HVAC system is designed to prevent the spreading of airborne radioactivity within the plant and to maintain the airborne radioactivity levels in the fuel handling area below the derived air concentration (DAC) values specified in 10 CFR Part 20, "Standards for Protection against Radiation," Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," by supplying and exhausting sufficient airflow. The system is also designed to control the gaseous effluent release less than the dose and concentration criteria specified in 10 CFR Part 50, Appendix I, and 10 CFR Part 20, Appendix B.

During normal mode, the fuel handling area supply AHU and the fuel handling area normal exhaust ACU operate to maintain suitable temperature and ventilation. The fuel handling area is maintained under a slightly negative pressure with respect to the surrounding areas by exhausting more air than supply air.

Upon receipt of an engineered safety feature actuation signal (ESFAS), fuel handling area emergency ventilation actuation signal (FHEVAS), or a high radiation signal, the fuel handling area supply AHU and normal exhaust ACU are stopped sequentially. In addition, the fuel handling area emergency exhaust ACU starts automatically. The fuel handling area is maintained under a slightly negative pressure by exhausting air from the fuel handling area.

9.4.3.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.4.2, "Spent Fuel Pool Area Ventilation System," and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.4.2.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the requirement that a system be capable of withstanding the effects of earthquakes.

2. GDC 5, "Sharing of structures, systems, and components," as it relates to the requirement that sharing a structure, system and component (SSC) between multiple units will not significantly impair the SSC's ability to perform their safety function in the event one unit experiences an accident condition.

3. GDC 60, "Control of releases of radioactive materials to the environment," as it relates to the requirement that a system be capable of controlling the release of gaseous radioactive effluents to the environment.

4. GDC 61, "Fuel storage and handling and radiation control," as it relates to the requirement that a system be capable of providing appropriate containment, confinement, and filtering to limit releases of airborne radioactivity to the environment from the fuel storage facility under normal and postulated accident conditions.

5. 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 are met, a plant that incorporates the design certification and is constructed will operate in conformance with the design certification and in compliance with the provisions of the AEA and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, the Fuel Handling Area HVAC System should meet the guidance of RG 1.29, "Seismic Design Classification," Revision 4, March 2007, Regulatory Position C.1, for safety-related portions and Regulatory Position C.2 for non-safety-related portions.

2. For GDC 5, acceptance is based on the determination that sharing of fuel handling area HVAC System structures systems and components in multiple-unit plants does not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

3. For GDC 60, fuel handling area HVAC System should meet the guidance of RG 1.52, Revision 4, June 2012, Regulatory Position C3, and RG 1.140, Regulatory Positions C.2 and C.3.

4. For GDC 61, fuel handling area HVAC System should meet the guidance of RG 1.13, as related to the design of the ventilation system for the spent fuel storage facility, Regulatory Position C.4.

5. For 10 CFR 52.47(b)(1), fuel handling area HVAC System should meet the guidance contained in SRP Sections 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria," and 14.3.7, "Plant Systems-Inspections, Tests Analyses and Acceptance Criteria."

9.4.3.4 Technical Evaluation

The fuel handling area HVAC System provides the following safety-related functions:

- Isolating of the normal supply AHU and normal exhaust ACU.
- Cooling of SPF cooling HX room (Div. I) and SPF cooling HX room (Div. II) by safety-related cubical coolers during plant normal, abnormal and accident conditions.
- Removing particulate matter and iodine by emergency exhaust ACU in each division.
- Maintaining a slightly negative pressure in the fuel handling area with respect to the surrounding area by the operation of emergency exhaust ACU.

The fuel handling area HVAC system provides the following non-safety-related functions:

- Maintains suitable temperature and ventilation by cubicle coolers, fuel handling area supply AHU and fuel handling area normal exhaust ACU.
- Carries radioactive contaminated air are in ducts that are sized for minimum air velocity, which is 12.7 m/sec (2,500 ft/min), to avoid the settling of radioactive contaminated particles and becoming a radiation source.
- Maintains a slightly negative pressure in the fuel handling area with respect to the surrounding area by the operation of fuel handling area supply AHU and fuel handling area normal exhaust ACU.

The staff reviewed DCD Tier 2, Figure 9.4.2-1, “Fuel Handling Area HVAC System Flow Diagram,” to verify that the system can perform its function according to design. The staff found that the two SFP Cooling HX Rooms were not connected to the two emergency exhaust ACUs. The staff was concerned that the Fuel Handling HVAC system would not be able to maintain a slightly negative pressure in the two SFP Cooling HX Rooms during accident conditions without this connection. Therefore, the staff issued Part 1 of RAI 172-8196 (ML15237A490), Question 09.04.02-01, to request clarification.

In its RAI response dated October 28, 2015 (ML15301A867), the applicant stated that:

> During normal operation, the spent fuel pool (SFP) cooling heat exchanger (HX) rooms are maintained at slightly negative pressure to prevent spreading of airborne radioactive materials. During the design basis accident condition, which is a fuel handling accident (FHA) inside the fuel handling area, as described in DCD Tier 2, Subsection 15.7.4, most radioactive releases arise from breached fuel assemblies in the SFP to the atmosphere above the SFP. Therefore, the safety-related fuel handling area emergency ventilation system covers this area above the SFP. This approach is consistent with the guidance in Appendix B to RG 1.183, which takes into account only the release path from the SFP to the fuel handling area above the SFP. Consideration of additional release paths, such as leakage from the spent fuel pool cooling and cleanup system, is not required by RG 1.183 or SRP 15.7.4.
>
> Even if the release path for leakage from the SFP HX is considered, it is believed that the radioactive release to the environment would be negligible because most of the volatile nuclides, such as noble gases and organic iodines, from the breached fuel in the SFP would not be transferred to the SFP HX and the partitioning of other iodines and particulates in the leaked fluid would be very low due to the low temperature of the SFP water. Therefore, it is not necessary to maintain the SFP HX room at negative pressure during the design basis accident.

The staff reviewed RG 1.183, Appendix B, and SRP Section 15.7.4. The applicant is correct that only the spent fuel storage area needs negative pressure to prevent radioactive releases during a fuel handling accident. Therefore, the staff considers its concerns as described in Part 1 of RAI 172-8196, Question 09.04.02-01 to be resolved.

The staff reviewed the DCD and supporting Tier 2 information in accordance with SRP Section 9.4.2, Section III. The results and conclusions reached are as follows.

9.4.3.4.1 GDC 2, Design bases for protection against natural phenomena

In DCD Tier 2, Section 9.4.2.1, the safety-related components are designed as seismic Category I equipment and remain functional during and following an SSE. Non-safety-related portions of this system in areas containing safety-related equipment are classified as seismic Category II to prevent adverse interaction with safety-related systems during a seismic event. As shown in DCD Tier 1, Table 2.7.3.2-1, “Fuel Handling Area HVAC System Components List,” and Tier 2, Table 9.4.2-1, “Equipment Parameters for Fuel Handling Area HVAC System,” the safety-related components given are designed as seismic Category I, and the non-safety-related components given are designed as seismic Category II, conforming to the guidance in RG 1.29.

In DCD Tier 2, Section 9.4.2.1, the applicant states that all safety-related components are located in a missile-protected structure that is designed to withstand the effects of natural phenomena such as tornadoes, hurricanes, and floods. Since the fuel handling area is located inside the Auxiliary Building, the staff reviewed the auxiliary building design as described in DCD Tier 2, Section 3.8.4 “Other seismic Category I Structures.” The staff finds that because the Auxiliary Building is a seismic Category 1 structure, it is missile protected and designed to withstand the effects of natural phenomena.

The staff reviewed the safety and quality group classification of structures, systems and components that are located in areas serviced by the Fuel Handling Area HVAC System as presented in DCD Tier 2, Table 3.2-1. The staff concluded that those areas containing safety-related equipment are serviced by the safety-related seismic Category I portion of the Fuel Handling Area HVAC System.

According to DCD Tier 2, 15.7.4.1, “Evaluation Model” [for radioactive release from a subsystem or component], after a FHA in the SFP, escaped radioactivity is detected by the fuel handling area radiation monitors so that the FHAEVAS signal is actuated. The post-FHA activity from the SFP is then drawn by the safety-grade fuel handling area emergency ventilation system equipped with high efficiency particulate air (HEPA) and charcoal prior to being released to the environment. The isolation of the normal supply AHU and normal exhaust ACU and the operation of emergency exhaust ACU are accomplished by safety-related and seismic Category I SSCs.

Also during accident conditions, cooling of SFP Cooling HX Rooms which contain the safety-related spent fuel pool cooling and cleanup system SSCs is performed by the SFP Cooling HX Room Cubicle Coolers. The staff finds that these cubicle coolers are safety-related and seismic Category I, thus designed to function to maintain suitable environmental conditions for the serviced equipment.

Since fuel handling area HVAC system components are located in a seismic Category I structure, and based on the safety and quality group classifications of fuel handling area HVAC System components that are required to function in order to perform the system safety-related functions as they are described in DCD Tier 2, Section 9.4.2.3, “Safety Evaluation,” the staff finds that the applicant has complied with the requirements of GDC 2 with respect to the system being capable of withstanding the effects of earthquakes by conforming to the guidelines of RG 1.29, Regulatory Position C.1, for safety-related portions and Regulatory Position C.2, for non-safety-related portions.

9.4.3.4.2 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the Fuel Handling Area HVAC System to ensure that the applicant has met the relevant requirements of GDC 5.

GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design is a single-unit station, and the requirements of GDC 5 met.

9.4.3.4.3 GDC 60, Control of releases of radioactive materials to the environment

GDC 60, control of releases of radioactive materials to the environment, requires that the nuclear power unit design include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

DCD Tier 2, Section 9.4.2.1, states that the system conforms with RGs 1.52, 1.140, and 4.21, derived air concentration (DAC) values specified in 10 CFR Part 20, the dose and concentration criteria specified in 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and limiting Conditions for Operation to Meet thee Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," and 10 CFR Part 20, Appendix B, and 25 percent of the dose limit in 10 CFR 50.34(a)(1) in the event of the design basis fuel handling accident in the fuel handling area.

The staff finds that RG 1.52, Regulatory Position C.3, is applicable to the Emergency Exhaust Air Cleaning Units (AU02A, AU02B), since these ACUs are required to function to mitigate the consequences of a design basis accident.

According to DCD Tier 2, Section 9.4.2.1, the design and construction of the Emergency Exhaust Air Cleaning Units (AU02A, AU02B) conform with ASME AG-1-2009. However, the staff's review of DCD Tier 2, Section 9.4.2.4, "Inspection and Testing Requirements," revealed that it did not address inspection and testing of the heating coils ACU heating coils as specified in AG-1, CA-5400. Therefore, the staff issued Part 2 of RAI 172-8196, Question 09.04.02-01 to request clarification.

In its RAI response dated October 28, 2015 (ML15301A867), the applicant stated that DCD Tier 2, Section 9.4.2.4, will be revised to specify that the electric heating coils in the ACUs will be inspected and tested in accordance with Section CA of ASME AG-1. Therefore, the staff considers its concerns as described in Part 2 of RAI 172-8196, Question 9.4.2-1 to be resolved. Part 2 of RAI 172-196, Question 09.04.02-01 is closed because the affected portion of DCD is revised accordingly.

The staff finds that RG 1.140, Regulatory Positions C.2 and C.3 are applicable to the Normal Exhaust Air Cleaning Unit (AU01), since this ACU performs normal exhaust air cleanup functions for the fuel handling area in the Auxiliary Building, and it is not required during a design basis accident.

The staff reviewed compliance with RG 1.52 for AU02A and AU02B as discussed below.

RG 1.52, Regulatory Position C.3

Section 6.5.1 of this report documents the staff review of the fuel handling area emergency exhaust system (FHAEES) against RG 1.52. As stated in Section 6.5.1, the staff finds that the system conforms to the acceptance criteria of SRP Section 6.5.1 for FHAEES and conforms to the guidance of RG 1.52. Regulatory Position C.3 provides the design criteria for ESF atmosphere cleanup systems.

During normal operation, both iodine filtration trains are secured and fully bypassed with the upstream and downstream dampers in the auto-closed position. Upon receipt of an ESFAS-FHEVAS signal or the common outlet duct high radiation signal, the fuel area emergency exhaust ACUs (AU02A and AU02B) start automatically and the exhaust air is redirected through the iodine filtration trains.

Therefore, because the FHAEES is designed to conform to the guidance of RG 1.52, including Regulatory Position C.3 as described in Section 6.5.1 of this report, the staff finds the design of AU02A and AU02B complies with GDC 60 regarding provisions to suitably control the release of gaseous and liquid radioactive effluents to the environment.

The staff reviewed compliance with RG 1.140 for AU01 as discussed below.

RG 1.140, Regulatory Position C.2

Per RG 1.140, Regulatory Position C.2.1, the design of a normal atmosphere cleanup system should be based on the anticipated operating ranges for temperature, pressure, relative humidity, and radiation levels during normal plant operations and anticipated operational occurrences. In DCD Tier 2, Section 9.4.2.1 the applicant states that the design temperature range for the fuel handling area is 10 °C to 40 °C (50 °F to 104 °F) and design and construction of ACUs conform with ASME AG-1-2009 and ASME N509-2002, “Nuclear Power Plant Air-Cleaning Units and Components.” The staff reviewed ASME AG-1 and ASME N509 to determine if the operating ranges for temperature, relative humidity, pressure, and radiation levels were identified for normal plant operations and anticipated operational occurrences.

Both ASME AG-1 and ASME N509 indicate that design requirements shall be specified for temperature, relative humidity, pressure, and radiation levels. While the applicant has only provided information on the operating ranges for temperature associated with normal plant operation for the fuel area HVAC system, the applicant’s commitment to use ASME AG-1 and ASME N509 provides assurance that the final design will consider pressures, relative humidity, and radiation levels for normal plant operations and anticipated operational occurrences. Therefore, the staff finds that the design of AU01 conforms to RG 1.140, Regulatory Position C.2.1.

In accordance with RG 1.140, Regulatory Position C.2.2, if the normal atmosphere cleanup system is located in an area with high radiation during normal plant operation, then adequate shielding of components and personnel from the radiation source should be provided. According to DCD Tier 2, Figure 1.2-14, “General Arrangement Auxiliary Building El. 100’-0”, AU01 and the interspersed ducts, dampers, and related instrumentation are located in the “Fuel Handling Area Normal Exhaust ACU RM” inside the auxiliary building. According to DCD Tier 2, Figure 12.3-4, “Radiation Zones(Normal) Auxiliary/Containment Building El.100’-0”,” this room is assessed as radiation zone 2 (not a high radiation zone) during normal operation. Radiation zone 2 means its maximum dose rate is less than 0.0025 mSv/hr (0.25 mrem/hr) based on the shielding design basis source terms presented in DCD Tier 2, Section 12.2, “Radiation

Sources." Since AU01 is not in a high radiation zone, the staff finds that the design of AU01 conforms to RG 1.140, Regulatory Position C.2.2.

In accordance with RG 1.140, Regulatory Position C.2.3, the operation of any normal atmosphere cleanup system should not degrade the expected operation of any ESF system that is required to operate after a design-basis accident. The staff concludes that the design conforms to this guidance with regard to the fuel handling area HVAC system, because the fuel handling area normal HVAC subsystem does not perform any ESF function and does not degrade the performance of the FHAEES since the normal HVAC subsystem AHU and ACU are stopped when the FHAEES is actuated per DCD Tier 2, Sections 9.4.2.2, "System Description."

In accordance with RG 1.140, Regulatory Position C.2.4, the design of a normal atmosphere cleanup system should consider any significant contaminants such as dust, chemicals, excessive moisture, or other particulate matter that could degrade the cleanup system's operation. Materials of construction and components shall be selected and tested to limit the generation of combustibles and contaminants per ASME N509, Section 4.4, "Environmental Design Condition," and various ASME AG-1 sections. The applicant has committed to RG 1.140 for the system design, as stated in DCD Tier 2, Sections 9.4.2.1. Therefore, the staff finds that the normal HVAC subsystem design will appropriately consider the expected airborne contaminants. Leak testing of system ductwork in accordance with ASME N511-2007, "In-Service Testing of Nuclear Air-Treatment, Heating, Ventilating, and Air-Conditioning," and ASME AG-1 is addressed in DCD Tier 2, Section 9.4.2.4. The staff concludes that the design conforms to the guidance in RG 1.140, Regulatory Position C.2.4.

RG 1.140, Regulatory Position C.3

RG 1.140, Regulatory Position C.3.1 states that a normal atmosphere cleanup system need not be redundant nor designed to seismic Category I classification; but at a minimum, a system should consist of the following components in the specified order:

- HEPA filters before the adsorbers,
- Iodine adsorbers (impregnated activated carbon),
- Fans, and
- Interspersed ducts, dampers, and related instrumentation.

RG 1.140 recommends that prefilters be installed upstream of the HEPA filters to increase their service life, and that HEPA filters be installed downstream of carbon adsorbers to retain carbon fines.

RG 1.140 does not call for an iodine adsorption component if the atmosphere cleanup system removes only particulate matter. This is the case of fuel handling area normal HVAC subsystem. The design of AU01 does not include iodine adsorber because iodine is not expected to be present in the fuel handling area during normal operation and anticipated operational occurrences (startup, shutdown, and refueling).

The staff reviewed the P&IDs for the system and concluded that the design of AU01 conforms to RG 1.140, Regulatory Position C.3.1.

To ensure reliable in-place testing, the volumetric air-flow rate of a single cleanup unit should be limited to approximately 849.51 m^3/min (30,000 CFM). If a total system air flow in excess of this rate is necessary, multiple units should be used per RG 1.140, Regulatory Position C.3.2. The staff reviewed DCD Tier 2, Section 9.4.2.2, and found that the exhaust air flow rate through AU01 is 28,450 cfm, less than the limiting flow of 30,000 CFM. The staff finds that the design of AU01 conforms to RG 1.140, Regulatory Position C.3.2.

In accordance with RG 1.140, Regulatory Position C.3.3, each normal atmosphere cleanup system should be instrumented to monitor and alarm for pertinent pressure drops and flow rates. The staff reviewed DCD Tier 2, Section 9.4.2.5, and found that AU01 outlet airflow rate indication and alarms are provided in the MCR. The staff reviewed P&IDs and found that local instruments are provided to measure AU01 HEPA filter and prefilter differential pressure. Therefore, the staff finds that the design of AU01 conforms to RG 1.140, Regulatory Position C.3.3.

Per RG 1.140, Regulatory Position C.3.4, to maintain the radiation exposure to operating and maintenance personnel ALARA, normal atmosphere cleanup systems and components should be designed to control leakage and facilitate maintenance, inspection, and testing.

Per DCD Tier 2, Section 9.4.2.1, the design and construction of ACUs conform with ASME AG-1 and ASME N509. Per DCD Tier 2, Section 9.4.2.4, leak testing of system ductwork is performed in accordance with ASME N511 and ASME AG-1. Since the requirements of leakage control, maintenance, inspection, and testing in ASME AG-1, ASME N509, and SME N511 are what RG1.140 specified, the staff concluded that the design of AU01 conforms to the guidance in RG 1.140, Regulatory Position C.3.4.

In accordance with the guidance in RG 1.140, Regulatory Position C.3.5, outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash and other contaminants on the operation of the system.

In DCD Tier 2, Table 3.2-1, the auxiliary building is a Safety Class 3 and seismic Category I Structure. Per GDC-2, the auxiliary building shall be 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. The staff reviewed Figure 9.4.2-1, and found that the system's outdoor air intake opening is equipped with a tornado damper to handle high winds. The staff concluded that the design of AU01 conforms to the guidance in RG 1.140, Regulatory Position C.3.5.

In accordance with the guidance in RG 1.140, Regulatory Position C.3.6, normal atmosphere cleanup system housings and ductwork should be designed to exhibit, on test, a maximum total leakage rate as defined in Article SA-4500 of ASME AG-1-1997.

Per DCD Tier 2, Section 9.4.2.4, leak testing of system ductwork is performed in accordance with ASME N511 and ASME AG-1. In addition, the applicant states that all ACUs are factory inspected and tested for housing leakage, filter bypass leakage, and airflow performance.

Therefore, the staff finds that the cited tests for AU01 conform with RG 1.140, Regulatory Position C.3.6.

Based on the above discussion, the staff finds that the Fuel Handling Area HVAC System conforms with RG 1.140, Regulatory Positions C.2 and C.3. Therefore, the staff finds that this system meets the requirements of GDC 60.

9.4.3.4.4 GDC 61, Fuel storage and handling and radioactivity control

The staff reviewed the fuel handling area HVAC system as it applies to RG 1.13, Regulatory Position C.4, which states that a controlled-leakage building should enclose the fuel to limit the potential release of radioactive iodine and other radioactive materials. If necessary to limit offsite dose consequences from a fuel handling accident or spent fuel pool boiling, the building should include an engineered safety feature filtration system that meets the guidelines outlined in RG 1.52.

The staff finds that component failure modes and effects and redundancy are described under Abnormal Operating Conditions in DCD Tier 2, Section 9.4.2.2. The safety-related portion of the system consists of two 100 percent capacity emergency exhaust ACUs and two safety-related cubicle coolers. The two emergency ACUs and two cubicle coolers are powered by separated Class 1E power sources. A review of the drawings and descriptions verified that the two automatically-operated isolation dampers upstream of the fuel handling area supply AHU and the two automatically-operated isolation dampers downstream of the fuel handling area normal exhaust ACU can separate the nonessential portions from the essential portions of the system. The review also supports that the system has been adequately designed to limit airborne activity during normal operation and in the event of a fuel handling accident.

According to DCD Tier 2, Section 9.4.2.1, the system is designed to maintain the fuel handling and storage area at a negative pressure relative to the atmosphere to prevent outleakage.

According to DCD Tier 2, Section 9.1.3, “Spent Fuel Cooling and Cleanup System (SFPCCS),” the SFPCCS is designed to collect system leakage. Floor drains in the SFP area are provided to collect and route radioactive liquid to the liquid radwaste system (LRS) for processing. The design features of the equipment and floor drainage system (EFDS) for the auxiliary building are described in DCD Tier 2, Section 9.3.3.

The staff notes that there was no mention of the potential impact on system components in the event of spent fuel pool boiling. According to DCD Tier 2, Section 9.1.3, the SFP cooling system is designated as safety-related and seismic Category I. The system is designed to remove the decay heat produced by the spent fuel assemblies during normal operations or accidents. Therefore, the staff believes that the fuel handling area HVAC system need not be designed for SFP bulk pool boiling conditions.

The staff finds that the fuel handling area HVAC system design complies with GDC 61 by conforming to the guidance in RG 1.13, Regulatory Position C.4 with respect to ensuring isolation of the normal ventilation system and actuating the emergency filtration and adsorption systems in the event of a fuel handling accident in the fuel handling and storage area and because the APR1400 design utilizes a controlled-leakage building which encloses the fuel to limit the potential release of radioactive iodine and other radioactive materials. The staff review of the ESF filtration trains as they relate to RG 1.52, and GDC 60 is discussed in Section 6.5.1 of this report.

9.4.3.4.5 ITAAC

The staff reviewed the proposed ITAAC for the Fuel Handling Area HVAC System and its associated safety-related features. The applicant's proposed ITAAC requirements in DCD Tier 1, Tables 2.7.3.2-3, and DCD Tier 2, Section 14.3 were reviewed. The staff finds that sufficient information has been provided to comply with SRP Section 14.3 and SRP Section 14.3.7.

The staff finds that the DCD Tier 1 ITAAC tables adequately address verification of the functional arrangement, physical separation, and seismic qualification of the system. The staff concludes that the design, fabrication, and inspection of the filter systems is in accordance with ASME AG-1 code requirements. The staff also concludes that ITAAC tables verify the minimum inventory of system Alarms Displays and Controls and the ITAAC verify required safety-related functions of the system. Acceptance criteria are based on meeting the relevant requirements of 10 CFR 52.47(b)(1), which requires that the KHNP DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable criteria met the provisions of Atomic Energy Act, and the NRC regulations. Based on this review, the staff has concluded that the fuel handling area HVAC system of a plant that incorporates the design certification will be built and will operate in accordance with NRC regulations, as the systems conform with RG 1.29, RG 1.52, RG 1.140, and RG 1.13

9.4.3.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related air handling units and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.2

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.4.3.6 Conclusion

The staff reviewed the APR1400 standard design Fuel Handling Area HVAC System using the acceptance criterial guidance defined in NUREG-0800, Section 9.4.2. The staff concludes that this system complies the requirements of GDC 2, GDC 5, GDC 60, and GDC 61. The ITAAC requirements were judged by the staff to be appropriate for this system based on its performance requirements and, therefore, the staff concludes the Fuel Handling Area HVAC System designs comply with 10CFR52.47(b)(1).

9.4.4 Turbine Generator Building HVAC System

9.4.4.1 Introduction

The turbine generator building HVAC system is designed to maintain the suitable environment for all equipment and personnel in the turbine generator building during normal plant operation and does not serve any safety-related functions. The staff's evaluation of this system against the relevant criteria is contained in the following subsections.

9.4.4.2 Summary of Application

DCD Tier 1: As stated in DCD Tier 1, Section 2.7.3.4, "Turbine Generator Building HVAC System," there are no DCD Tier 1 entries for this system.

DCD Tier 2: In DCD Tier 2, Sections 9.4.4.1, "Design Bases," the applicant states that the system is designed to:

1. Provide a suitable environment for the operation of equipment and personnel access as required for inspection, testing, and maintenance.

2. Minimize hot spots in the general areas within the turbine generator building.

3. Provide ventilation for the enclosed rooms and exhaust the air from these rooms to the atmosphere to limit oil fumes, toxic gases, and hydrogen concentration.

9.4.4.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.4.4, "Turbine Area Ventilation System," and are summarized below. The review of the turbine generator building HVAC system includes systems contained in the turbine building and their relationship, if any, to safety-related equipment areas. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.4.4.

1. GDC 2, "Design bases for protection against natural phenomena," indicates that a system shall be capable of withstanding the effects of earthquakes.

2. GDC 5, "Sharing of structures, systems, and components," indicates that sharing a structure, system or component between multiple units will not significantly impair the ability of the SSCs to perform its safety function in the event one unit experiences an accident condition.

3. GDC 60, "Control of releases of radioactive materials to the environment," indicates that a system is capable of controlling the release of gaseous radioactive effluents to the environment. GDC 60 requires provisions to be included in the nuclear power unit design to ensure suitable controls on the release of radioactive materials in gaseous effluents during normal reactor operation, including anticipated operational occurrences.

4. 10 CFR 52.47(b)(1) requires 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 are met, a plant that incorporates the design certification and is constructed will operate in conformance with the design certification, the provisions of the AEA and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, the turbine generator building HVAC system should conform to the guidance provided in RG 1.29, Regulatory Position C.1 for safety-related portions of the system and Regulatory Position C.2 for non-safety-related portions of the system.

2. For GDC 5, acceptance is based on the determination that sharing of Turbine Generator Building HVAC System SSCs in multiple-unit plants does not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

3. For GDC 60, the turbine generator building HVAC system should conform to the guidance of RG 1.52 and RG 1.140 as they relate to the design, inspection, testing and maintenance criteria for post-accident and normal atmosphere cleanup systems, ventilation exhaust systems, air filtration, and adsorption units of light-water-cooled nuclear power plants. The applicable regulatory position for RG 1.52, Revision 4, is C.3. The applicable regulatory positions for RG 1.140, Revision 2, are C.2 and C.3.

9.4.4.4 Technical Evaluation

The staff reviewed the turbine generator building HVAC system and supporting DCD Tier 2 information in accordance with SRP Section 9.4.4, Section III, “Review Procedures.” In accordance with the SRP, the review focused on the system functional performance requirements and the methods and equipment provided for air treatment equipment for the system to determine whether the ventilation system or portions of the system have been designed or need to be designed as a safety-related system. The results and conclusions reached are as follows

9.4.4.4.1 **GDC 2, Design bases for protection against natural phenomena**

The guidance for GDC 2 is based on RG 1.29, Regulatory Positions C.1 for safety-related, and C.2 for non-safety-related SSCs, if its failure could reduce the functioning of safety-related SSCs. Any SSCs not falling into the Regulatory Positions C.1 and C.2, are considered seismic Category III. In DCD Tier 2, Section 9.4.4, the applicant states that the system is non-safety-related and seismic Category III. The staff reviewed DCD Tier 2, Table 3.2-1. The staff finds that the Turbine Generator Building is assigned a Safety Classification as “NNS” and seismic Category as “seismic Category Class III.” The staff finds that the turbine generator building HVAC system, component safety class NNS, is designated non-safety-related and seismic Category III. The staff reviewed the safety classification of SSCs in the turbine generator building serviced by the HVAC system and finds that there are no safety-related components that are served by or would be adversely affected by failure of the HVAC systems. Therefore, the staff finds that DCD Tier 2, Chapter 3, and DCD Tier 2, Chapter 9, are consistent with regard to the safety and seismic classifications for the turbine island ventilation system. Accordingly, based on these classifications, the staff finds that the guidance in RG 1.29 is met.

9.4.4.4.2 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the turbine generator building HVAC system to ensure that the relevant requirements of GDC 5 are met.

GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design certification is only for a single-unit, and the requirements of GDC 5 are satisfied.

9.4.4.4.3 GDC 60, Control of releases of radioactive materials to the environment

GDC 60, control of releases of radioactive materials to the environment, requires that the nuclear power unit design include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

Since the Turbine Generator Building does not contain any radioactive materials and the turbine generator building HVAC system does not have air filtration and adsorption units, GDC 60 is not applicable.

9.4.4.4.4 ITAAC

The staff notes that ITAAC information is not provided for the turbine generator building HVAC system. The staff finds this acceptable because this system is non-safety-related, and serves areas that do not contain safety-related SSCs. The staff finds that adequate inspections and tests for these systems are performed in the Initial Plant Test Program described in DCD Tier 2, Section 14.2. An evaluation of the Plant Test Program is contained in Chapter 14 of this report.

9.4.4.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related air handling units and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.4

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.4.4.6 Conclusion

The staff reviewed the APR1400 standard design turbine generator building HVAC system using the acceptance criteria guidance defined in NUREG-0800, Section 9.4.4. The staff concludes that this system complies with the requirements of GDC 2, and that GDC 5 and GDC 60 in this case. There were no ITAAC requirements and this were judged by the staff to be appropriate. Therefore, the staff concludes that the Turbine Generator Building HVAC System design complies with 10 CFR 52.47(b)(1).

9.4.5 Engineered Safety Feature Ventilation System

9.4.5.1 Introduction

The function of the engineered safety feature ventilation system (ESFVS) is to provide a suitable and controlled environment for engineered safety feature components following certain anticipated transients and design-basis accidents. The following ventilation systems which the staff considers subject to review under NUREG-0800, Section 9.4.5, "Engineered Safety Feature Ventilation System" are:

1. Emergency Diesel Generator Area HVAC System, which services two EDG areas located in the auxiliary building and two EDG areas located in the EDGB.
2. Electrical and I&C Equipment Areas HVAC System, which services electrical equipment rooms, instrument equipment rooms, and control equipment rooms in the auxiliary building.
3. Auxiliary Building Controlled Area HVAC System, which services the radiologically controlled areas except the fuel handling area in the auxiliary building.
4. Essential Service Water (ESW) Building and CCW Heat Exchanger Building HVAC System, which services the areas in ESW building and CCW heat exchanger building as designed in detail by a COL applicant. Because it is the responsibility of the COL applicant to provide HVAC system design information if an HVAC system is required, this system is not reviewed in this report.

The staff's evaluation of this system against the relevant criteria is contained in the following subsections.

9.4.5.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is discussed in DCD Tier 1, Section 2.7.3.5, "Engineered Safety Feature Ventilation System."

DCD Tier 2: The applicant has provided system descriptions in DCD Tier 2, Section 9.4.5, "Engineered Safety Feature Ventilation System."

ITAAC: ITAAC requirements are given in DCD Tier 1, Table 2.7.3.5-3, "Engineered Safety Feature Ventilation System ITAAC."

Technical Specifications: TSs are as indicated in DCD Tier 2, Section 16, "Technical Specifications," 3.7.12 "Auxiliary Building Controlled Area Emergency Exhaust System (ABCAEES)."

9.4.5.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.4.5, and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.4.5.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to the system being capable of withstanding the effects of earthquakes.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to the ESFVS being appropriately protected against dynamic effects and being designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to shared systems and components important to safety.

4. GDC 17, "Electric power systems," as it relates to ensuring proper functioning of the essential electric power system.

5. GDC 60, "Control of releases of radioactive materials to the environment," as it relates to the system being capable to suitably control release of gaseous radioactive effluents to the environment.

6. 10 CFR 50.63, as it relates to necessary support systems providing sufficient capacity and capability for coping with a SBO event.

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 AEA, and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the ESFVS conforming to the guidance of RG 1.29, Regulatory Position C.1, for safety-related portions and Position C.2 for non-safety-related portions.

2. For GDC 4, acceptance is based on the ESFVS conforming to the guidance, as it applies to the ESFVS, of NUREG-0800, Sections 3.5.1.1, "internally Generated Missiles (Outside Containment)"; 3.5.1.4, "Missiles Generated by Tornados and Extreme Winds," 3.5.2, "Structures, Systems, and Components to be Protected from Externally-Generated Missiles," and 3.6.1, "Plant Design for Protection Against Postulated Piping failures in Fluid systems outside Containment."

3. For GDC 5, acceptance is based on the determination that sharing of ESFVS SSCs in multiple-unit plants does not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

4. For GDC 17, acceptance is based on the ESFVS conforming to the guidance of NUREG/CR-0660, “Enhancement of Onsite Emergency Diesel Generator Reliability,” Item 2 under Subsection A, and Item 1 under Subsection C of the “Recommendations” for protection of essential electrical components from failure due to the accumulation of dust and particulate materials.

5. For GDC 60, acceptance is based on the ESFVS conforming to the guidance of RG 1.52 and RG 1.140, as related to design, inspection, testing, and maintenance criteria for post-accident and normal atmosphere cleanup systems, ventilation exhaust systems, air filtration, and adsorption units.

6. For 10 CFR 50.63, acceptance is based on the ESFVS conforming to the guidance of RG 1.155, including Regulatory Position C.3.2.4.

7. For 10 CFR 52.47(b)(1), acceptance is based on the ESFVS conforming to the guidance contained in NUREG-0800, Sections 14.3, and 14.3.7.

9.4.5.4 Technical Evaluation

The staff reviewed the DCD and supporting DCD Tier 2 information in accordance with SRP Section 9.4.5, Section III, “Review Procedures.” The results and conclusions reached by the staff are as follows:

9.4.5.4.1 **GDC 2, Design bases for protection against natural phenomena**

Emergency Diesel Generator Area HVAC System

The design features described in DCD Tier 2, Section 9.4.5, including Table 9.4.5-1, “Equipment Parameters for Engineered Safety Feature Ventilation System,” indicate that the system is safety-related and seismic Category I.” The staff finds that because the EDG Area HVAC system is itself a seismic Category I system and is located in a seismic Category I structure, it is therefore protected against natural phenomena. This meets the guidance of RG 1.29, Regulatory Position C.1. Therefore, the staff finds that this system complies with the requirements of GDC 2.

Electrical and I&C Equipment Areas HVAC System

The staff reviewed DCD Tier 2, Figure 9.4.5-2, “Electrical and I&C Equipment Areas HVAC System Flow Diagram,” and finds that safety-related and non-safety-related portions of the system are not connected. Within the DCD, all safety related portions of the electrical and I&C HVAC system are classified as seismic Category I and all non-safety related portions of the system are classified as seismic Category II. The staff finds that this conforms to the guidance of RG 1.29 and, therefore, this system complies with the requirements of GDC 2.

Auxiliary Building Controlled Area HVAC System

The staff reviewed DCD Tier 2, Figures 9.4.5-3 and finds that essential portions of the system, including the isolation dampers separating essential from nonessential portions, are classified seismic Category I. Also, nonessential portions of the system are classified seismic Category II.

The staff finds that this conforms to the classification guidance of RG 1.29, Regulatory Position C.1, for safety-related portions and RG 1.29, Regulatory Position C.2, for non-safety-related portions of the system. Therefore, the staff finds that this system complies with the requirements of GDC 2.

The staff finds that the safety-related portion of the ESFVS is designed to seismic Category I in accordance with RG 1.29, Regulatory Position C.1. Those non-safety-related portions of the ESFVS of which continued function is not required, but of which failure could reduce the functioning of any seismic Category I system components to an unacceptable safety level, are designed to conform to RG 1.29, Regulatory Position C.2.

The staff also finds the design of the auxiliary building and EDGB that house the ESFVS are seismic Category I structures that are also located and designed to provide protection from floods, hurricane/tornado winds, and missiles. The staff notes that DCD 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 such as earthquakes, tornadoes, hurricanes, floods, and external missiles. Therefore, the staff finds that the ESFVS complies with the requirements of GDC 2.

9.4.5.4.2 GDC 4, Environmental and dynamic effects design bases

Emergency Diesel Generator Area HVAC System

In DCD Tier 2, Section 9.4.5.1.1, the applicant states that the four EDG areas are located inside the Auxiliary Building and the EDGB. As discussed above, both buildings are designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, and external missiles.

The analysis of a postulated high-energy line failure is provided in DCD Tier 2, Sections 3.6.1, and 3.6.2.

In accordance with DCD Tier 2, Section 3.11 and Table 3.11-3, Sheets 38-39, mechanical, electrical, and I&C equipment important to safety is qualified to meet performance requirements under the environmental and operating conditions in which the equipment is required to function and during the length of time for which their function is required. Therefore, the staff finds that this system complies with the requirements of GDC 4.

Electrical and I&C Equipment Areas HVAC System

In DCD Tier 2, Section 9.4.5.2.2, “Electrical and I&C Equipment Areas HVAC Systems,” the applicant states that the system serves certain rooms in the auxiliary building. As discussed above, the auxiliary building is designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, and external missiles.

The analysis of a postulated high-energy line failure is provided in DCD Tier 2, Sections 3.6.1, and 3.6.2.

In accordance with DCD Tier 2, Section 3.11 and Table 3.11-3, Sheets 40-42, mechanical, electrical, and I&C equipment important to safety is qualified to meet performance requirements under the environmental and operating conditions in which the equipment is required to function and during the length of time for which their function is required. Therefore, the staff finds that this system complies with the requirements of GDC 4.

Auxiliary Building Controlled Area HVAC System

In DCD Tier 2, Section 9.4.5.1.3, "Auxiliary Building Controlled Area HVAC System," the applicant states that the system serves the radiological controlled areas except the fuel handling area in the auxiliary building. As discussed above, the auxiliary building is designed to withstand the effects of natural phenomena, such as earthquakes, tornados, hurricanes, floods, and external missiles.

The analysis of a postulated high-energy line failure is provided in DCD Tier 2, Sections 3.6.1, and 3.6.2.

In accordance with DCD Tier 2, Section 3.11 and Table 3.11-3, Sheets 43-44, mechanical, electrical, and I&C equipment important to safety is qualified to meet performance requirements under the environmental and operating conditions in which the equipment is required to function and during the length of time for which their function is required. Therefore, the staff finds that this system complies with the requirements of GDC 4.

Based on the above DCD statements, the staff finds that the ESFVS design appropriately addresses postulated adverse environmental conditions and dynamic effects and, therefore, complies with the requirements of GDC 4.

9.4.5.4.3 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the ESFVS to ensure that the relevant requirements of GDC 5 are met.

GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design is a single-unit station and the requirements of GDC 5 are satisfied.

9.4.5.4.4 GDC 17, Electric power systems

GDC 17 relates to ensuring that the essential electric power system functions properly. The staff finds that GDC 17 is applicable to emergency diesel generator area HVAC system and electrical and I&C equipment areas HVAC system. The review of these two systems against GDC 17 is discussed below.

Emergency Diesel Generator Area HVAC System

Based on the review of DCD Tier 2, Figure 9.4.5-1, “Emergency Diesel Generator Area HVAC System Flow Diagram,” the staff finds that the EDG room serviced by the EDG area HVAC system is protected from dust accumulation using roughing filters of the normal supply AHUs.

In DCD Tier 2, Section 9.4.5.1.1, the applicant states that the EDG area HVAC system conforms with 10 CFR Part 50 Appendix A, GDC 17, by protecting electric contacts and relays from dust and dirt in the EDG rooms, which is accomplished by taking filtered air from a height of at least 7 m (20 ft) above ground level.

In DCD Tier 2, Table 8.1-2, “Criteria and Guidelines for Electric Power Systems,” shows that essential electrical equipment conforms to the guidelines of NUREG/CR-0660, “Enhancement of Onsite Emergency Diesel Generator Reliability.”

NUREG-0800, Section 9.4.5, “Engineered Safety Feature Ventilation System,” is used by the staff to review this system. Section II of this SRP “Acceptance Criteria,” Item 4 under Technical Rationale, provides the following guidance to comply with GDC 17:

> With regard to the ESFVS, the plant design should ensure that electrical contacts and relays in diesel generator rooms are protected from dust, dirt, and grit.

The above guidance is also mentioned in NUREG/CR-0660, Item 2 under Subsection A, Recommendations. RAI 214-8250 (ML15259A529), Question 09.04.05-01, was issued to request the applicant to explain how the above guidance is met.

In a November 4, 2015, response (ML15308A569), the applicant states that:

> DCD Tier 2, Section 9.4.5.1.1 describes that “The EDG area HVAC system conforms with 10 CFR Part 50 Appendix A, GDC 17, by protecting electric contacts and relays from dust and dirt in the EDG rooms, which is accomplished by taking filtered air from a height of at least 7 m (20 ft) above ground level..” The EDG area HVAC system has air intakes located at least 7 m (20 ft) above ground level to prevent taking dust and dirt from the ground and each EDG room normal supply air handling unit (AHU) of the EDG area HVAC system has a prefilter as described in Section 9.4.5.2.1.1 and shown in Figure 9.4.5-1 to provide filtered air to the EDG rooms.

Since NUREG/CR-0660, Section A, Item 2, Recommendation c, states that “ventilation air for the DG room should be taken about 20 feet above the adjacent ground surface because of dust blown about by wind and/or passing vehicles,” the staff believes that the applicant’s response adequately explains how the plant design ensures that electrical contacts and relays are protected from dust, dirt and grit. The staff considers RAI 214-8250, Question 09.04.05-01, resolved.

Based on the above review, the staff finds that the system complies with the requirements of GDC 17.

Electrical and I&C Equipment Areas HVAC System

Based on the review of DCD Tier 2, Figures 9.4.5-2, “Electrical and I&C Equipment Areas HVAC System Flow Diagram,” and Figures 9.4.3-1, “Auxiliary Building Clean Area HVAC

System Flow Diagram," the staff finds that the essential electrical equipment serviced by the electrical and I&C equipment areas HVAC system is protected from dust accumulation using roughing filters on the supply AHUs.

In DCD Tier 2, Section 9.4.5.1.2, the applicant states that electrical and I&C equipment areas HVAC system conforms with 10 CFR Part 50 Appendix A, GDC 17, by protecting electric contacts and relays from dust and dirt in the electrical and I&C equipment rooms. This is accomplished by using filtered air and taking air from a height of at least 7 m (20 ft) above ground level. Therefore, the staff finds that this system complies with the requirements of GDC 17.

Based on the above, the staff finds that the design of the safety-related portions of the ESFVS complies with GDC 17 regarding the protection of essential electrical components from failure due to the accumulation of dust and particulate materials.

9.4.5.4.5 GDC 60, Control of releases of radioactive materials to the environment

The staff finds that GDC 60 is applicable to the auxiliary building controlled area HVAC system. The review of this system against GDC 60 is discussed below.

GDC 60 requires that the nuclear power unit design includes means to control the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

DCD Tier 2, Section 9.4.5.1.3, states that the system conforms with RGs 1.52, 1.140, and 4.21, derived air concentration (DAC) values specified in 10 CFR Part 20, the dose and concentration criteria specified in 10 CFR Part 50, Appendix I and 10 CFR Part 20, Appendix B, and 100 percent of the dose limit in 10 CFR 50.34(a)(1) in the event of a LOCA.

The staff finds that RG 1.52, Regulatory Position C.3 is applicable to the emergency exhaust ACUs (AU01A, AU01B, AU01C, AU01D) because these ACUs are required to function to mitigate the consequences of a design basis accident.

According to DCD Tier 2, Section 9.4.5.1.3, the design and construction of ACUs (AU01A, AU01B, AU01C, AU01D, AU03, AU04, AU05, AU06, AU07, and AU08) conform to ASME AG-1-2009. The staff reviewed AG-1 and found that ACU heating coils should be inspected and tested per AG-1, CA-5400. Because DCD Tier 2, Section 9.4.5.4.3, "Auxiliary Building Controlled Area HVAC System," did not address the inspection and testing requirements of heating coils, RAI 214-8250, Question 09.04.05-02, Part 1, was issued to request clarification.

In a November 4, 2015, response (ML15308A569), the applicant states that (ML15308A569):

> DCD Tier 2, Section 9.4.5.4.3 will be revised to clarify that the heating coils of ACUs in the auxiliary building controlled area HVAC system are inspected and tested in accordance with section CA-5400 of ASME AG-1.

The staff has confirmed that the affected DCD has been revised and considers Part 1 of RAI 214-8250, Question 09.04.05-02, resolved.

The staff finds that RG 1.140, Regulatory Positions C.2 and C.3 are applicable to the Normal Exhaust ACUs (AU03, AU04, AU05, AU06, AU07, AU08) because these ACUs perform normal exhaust air cleanup functions for the radiologically controlled areas in the Auxiliary Building except the fuel handling area, and these Normal exhaust ACUs are not required during a design basis accident

The staff reviewed compliance with RG 1.52 for emergency exhaust ACUs (AU01A, AU01B, AU01C, and AU01D) as discussed below.

RG 1.52, Regulatory Position C.3

Section 6.5.1 of this report documents the staff review of the auxiliary building controlled area emergency exhaust system (ABCAEES) against RG 1.52. As stated in Section 6.5.1, the staff finds that the system conforms to the acceptance criteria of SRP Section 6.5.1 for ABCAEES and conforms to the guidance of RG 1.52. Regulatory Position C.3 provides the design criteria for ESF atmosphere cleanup systems.

During normal operation, all iodine filtration trains (AU01A, AU01B, AU01C, and AU01D) are secured and fully bypassed with the upstream and downstream dampers in the auto-closed position. Upon receipt of an ESFAS-SIAS signal, the fuel area emergency exhaust ACUs start automatically and the exhaust air is redirected through the iodine filtration trains.

Therefore, because the ABCAEES is designed to conform to the guidance of RG 1.52, including Regulatory Position C.3, as described in Section 6.5.1 of this report, the staff finds the design of Emergency Exhaust ACUs complies with GDC 60 regarding provisions to suitably control the release of gaseous and liquid radioactive effluents to the environment.

The staff reviewed compliance with RG 1.140, for normal exhaust ACUs (AU03, AU04, AU05, AU06, AU07, and AU08) as discussed below.

RG 1.140, Regulatory Position C.2

Per RG 1.140, Regulatory Position C.2.1, the design of a normal atmosphere cleanup system should be based on the anticipated operating ranges for temperature, pressure, relative humidity, and radiation levels during normal plant operations and anticipated operational occurrences. In DCD Tier 2, Section 9.4.5.1.3, the applicant specifies the design temperature range for the areas served and states that design and construction of ACUs conform to ASME AG-1-2009 and ASME N509-2002. The staff reviewed ASME AG-1 and ASME N509, to determine if the operating ranges for temperature, relative humidity, pressure, and radiation levels were identified for normal plant operations and anticipated operational occurrences.

Both ASME AG-1 and ASME N509, indicate that design requirements shall be specified for temperature, relative humidity, pressure, and radiation levels. While the applicant has only provided information on the operating ranges for temperature associated with normal plant operation for the areas served, the applicant's commitment to use ASME AG-1 and ASME N509, provides assurance that the final design will consider pressures, relative humidity, and radiation levels for normal plant operations and anticipated operational occurrences. Therefore, the staff finds that the design of normal exhaust ACUs conforms to RG 1.140, Regulatory Position C.2.1.

In accordance with RG 1.140, Regulatory Position C.2.2, if the normal atmosphere cleanup system is located in an area with high radiation during normal plant operation, then adequate shielding of components and personnel from the radiation source should be provided.

According to DCD Tier 2, Figures 1.2-11 to 1.2-18, all ACUs and the interspersed ducts, dampers, and related instrumentation are located in rooms inside the auxiliary building. According to DCD Tier 2, Figures 12.3-3 to 12.3-9, these room are assessed as radiation zones from 2 to 7 during normal operation. The staff reviewed DCD Tier 2, Section 12.3, "Radiation Protection Design Features." Designs features are in place to provide adequate shielding between high-radiation areas and the low-radiation areas that are occupied by plant personnel. According to DCD Tier 2, Table 12.3-4, "Design Basis Radiation Shield Thicknesses," minimum required shielding thicknesses for rooms in the Auxiliary Building are identified.

Further staff analysis of the protection measures is provided in Section 12.3 of this report. The staff finds that the design of Normal Exhaust ACUs conforms to RG 1.140, Regulatory Position C.2.2.

In accordance with RG 1.140, Regulatory Position C.2.3, the operation of any normal atmosphere cleanup system should not degrade the expected operation of any ESF system that is required to operate after a design-basis accident. The auxiliary building controlled area normal exhaust ACUs do not perform any ESF function and do not degrade the performance of the expected safety function since the controlled area normal supply AHUs and normal exhaust ACUs are stopped and isolated by dampers when the engineered safety features actuation system – safety injection actuation signal (ESFAS-SIAS) is actuated per DCD Tier 2, Section 9.4.5.2.3.1 "Auxiliary Building Controlled Area I and II HVAC Subsystems." The high energy line break (HELB) Area HVAC Subsystem does not degrade the performance of any safety function because the HELB area supply AHU and exhaust ACUs are not connected to any safety related SSCs.

Because the normal atmosphere cleanup system does not degrade the expected operation of any ESF system, the staff concludes that the design conforms to this guidance in RG 1.140, Regulatory Position C.2.3.

In accordance with RG 1.140, Regulatory Position C.2.4, the design of a normal atmosphere cleanup system should consider any significant contaminants such as dust, chemicals, excessive moisture, or other particulate matter that could degrade the cleanup system's operation. Per ASME N509, Section 4.4, and various ASME AG-1 sections, materials of construction and components shall be selected and tested to limit the generation of combustibles and contaminants. The applicant has committed to RG 1.140 along with ASME N509 and ASME AG-1, for the system design, as stated in DCD Tier 2, Sections 9.4.5. Therefore, the staff finds that the system design will appropriately consider the expected airborne contaminants. Leak testing of system ductwork in accordance with ASME N511-2007, and ASME AG-1 is addressed in DCD Tier 2, Section 9.4.5.4, "Inspection and Testing Requirements." The staff concludes that the design conforms to the guidance in RG 1.140, Regulatory Position C.2.4.

RG 1.140, Regulatory Position C.3

RG 1.140, Regulatory Position C.3.1, states that a normal atmosphere cleanup system need not be redundant nor designed to seismic Category I classification; but at a minimum, a system should consist of the following components in the specified order:

HEPA filters before the adsorbers,

1. Iodine adsorbers (impregnated activated carbon),
2. Fans, and
3. Interspersed ducts, dampers, and related instrumentation.

RG 1.140 recommends that prefilters be installed upstream of the HEPA filters to increase their service life, and that HEPA filters be installed downstream of carbon adsorbers to retain carbon fines. The design of the system includes these features.

The staff reviewed the P&IDs for the system and concluded that the design of AU03, AU04, AU05, AU06, AU07, and AU08 conforms to RG 1.140, Regulatory Position C.3.1 because the system includes all of the recommended components.

To ensure reliable in-place testing, the volumetric air-flow rate of a single cleanup unit should be limited to approximately 849.51 m^3/min (30,000 cfm). If a total system air flow in excess of this rate is necessary, multiple units should be used per RG 1.140, Regulatory Position C.3.2. The staff reviewed DCD Tier 2, Section 9.4.5.2.3.1, and found that the exhaust air flow rate through AU05 and AU07 is 38,000 cfm. Also, the exhaust air flow rate through AU06 and AU08 is 36,150 cfm.

The applicant did not indicate whether multiple-units for AU05, AU07, AU06 and AU08 would be used. Therefore, to conform to the guidance in RG 1.140, Regulatory Position C.3.2, in RAI 214-8250, Question 09.04.05-02, Part 2, the staff requested that the applicant provide data regarding the air flow rates for these ACUs.

In a November 4, 2015, response (ML15308A569) to RAI 214-8250, Question 09.04.05-02, Part 2 of 2, the applicant states that:

> In the APR1400 standard design, the auxiliary building controlled area HVAC system uses 1,500~2,000 CFM HEPA filters and the auxiliary building controlled area normal exhaust ACUs can allow at least 45,000 CFM air-flow rate without increasing the physical size and changing the filter layout of 3 HEPA filters high and 10 HEPA filters wide. And in-place test equipment such as aerosol generators for in-place testing has been developed and it currently has the capability to perform reliable in-place testing for ACUs up to 65,000 CFM. Therefore, the auxiliary building controlled area normal exhaust ACUs, which have 38,000 CFM or 36,150 CFM air-flow rate per single ACU can ensure convenient maintenance and reliable in-place testing and the auxiliary building controlled area HVAC system would not need to limit the air-flow rate of a single ACU to 30,000 CFM.

The staff reviewed DOE HDBK-1169-2003, Section 4.4.11, where higher than the traditional 1,500 cfm HEPA filters are described. Because APR 1400 is using 1,500 – 2,000 cfm HEPA filters and in-place test equipment up to 65,000 cfm, the staff considers Part 2 of RAI 214-8250, Question 09.04.05-02, resolved.

The staff finds that the design of normal exhaust ACUs conforms to RG 1.140, Regulatory Position C.3.2.

In accordance with RG 1.140, Regulatory Position C.3.3, each normal atmosphere cleanup system should be instrumented to monitor and alarm for pertinent pressure drops and flow rates. The staff reviewed DCD Tier 2, Section 9.4.5.5.3, "Auxiliary Building Controlled Area HVAC System," and found that all ACU's outlet airflow rate indication and alarms are provided in the MCR. The staff reviewed P&IDs and found that local instruments are provided to measure all ACU's prefilter, HEPA filter and carbon adsorber differential pressure. Therefore, the staff finds that the design of AU03, AU04, AU05, AU06, AU07, and AU08 conforms to RG 1.140, Regulatory Position C.3.3.

Per RG 1.140, Regulatory Position C.3.4, to maintain the radiation exposure to operating and maintenance personnel ALARA, normal atmosphere cleanup systems and components should be designed to control leakage and facilitate maintenance, inspection, and testing.

Per DCD Tier 2, Section 9.4.5.1.3, the design and construction of ACUs conform to ASME AG-1 and ASME N509. Per DCD Tier 2, Section 9.4.5.4, leak testing of system ductwork is performed in accordance with ASME N511 and ASME AG-1. Because RG1.140 specified that the design meet the requirements of leakage control, maintenance, inspection, and testing in ASME AG-1, ASME N509, and ASME N511, the staff concluded that the design of AU03, AU04, AU05, AU06, AU07, and AU08 conforms to the guidance in RG 1.140, Regulatory Position C.3.4.

In accordance with the guidance in RG 1.140, Regulatory Position C.3.5, outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash and other contaminants on the operation of the system.

In DCD Tier 2, Table 3.2-1, the auxiliary building is a Safety Class 3 and seismic Category I structure. Per GDC-2, the Auxiliary Building shall be 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. Because it is a Safety Class III, seismic Category I building, the design provides devices to protect outdoor air intake openings. This conforms to the guidance in RG 1.140, Regulatory Position C.3.5.

In accordance with the guidance in RG 1.140, Regulatory Position C.3.6, normal atmosphere cleanup system housings and ductwork should be designed to exhibit, on test, a maximum total leakage rate as defined in Article SA-4500 of ASME AG-1-1997.

Per DCD Tier 2, Section 9.4.5.4, leak testing of system ductwork is performed in accordance with ASME N511 and ASME AG-1. In addition, the applicant states that all ACUs are factory inspected and tested for housing leakage, filter bypass leakage, and airflow performance.

Therefore, the staff finds that the cited tests for AU03, AU04, AU05, AU06, AU07, and AU08 conform to RG 1.140, Regulatory Position C.3.6.

Based on the above discussion, the staff finds that the auxiliary building controlled area HVAC system conforms to RG 1.52, Regulatory Position C3, and RG 1.140, Regulatory Positions C.2 and C.3. Therefore, the staff finds that this system meets the requirements of GDC 60.

9.4.5.4.6 10 CFR 50.63 Loss of all alternating current power

In DCD Tier 2, Section 8.4.1.1, the applicant states that, during an SBO, a non-Class 1E AAC GTG with sufficient capacity, capability, and reliability provides power for the set of required loads (non-design-basis accident) to bring the plant to safe shutdown. The AAC GTG is started and manually connected to the set of required shutdown equipment within 10 minutes in accordance with Position C.3.2.5 of RG 1.155. Also, the ability of KHNP ESF ventilation systems to cope with station blackout is assessed against the criteria in accordance with RG 1.155.

Emergency Diesel Generator Area HVAC System

In DCD Tier 2, Section 9.4.5.1.2, the applicant states that during an SBO, the emergency diesels are not operating, and there are no other significant heat loads, therefore, the EDG area HVAC system is not required.

Electrical and I&C Equipment Areas HVAC System

In DCD Tier 2, Section 9.4.5.1.2, the applicant states that, during an SBO, the safety-related components of the electrical and I&C equipment areas HVAC system are powered from the AAC source. The electrical and I&C equipment areas HVAC system is unavailable for 10 minutes until the AAC generator restores power after an SBO occurs.

Auxiliary Building Controlled Area HVAC System

In DCD Tier 2, Section 9.4.5.1.3, the applicant states that, during an SBO, the safety-related isolation dampers are closed due to loss of the isolation damper power source. The auxiliary building controlled area pressure is maintained to limit release of airborne radioactivity.

Based on the above DCD statements, the staff finds the design of the ESFVS complies with 10 CFR 50.63 regarding the capability for responding to a SBO, because in the event of an SBO, the EDG area HVAC system has no significant heat load. The remaining ESFVS would be powered by the AAC GTG and, would therefore, have power to continue to function to maintain acceptable conditions in the areas with safety-related SSCs. Thus, ESF equipment located in these locations are not expected to endure environmental conditions that would result from a loss of HVAC.

9.4.5.4.7 ITAAC

The staff reviewed the ITAAC requirements in DCD Tier 1, Tables 2.7.3.5-3, “Engineering Safety Feature Ventilation System ITAAC,” and DCD Tier 2, Section 14.3.2.7, “ITAAC for Plant Systems.”

Acceptance criteria are based on meeting the relevant requirements of 10 CFR 52.47(b)(1), which requires that the KHNP DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable criteria met the provisions of the AEA and NRC regulations. The staff finds the ITAAC acceptance criteria for ESFVS appropriate because it conforms to

RG 1.155. Therefore, the staff finds the ITAAC requirements acceptable in complying with the requirements of 10 CFR 52.47(b)(1).

9.4.5.4.8 Technical Specifications

Technical specification and surveillance requirements for ESFVS (DCD Tier 2, Chapter 16) were reviewed by the staff and are discussed as follows:

Emergency Diesel Generator Area HVAC System

This system is not addressed in proposed TSs.

There are TSs for the emergency alternating current sources of power. TSs 3.8.1, "AC sources – Operating, Technical Specifications 3.8.2," and "AC sources – Shutdown," require the emergency alternating current power supplies to be operable. Section 1 of TSs defines operability to include, "all necessary attendants … auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its specified function(s) are also capable of performing their related support function(s)." Because the operability of EDG area HVAC system is covered under TSs 3.8.1, the staff finds that specific TSs are not necessary.

Electrical and I&C Equipment Areas HVAC System

This system is not addressed in proposed TSs.

A review of NUREG-1432, "Standard Technical Specifications Combustion Engineering Plants," Volume 1 & 2, Revision 4, shows that similar systems are not included in the STS. As a result, the staff finds that specific TSs on Electrical and I&C Equipment Areas HVAC System are not necessary.

Auxiliary Building Controlled Area HVAC System

Auxiliary building controlled area HVAC system is addressed in proposed DCD Tier 2, Chapter 16, TSs 3.7.12, "Auxiliary Building Controlled Area Emergency Exhaust System (ABCAEES)" and B 3.7.12, "Auxiliary Building Controlled Area Emergency Exhaust System." The staff finds the TSs acceptable, because the design bases were correctly translated into the specifications. ABCAEES must be operable in Modes 1, 2, 3, and 4.

DCD, Tier 2, Chapter 16, Surveillance Requirement 3.7.12.4, verifies the ability of the system to draw down the mechanical penetration rooms and the safety-related mechanical equipment rooms to a negative pressure ≤ -6.35 mm (-0.25 inches) water gauge at a flow rate of ≤ 5,097 m^3/hr (3,000 cfm) within 300 seconds using one division of ABCAEES in accordance with the system design. The staff finds this surveillance acceptable because it ensures that the capability to adequately draw down and maintain a negative pressure in the mechanical penetration rooms and the safety-related mechanical equipment rooms is periodically verified.

9.4.5.5 Combined License Information Items

The following is a list of applicable COL information items.

Table 9.4.5-1 Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related air handling units and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.5.2.1.1, 9.4.5.2.3.1, 9.4.5.2.3.2
9.4(3)	The COL applicant is to provide the system design information of ESW building and CCW heat exchanger building HVAC system including flow diagram, if the ESW building and CCW heat exchanger building require the HVAC system.	9.4.5
9.4(4)	The COL applicant is to provide the capacities of heating coils of electric duct heaters affected by site-specific conditions.	9.4.5.2.1.3, 9.4.5.2.2.3, 9.4.5.2.2.5

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.4.5.6 Conclusion

The ESFVS was reviewed to the acceptance criteria guidance defined in NUREG-0800, Section 9.4.5. The staff concludes that this system complies with the requirements of GDC 2, GDC 5, GDC 4, GDC 17, and GDC 60. Because the APR 1400 design is a single unit, GDC 5 is not applicable.

The staff finds that the ESFVS design complies with the requirements of 10 CFR 50.63. Additionally, because the EDGs are not required to function in an SBO, requirements of 10 CFR 50.63 do not apply.

The staff concludes that the TS requirements will ensure that ESFVS design complies with the requirements of 10 CFR 52.47(a)(11).

The staff concludes that the ITAAC requirements will ensure that the ESFVS can be properly inspected, tested, and operated in accordance with the design basis as described in the DCD and, therefore, consider that the ESFVS design complies with 10 CFR 52.47(b)(1).

9.4.6 Reactor Containment Building HVAC System and Purge System

9.4.6.1 Introduction

This section evaluates DCD Section 9.4.6, "Reactor Containment Building HVAC System and Purge System."

The reactor containment building HVAC system is designed to maintain the appropriate environmental conditions inside the reactor containment building during plant normal operation.

The reactor containment building purge system is designed to clean up the containment atmosphere during normal operation and to maintain suitable environmental conditions during refueling condition.

9.4.6.2 Summary of Application

DCD Tier 1: DCD Tier 1, Section 2.7.3.6 "Reactor Containment Building HVAC System and Purge System," provides the system functional arrangement and fire damper design requirements.

DCD Tier 2: In DCD Tier 2, Section 9.4.6.1, "Design Bases," and Section 9.4.6.2, "System Description," the applicant states that, in part, as follows:

The reactor containment building HVAC system is designed to:

1. Maintain containment atmosphere temperature during normal operation.

2. Provide proper mixing during containment integrated leakage rate test (ILRT).

3. Maintain temperature in the in-core instrumentation (ICI) chase and reactor cavity during normal operation.

4. Remove the heat dissipated by the control element drive mechanism (CEDM) coils during normal plant operation.

5. Comply with RG 4.21.

The reactor containment building purge system is designed to:

1. Provide the proper atmosphere and adequate ventilation for personnel before and during periods of personnel access for refueling and maintenance operations when the plant is in cold shutdown.

2. Control containment airborne fission products during normal plant operation and shutdown conditions to allow containment access.

3. Purge containment atmosphere for personnel access following a LOCA.

4. Meet GDC 60 and 61.

5. Meet GDC 2 and 10 CFR 50.34(f)(2)(xv) for the containment isolation components
6. Comply with ASME AG-1, ASME N509, RGs 1.140 and 4.21 for the design of ACUs.

9.4.6.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.4.2, “Spent Fuel Pool Area Ventilation System.” The staff has also determined the requirements of 10 CFR 50.34(f)(xv) are relevant to this system. These relevant regulatory criteria are summarized below

1. GDC 2, “Design bases for protection against natural phenomena,” as it relates to the requirement that a system be capable of withstanding the effects of earthquakes.
2. GDC 5, “Sharing of structures, systems, and components,” as it relates to the requirement that sharing a SSC between multiple units will not significantly impair the SSC’s ability to perform their safety function in the event one unit experiences an accident condition.
3. GDC 60, “Control of releases of radioactive materials to the environment,” as it relates to the requirement that a system be capable of controlling the release of gaseous radioactive effluents to the environment.
4. GDC 61, “Fuel storage and handling and radioactivity control,” as it relates to the requirement that a system be capable of providing appropriate containment, confinement, and filtering to limit releases of airborne radioactivity to the environment from the fuel storage facility under normal and postulated accident conditions.
5. 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 are met, a plant that incorporates the design certification and is constructed will operate in conformance with the design certification and in compliance with the provisions of the AEA and NRC regulations.
6. 10 CFR 50.34(f)(xv) as it relates to achieving purge times consistent with maintaining doses ALARA and providing high assurance of reliable isolation under accident conditions.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the reactor containment building HVAC system and purge system should meet the guidance of RG 1.29, “Seismic Design Classification,” Regulatory Position C.1, for safety-related portions and Regulatory Position C.2 for non-safety-related portions.
2. For GDC 5, acceptance is based on the determination that sharing of reactor containment building HVAC system and purge system structures systems and components in multiple-unit plants does not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

3. For GDC 60, acceptance is based on the reactor containment building HVAC system and purge system should conform to the guidance of RG 1.52 and RG 1.140, as they relate to the design, inspection, testing, and maintenance criteria for post-accident and normal atmosphere cleanup systems, ventilation exhaust systems, air filtration, and adsorption units of light-water-cooled nuclear power plants. The applicable regulatory position for RG 1.52, Revision 4 is C.3. The applicable regulatory positions for RG 1.140, Revision 2 are C.2 and C.3.

4. For GDC 61, acceptance is based on the reactor containment building HVAC system and purge system should meet the guidance of RG 1.13, as related to the design of the ventilation system for the spent fuel storage facility, Regulatory Position C.4.

5. For 10 CFR 52.47(b)(1), acceptance is based on the reactor containment building HVAC system and purge system should meet the guidance contained in SRP Sections 14.3, “Inspections, Tests, Analyses, and Acceptance Criteria,” and 14.3.7, “Plant Systems-Inspections, Tests Analyses and Acceptance Criteria.”

6. For 10 CFR 50.34(f)(xv), acceptance is based on reasonable assurance of maintain radiation doses ALARA for the purge function and on the requirements of SRP Section 6.2.4, for the isolation function.

9.4.6.4 Technical Evaluation

The Reactor Containment Building HVAC System consists of the following subsystems:

1. Reactor containment building cooling subsystem (RCFCS).

2. Reactor cavity cooling subsystem.

3. CEDM cooling subsystem.

The RCFCS consists of four 50 percent capacity reactor containment fan coolers (RCFCs), four 50 percent capacity annulus area recirculation fans, ductwork, and duct accessories.

RCFCs run at high speed during normal plant operation and at low speed during ILRT to prevent fan motor overload due to high density air as a result of higher containment pressure.

The reactor cavity cooling subsystem consists of one 100 percent capacity AHU, ductwork, instrumentation and controls. The AHU has a cooling coil and two 100 percent capacity fans.

The CEDM cooling subsystem consists of three 50 percent capacity fans with instruments for operation monitoring.

The reactor containment building HVAC system is non-safety-related.

The Reactor Containment Building purge system is non-safety-related except for containment isolation components. The reactor containment building purge system consists of the following subsystems:

1. High Volume Purge Subsystem.

2. Low Volume Purge Subsystem.

The subsystem exhaust and supply penetrations through the containment are provided with two containment isolation valves in series in each line, with one inside and one outside the containment. The containment isolation valves are automatically closed upon receipt of an engineered safety feature actuation signal – containment purge isolation actuation signal (ESFAS-CPIAS) or an engineered safety feature actuation signal – containment isolation actuation signal (ESFAS-CIAS), and the operating purge subsystem stops. The subsystem provides filtered outside air into the containment dome area and around refueling pool.

The high volume purge subsystem consists of one 100 percent capacity supply AHU and two 50 percent capacity ACUs, containment isolation valves, ductwork, duct accessories, instrumentation and controls. This subsystem operates during cold shutdown and refueling conditions.

The low volume purge subsystem consists of two 100 percent capacity supply fans and two 100 percent capacity exhaust ACUs, containment isolation valves, ductwork, duct accessories, instrumentation and controls. This subsystem operates during normal operation, when needed.

According to BTP 6-4, B.1.F, the on-line purge system isolation valve closure times should not exceed five seconds to facilitate compliance with 10 CFR Part 100, “Reactor Site Criteria,” for offsite radiological consequences. The on-line purge system is defined by BTP 6-4 as a system that purges the containment for the operational modes of power operation, startup, hot standby and hot shutdown. The low volume purge subsystem fits this category. According to DCD Tier 2, Section 9.4.6.3.2, “Reactor Containment Building Purge System,” the closure time of containment low volume purge containment isolation valves does not exceed 5 seconds. The staff finds that BTP 6-4, B.1.F is satisfied. The staff review of this subject is further discussed in Section 6.2.4 of this report.

10 CFR 50.34(f)(2)(xv) is applied by the applicant to the design of the reactor containment building purge system. 10 CFR 50.34(f)(2)(xv) requires that the design:

- Provide a capability for containment purging/venting designed to minimize the purging time consistent with ALARA principles for occupational exposure.
- Provide and demonstrate high assurance that the purge system will reliably isolate under accident conditions.

Per the DCD, the low volume purge subsystem of the reactor containment building purge system normally operates in an exhaust mode but can be placed in a recirculation mode. Upon detection of high level of radioactivity at the common discharge duct, the subsystem is placed in the recirculation mode. The discharged air filtered from the low volume purge exhaust ACU flows back into the containment building through the low volume purge supply fan until the level of radioactivity returns back to below the preset value. The staff review of “Design Features for Minimization of Contamination,” is further discussed in Section 9.4.8, “Design Features for Minimization of Contamination,” of this report.

The reactor containment building purge system is equipped with redundant containment isolation valves. The containment isolation valves are designed, constructed, and tested in accordance with ASME Section III, safety Class 2, seismic Category I. Also the CINs are powered from Class 1E and AAC source. The staff review of the “Containment Isolation System,” is further discussed in Section 6.2.4, “Containment Isolation System,” of this report.

Based on above review, the staff finds that 10 CFR 50.34(f)(2)(xv) is satisfied.

9.4.6.4.1 GDC 2, Design bases for protection against natural phenomena

The guidance for GDC 2 is based on RG 1.29, Regulatory Positions C.1, for safety-related SSCs and C.2 for non-safety-related SSCs, if its failure could reduce the functioning of safety-related SSCs. Any SSCs not falling into the Regulatory Positions C.1 and C.2 are considered seismic Category III. DCD Tier 2, Sections 9.4.6.1.1, "Reactor Containment Building HVAC System," and 9.4.6.1.2, "Reactor Containment Building Purge System," state that the reactor containment building HVAC and purge system components and ductwork including supports are non-safety-related and are designed to meet seismic Category II. Redundant containment isolation valves are designed, constructed, and tested in accordance with ASME Section III, safety Class 2, and seismic Category I.

The staff reviewed the safety classification of SSCs serviced by this HVAC system and finds that DCD Tier 2, Section 9.4.6, is consistent with regard to the safety and seismic classifications – all safety-related components are seismic Category I and all non-safety-related portions of the system in areas containing safety-related equipment are seismic Category II. Because the various portions of the system are properly classified, the staff finds that the guidance in RG 1.29, is satisfied and therefore, the design meets GDC 2.

9.4.6.4.2 GDC 5, Sharing of structures, systems, and components

The staff reviewed the design of the reactor containment building HVAC system and purge system to ensure that the relevant requirements of GDC 5 are met.

GDC 5 governs the sharing of SSCs important to safety among nuclear power plant units in order to ensure such sharing will not significantly impair their ability to perform their safety functions. The APR1400 design certification is only for a single-unit, and the requirements of GDC 5 are satisfied.

9.4.6.4.3 GDC 60, Control of releases of radioactive materials to the environment

GDC 60, "Control of releases of radioactive materials to the environment," requires that the nuclear power unit design include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal operations.

Since the reactor containment building does not contain any gaseous and liquid effluents during normal operations, the staff finds that GDC 60 is not applicable to the reactor containment building HVAC system and that it is appropriate for the reactor containment building HVAC system to not have air filtration and adsorption units.

For the Reactor Containment Building purge system, the staff reviewed DCD Tier 2, Section 9.4.6.2.2.1, "High Volume Purge Subsystem." The applicant stated that each of the high volume purge exhaust ACUs (AU04 and AU05) consists of a prefilter, a HEPA filter, and a fan. The staff also reviewed DCD Tier 2, Section 9.4.6.2.2.2. The applicant stated that each of the low volume purge exhaust ACUs (AU02 and AU03) consists of a moisture separator, an electric heating coil, a prefilter, a HEPA filter, a carbon adsorber, a postfilter, and a fan.

The staff finds that GDC 60 and RG 1.140, Regulatory Positions C.2 and C.3, are applicable to the Reactor Containment Building purge system since these ACUs (AU02, AU03, AU04, and AU05) perform normal atmosphere cleanup functions for the Reactor Building in the APR1400 design. The staff finds that this system is not required to function to mitigate the consequences of a design basis accident.

The staff reviewed compliance with RG 1.140 for the Reactor Containment Building Purge System against Regulatory Positions C.2 and C.3 as discussed below.

RG 1.140, Regulatory Position C.2

The design of a normal atmosphere cleanup system should be based on the anticipated operating ranges for temperature, pressure, relative humidity, and radiation levels during normal plant operations and anticipated operational occurrences per RG 1.140, Regulatory Position C.2.1. In DCD Tier 2, Section 9.4.6.1.2, the applicant states that the design and construction of the ACUs conform to ASME AG-1-2009, "Code on Nuclear Air and Gas Treatment," and ASME N509-2002, "Nuclear Power Plant Air-Cleaning Units and Components." The staff reviewed ASME AG-1-2009, to determine if the operating ranges for temperature, relative humidity, pressure, and radiation levels were identified for normal plant operations and anticipated operational occurrences.

ASME AG-1, indicates that design requirements shall be specified for temperature, relative humidity, pressure, and radiation levels. ASME AG-1, does not provide the actual operating ranges. The applicant's commitment to use of both RG 1.140 and ASME AG-1, provides assurance that the final design will consider both pressures and radiation levels for normal plant operations and anticipated operational occurrences. Therefore, the staff finds that Reactor Containment Building purge system conforms to RG 1.140, Regulatory Position C.2.1.

If the normal atmosphere cleanup system is located in an area with high radiation during normal plant operation, then adequate shielding of components and personnel from the radiation source should be provided in accordance with RG 1.140, Regulatory Position C.2.2.

According to DCD Tier 2, Figure 1.2-18, "General Arrangement Auxiliary Building El. 174'-0"," all the ACUs (AU02, AU03, AU04, and AU05) are located in the auxiliary building, EL. 174'-0". According to DCD Tier 2, Figure 12.3-8, the rooms containing all the ACUs are assessed as radiation zone 4 (not a high radiation zone) during normal operation. Radiation zone 4 means its maximum dose rate is less than 0.2 mSv/hr (20 mrem/hr) based on the shielding design basis source terms presented in DCD Tier 2, Section 12.2. This means areas with a max dose rate less than 0.2 mSv/hr are designated as "zone 4." Since the ACUs are not located in high radiation zones, the staff finds that the design of ACUs conforms to RG 1.140, Regulatory Position C.2.2.

The operation of any normal atmosphere cleanup system should not degrade the expected operation of any ESF system that is required to operate after a design-basis accident in accordance with RG 1.140, Regulatory Position C.2.3.

According to DCD Tier 2, Sections 9.4.6.1.2, the Reactor Containment Building purge system does not perform any ESF function except the containment isolation valves which would isolate during an accident and not degrade any other ESF function. The staff concludes that the design conforms to the guidance in RG 1.140, Regulatory Position C.2.3.

The design of a normal atmosphere cleanup system should consider any significant contaminants such as dust, chemicals, excessive moisture, or other particulate matter that could degrade the cleanup system's operation in accordance with RG 1.140, Regulatory Position C.2.4. Materials of construction and components shall be selected and tested to limit the generation of combustibles and contaminants per ASME N509, Section 4.4, and various sections in ASME AG-1. The staff noted that the applicant has committed to RG 1.140, along with ASME N509 and ASME AG-1, for the system design, as stated in DCD Tier 2, Section 9.4.6.1.2. Therefore, the staff finds that the purge system design will appropriately consider the expected airborne contaminants. Leak testing of system ductwork in accordance with ASME N511-2007 and ASME AG-1-2009, is addressed in DCD Tier 2, Section 9.4.6.4.2, "Reactor Containment Building Purge System." The staff concludes that the design conforms to the guidance in RG 1.140, Regulatory Position C.2.4.

RG 1.140, Regulatory Position C.3

RG 1.140, Regulatory Position C.3.1, states that a normal atmosphere cleanup system need not be redundant nor designed to seismic Category I classification; but at a minimum, a system should consist of the following components in the specified order:

- HEPA filters before the adsorbers,
- Iodine adsorbers (impregnated activated carbon),
- Fans, and
- Interspersed ducts, dampers, and related instrumentation.

RG 1.140, recommends that prefilters be installed upstream of the HEPA filters to increase their service life, and that HEPA filters be installed downstream of carbon adsorbers to retain carbon fines. The DCD includes these features.

The staff reviewed the P&IDs for the low volume purge subsystem and concluded that this subsystem conforms to the guidance in RG 1.140, Regulatory Position C.3.1, because it contains the components specified above.

RG 1.140, does not call for an iodine adsorption component if the atmosphere cleanup system removes only particulate matter. This is the case of high volume purge subsystem. The design of AU04 and AU05 does not include iodine adsorber because iodine is not expected to be present in the Reactor Containment Building during cold shutdown and refueling conditions.

To ensure reliable in-place testing, the volumetric air-flow rate of a single cleanup unit should be limited to approximately 849.51 m^3/min (30,000 CFM). If a total system air flow in excess of this rate is necessary, multiple units should be used per RG 1.140, Regulatory Position C.3.2.

The staff reviewed DCD Tier 2, Section 9.4.6, "Reactor Containment Building HVAC System and Purge System," the exhaust air flow rates through AU02, AU03, AU04, and AU05 are 1,500 cfm, 1500 cfm, 27,000, and 27,000 cfm – all less than the limiting flow of 30,000 cfm. The staff finds that the design of all ACUs (AU02, AU03, AU04, AU05) conforms to RG 1.140, Regulatory Position C.3.2.

Each normal atmosphere cleanup system should be instrumented to monitor and alarm for pertinent pressure drops and flow rates, in accordance with RG 1.140, Regulatory Position C.3.3. The staff reviewed DCD Tier 2, Section 9.4.6, and found that local instruments are provided to monitor differential pressure for moisture separator, prefilter, HEPA, adsorber, and postfilter. Also, there are local flow rate indicators. Therefore, the staff finds that the design of all ACUs (AU02, AU03, AU04, AU05) conforms to RG 1.140, Regulatory Position C.3.3.

To maintain the radiation exposure to operating and maintenance personnel ALARA, normal atmosphere cleanup systems and components should be designed to control leakage and facilitate maintenance, inspection, and testing, per RG 1.140, Regulatory Position C.3.4.

The staff reviewed DCD Tier 2, Sections 12.1.1, and finds the information acceptable because it clarifies the requirements to follow ALARA principles of RG 8.8, for the design of normal atmosphere cleanup systems.

Per DCD Tier 2, Section 9.4.6.1.2, the Reactor Containment Building purge system is designed to comply with ASME AG-1 and ADME N509. Per DCD Tier 2, Section 9.4.1.4, “Inspection and Testing Requirements,” leak testing of system ductwork is performed in accordance with ASME N511 and ASME AG-1. Since the requirements of leakage control, maintenance, inspection, and testing in ASME AG-1, ASME N509, and ASME N511 are what RG 1.140 specified, the staff concludes that the design of the system conforms with the guidance in RG 1.140, Regulatory Position C.3.4.

Outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash and other contaminants on the operation of the system in accordance with the guidance in RG 1.140, Regulatory Position C.3.5.

In DCD Tier 2, Table 3.2-1, the Auxiliary Building is a Safety Class 3 and seismic Category I structure. Per GDC 2, the auxiliary building will be 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. The staff reviewed Figure 1.2-18 and found that the system’s air intake opening is adequately protected by being located inside the auxiliary building. The staff concluded that the design of the Reactor Containment Building purge system conforms to the guidance in RG 1.140, Regulatory Position C.3.5.

Normal atmosphere cleanup system housings and ductwork should be designed to exhibit, on test, a maximum total leakage rate as defined in Article SA-4500 of ASME AG-1-1997.

Per DCD Tier 2, Section 9.4.6.4.2, leak testing of the Reactor Containment Building purge system ductwork is performed in accordance with ASME N511 and ASME AG-1. In addition, the applicant states that the design and construction of ACUs conform to ASME AG-1.

Therefore, the staff finds that the cited test standards for the Reactor Containment Building Purge System conform to RG 1.140, Regulatory Position C.3.6.

Based on the above discussion, the staff finds that the Reactor Containment Building Purge System conforms to RG 1.140, Regulatory Positions C.2 and C.3. Therefore, the staff finds that this system meets the requirements of GDC 60.

9.4.6.4.4 GDC 61, Fuel storage and handling and radioactivity control

The staff reviewed the reactor containment building HVAC system and purge system as it applies to RG 1.13, Regulatory Position C.4, which states that a controlled-leakage building should enclose the fuel to limit the potential release of radioactive iodine and other radioactive materials. If necessary to limit offsite dose consequences from a fuel handling accident, the building should include an engineered safety feature filtration system that meets the guidelines outlined in RG 1.52.

A review of DCD Tier 2, Section 9.4.6.1.2 verified that the Reactor Containment Building purge system is isolated by containment isolation valves upon receipt of an ESFAS-CPIAS or an ESFAS-CIAS signal.

A review of DCD Tier 2, Section 9.4.6.2.2.2, "Low Volume Purge System," verified that upon detection of a high level of radioactivity at the common discharge duct, the operating low volume purge exhaust ACU stops automatically. The low volume purge subsystem is placed in the recirculation mode manually until the level of radioactivity returns back to below the preset value.

The containment is opened when the High Volume Purge Subsystem is operating. If an FHA happens in this state, the containment purge isolation actuation signal (CPIAS) is actuated by the safety-related RMS, which provides a prompt signal of high airborne radiation. The containment purge system is also designed to close the isolation valve of the low volume exhaust system in a shorter time than the transit time of radioactive materials through the inner damper of low volume exhaust system. These requirements are applicable when irradiated fuel is moved in the containment (i.e., during a refueling outage) to confine the post-FHA release inside the containment and eliminate any potential activity release to the environment. Even if LOOP is assumed in the FHA analysis, the radioactive materials do not escape to the environment because the isolation valves of the purge system is designed to be closed when the normal power is lost. The FHA analysis is reviewed in Section 15 of this report.

According to DCD Tier 2, Section 6.2.4, the Reactor Containment Building is an essentially leak-tight building that is periodically leak tested in accordance to 10 CFR Appendix J. This design would enclose the fuel to limit the potential release of radioactive iodine and other radioactive materials. The radioactivity control issues related to leakage of reactor containment building and containment isolation valves are further reviewed in Section 6.2.4 of this report.

The design features of the equipment and floor drainage system (EFDS) for the Reactor Containment Building are described in Tier 2, Section 9.3.3.

The staff finds that the Reactor Containment Building HVAC System and Purge System design complies with GDC 61 by conforming to the guidance in RG 1.13, Regulatory Position C.4.

9.4.6.4.5 ITAAC

The staff notes that ITAAC information is not provided for the reactor containment building HVAC system and purge system. The staff finds this acceptable because this system is non-safety-related. The adequacy of inspections and tests described in the Initial Plant Test Program are discussed in Section 14.2 of this report.

9.4.6.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(1)	The COL applicant is to provide the capacities of heating coils in the safety-related air handling units and cooling and heating coils in the non-safety-related air handling units affected by site-specific conditions.	9.4.6

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.4.6.6 Conclusion

The reactor containment building HVAC system and purge system was reviewed to the acceptance criterial guidance defined in NUREG-0800, Section 9.4.2. The staff concludes that this system complies with the requirements of GDC 2, GDC5, GDC 60, and GDC 61. The staff concludes that the ITAAC requirements will ensure that the system can be properly inspected, tested, and operated in accordance with DCD requirements and, therefore, consider that the system design compiles with 10 CFR 52.47(b)(1).

9.4.7 Compound Building HVAC System

The staff has performed its review of the Compound Building HVAC system in Section 9.4.3.

9.4.8 Design Features for Minimization of Contamination

9.4.8.1 Introduction

The APR1400 HVAC systems that service areas that may contain radiologically contaminated materials are designed with features to meet the requirements of 10 CFR 20.1406 and RG 4.21. The staff's review of these features is contained in the following subsections.

9.4.8.2 Summary of Application

DCD Tier 1: There are no DCD Tier 1 entries specific to this section.

DCD Tier 2: The applicant has provided system descriptions in DCD Tier 2, Section 9.4.8, "Design Features for Minimization of Contamination."

9.4.8.3 Regulatory Basis

10 CFR 20.1406, "Minimization of contamination," requires the submittal of design information and operational procedures for (1) minimizing radioactive waste generation and contamination of the facility and the environment, and (2) facilitating decommissioning.

As specifically stated in 10 CFR 20.1406:

> The applicant should describe how facility design will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.
>
> The applicant should, to the extent practicable, conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface.

Acceptance criteria adequate to meet the above requirements:

> Acceptance is based on the facility design conforming to the guidance contained in RG 4.21. The principles embodied in the philosophy of RG 4.21 are threefold: (1) prevention of unintended releases; (2) early detection, if there is unintended release of radioactive contamination; and (3) prompt assessment to support a timely and appropriate response.

RG 4.21, contains four Regulatory Positions: C1, Minimizing Facility Contamination; C2, Minimizing Contamination of the Environment; C3, Facilitation of Decommissioning; and C4, Implementation. RG 1.42, "Interim Licensing policy on as low as Practicable for Gaseous Radioiodine Releases from Light-Water-Cooled Nuclear Power Reactors," contains guidance on maintaining radioiodine releases ALARA.

9.4.8.4 Technical Evaluation

These APR1400 HVAC systems may contain radiologically contaminated materials:

1. Fuel Handling Area HVAC System.
2. Auxiliary Building Controlled Area HVAC System.
3. Reactor Building Containment Building HVAC System.
4. Reactor Containment Building Purge System.
5. Compound Building HVAC System.

For the whole APR1400 facility, the principles of RG 4.21, and the control methods suggested in the regulations are the basis of the design objectives and the operational objectives that are described in DCD Tier 2, Section 12.4.2, "Minimization of Contamination and Radioactive Waste Generation." There are a total of six objectives:

> Objective 1 – Prevention/Minimization of Unintended Contamination
>
> Objective 2 – Provision of Adequate and Early Leak Detection Capability

Objective 3 – Reduction of Cross-Contamination, Decontamination, and Waste Generation

Objective 4 – Decommissioning Planning

Objective 5 – Operations and Documentation

Objective 6 – Site Radiological Environmental Monitoring

DCD Tier 2, Table 12.4-10, "NRC RG 4.21 Design Objectives and Applicable DCD Subsection Information for Minimizing Contamination and Generation of Radioactive Waste," describes that the above five HVAC systems, containing possible radiologically contaminated materials, have received full RG 1.42, evaluation to satisfy the above six objectives.

For the APR1400 HVAC systems the review of the above five systems that address the design and the operational objectives against RG 1.42, is discussed below.

9.4.8.4.1 Prevention/Minimization of Unintended Contamination

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

- The system components in radiologically controlled areas are fabricated from materials such as carbon and stainless steels that are compatible with the environment and are welded construction for the life-cycle planning.
- Upon detection of high level radioactivity at the common discharge duct, the reactor containment building purge system is placed in the recirculation mode. The discharged air flows back to the containment building.
- The chilled water side of the reactor cavity AHU, cubicle coolers, and reactor containment fan coolers (RCFCs) are operated at a higher pressure than the atmospheric pressure in the equipment area to prevent the contamination of the chilled water.
- The mounting frames of the HEPA filter and carbon adsorber are stainless steel and of welded construction for life-cycle planning.
- Doors and door frames of all ACUs are marine bulkhead type or an equivalent airtight construction to minimize leakage.
- All ACU housing penetrations are sealed by welds or adjustable compression-gland type seals to prevent unfiltered in-leakage.
- All drain lines from ACUs, the reactor cavity AHU, cubicle coolers, and RCFCs are sloped and routed to the protective equipment drain.

Based on its engineering judgement, the staff finds the above system features conform to RG 4.21, Regulatory Position C1, to minimize facility contamination.

9.4.8.4.2 Provision of Adequate and Early Leak Detection Capability

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

> The ACU housing leak test in the manufacturer's shop and in the field following the recommended test frequency described in ASME AG-1, to prevent unfiltered in-leakage.
>
> Mounting frame leak tests of HEPA filters and carbon adsorbers are performed in the manufacturer's shop and at the site following the recommended test frequencies described in ASME AG-1, to prevent unfiltered in-leakage.
>
> Radiation monitors are provided at the outlet of ACUs to monitor the radiological contamination levels.

The staff considers the above system features conform to RG 1.42, Regulatory Positions C1 and C2, to minimize contamination of facility.

9.4.8.4.3 Reduction of Cross-Contamination, Decontamination, and Waste Generation

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

> The ACU is designed to operate slightly below atmospheric pressure through the use of an induced fan to minimize air leakage. All ducts of welded construction are to minimize cross-contamination.
>
> HVAC component housing surface is painted smooth for corrosion protection, ease of decontamination, and cleaning.
>
> HEPA filters capture radioactive particles and carbon adsorbers remove organic and inorganic forms of iodine from the air stream.
>
> Adequate space is provided around the HVAC equipment to enable prompt assessment and responses when required.

The staff compared the application to the guidance in RG 4.21, Regulatory Positions C1 and C2, and determined that the application is in conformance with NRC guidance and is therefore acceptable.

9.4.8.4.4 Decommissioning Planning

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

> The ACUs, reactor cavity AHU, cubicle coolers, low volume purge supply fans, and RFCs are designed and fabricated as modular units and compartments for easy decommissioning.

The staff considers the above system feature conforms to RG 1.42, Regulatory Position C3, for facilitation of decommissioning.

9.4.8.4.5 Operations and Documentation

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

> Adequate work space between mounting frames for the ACUs is provided to facilitate maintenance and minimize the potential for the spread of contamination.
>
> Carbon removal from the carbon adsorber is facilitated by the use of portable pneumatic carbon removal equipment to minimize spillage.
>
> ACUs, the reactor cavity AHU, cubicle coolers, low volume purge supply fans, and RCFCs are designed with adequate instrumentation to be remotely operated with manual initiation and stopped from the MCR and the RSR.
>
> The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and decontamination control.

The staff compared the application to the guidance in RG 4.21, Regulatory Positions C1 and C2, and determined that the application is in conformance with NRC guidance and is therefore acceptable.

9.4.8.4.6 Site Radiological Environmental Monitoring

Based on DCD Tier 2, Section 9.8, the following is a summary of the major HVAC system features related to this objective:

> The air quality around the plant is sampled and analyzed routinely for contamination levels and migration pathways as part of the Site Radiological Environmental Monitoring Program. Potential contaminated HVAC systems are expected to be included in this program.
>
> This objective is met by developing a conceptual site model (COL 12.4 (2)).

The staff considers the above system feature conforms to RG 1.42, Regulatory Position C2, to minimize contamination of the environment.

9.4.8.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.4(5)	The COL applicant is to establish operational procedures and maintenance programs as related to leak detection and containment control.	9.4.8

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.4.8.6 Conclusion

The staff finds that the design provisions for the APR1400 HVAC systems meet the requirements of 10 CFR 20.1406 and conform to the guidelines of RG 4.21. Section 12.4, "Dose Assessment and Minimization of Contamination," of this report further addresses the APR1400 design in accordance with 10 CFR 20.1406.

9.5 Other Auxiliary Systems

9.5.1 Fire Protection Program

9.5.1.1 Introduction

The fire protection system (FPS) is the integrated complex of equipment and components that provide early fire detection, notification, and suppression in order to limit the spread of fire. The FPS is part of the overall fire protection program (FPP) which includes the plant design and layout, as well as components, procedures, analyses, and personnel used in defining and carrying out all activities of fire protection. The objectives of the APR1400 FPP are to minimize both the probability of occurrence and the consequences of a fire. The FPP is designed to provide reasonable assurance, through defense-in-depth, that any fire that occurs does not prevent the performance of necessary safe-shutdown functions, and that radioactive release to the environment in the event of a fire will be minimized. The staff's analysis of the applicant's FPS is provided below.

9.5.1.2 Summary of Application

DCD Tier 1: The FPS is described in DCD Tier 1, Section 2.7.5.2, "Fire Protection System." The basic configuration of the normal fire suppression system, the seismic Category 1 fire suppression system, and the clean agent fire suppression system are shown in DCD Tier 1, Figure 2.7.5.2.1, "Fire Protection System." FPS components and instrumentation data are listed in DCD Tier 1, Tables 2.7.5.2-1, "Fire Protection System Components List," and 2.7.5.2-2, "Fire Protection Systems Instrument List," respectively.

DCD Tier 2: The design basis and description of the FPP are provided in DCD Tier 2, Section 9.5.1, "Fire Protection Program." In addition, DCD Tier 2, Table 9.1.5-1, "Fire Protection Program Conformance with NRC RG 1.189 [Fire Protection for Nuclear Power Plants]," is a point-by-point comparison of the conformance of the APR1400 FPP with the guidelines of RG 1.189. A large amount of the tasks identified in this table is assigned to a future COL applicant since it is the COL's responsibility to fully establish a FPP, including organization, training, and qualification of personnel, administrative controls of combustibles and ignition sources, firefighting procedures, and quality assurance.

Section 9.5.1.1, "Design Bases," states that the APR1400 FPP is designed to satisfy 10 CFR 50.48, "Fire Protection," and SRP Section 9.5.1.1 by:

- Minimizing the potential for fire and explosions by controlling, separating, and limiting the quantities of combustibles and sources of ignition, and by preventing the spread of fire by subdividing plant buildings into fire areas separated by fire barriers and into fire zones or compartments, which are capable of substantially confining fire impact;

- Providing the capability to rapidly detect, control, and promptly extinguish fires that do occur;

- Providing 3-hour fire-rated barriers between redundant divisions of safety-related equipment; and

- Preventing the release of radioactive contamination.

DCD Tier 2, Appendix 9.5A, "Fire Hazard Analysis," provides information on the fire hazards analysis by evaluating the potential for the occurrence of fire within the plant and demonstrating that the plant maintains the capability to perform safe shutdown functions and minimize the release of radioactive material to the environment in the event of a fire.

Initial Test Program: Inspection and testing of the FPS prior to plant operation is described in DCD Tier 2, Section 14.2.12.1.85, "Fire Protection System Testing."

ITAAC: ITAAC for the FPS are given in DCD Tier 1, Table 2.7.5.2-3, "Fire Protection System ITAAC."

Technical Specifications: There are no TSs requirements associated with the FPP.

9.5.1.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 9.5.1.1, "Fire Protection Program," Revision 1, and are summarized below.

10 CFR 50.48, Item (a)(4) requires, in part, that each applicant for a design certification under 10 CFR Part 52 must have a description and analysis of the fire protection design features for the standard plant necessary to demonstrate compliance with GDC 3, "Fire protection."

GDC 3, "Fire protection," as it relates to establishing the criteria for the fire and explosion protection of structures, systems, and components important to safety, as well as the criteria for fire detection and firefighting systems and the use of noncombustible and heat resistant materials throughout the plant.

10 CFR 52.47, "Contents of applications; technical information," Item (b)(1) which requires that a design certification application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if inspections, tests, and analyses are performed and acceptance criteria are met, a facility that incorporates the design certification has been constructed and will be operated in accordance with the design certification, the provisions of the AEA and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 3, RG 1.189 provides guidance and acceptance criteria for one acceptable approach for an FPP that meets regulatory requirements. RG 1.189 Regulatory Position 8.4 "Applicable Industry Codes and Standards," states in part:

   "In general, the FPP for new LWR designs should comply with the provisions specified in National Fire Protection Association (NFPA 804) "Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants" as they relate to the protection of post-fire safe-shutdown capability and the mitigation of a radiological release resulting from a fire. However, the NRC has not formally endorsed NFPA 804, and some of the guidance in the NFPA standard may conflict with regulatory requirements. When conflicts occur, the applicable regulatory requirements and guidance, including the guidance in this regulatory guide, will govern."

2. In addition to the regulatory requirements and guidance provided above, SRP Section 9.5.1.1 provides enhanced fire protection criteria for new reactor designs as documented in SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements," dated January 12, 1990; SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," dated April 2, 1993; and SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs," dated March 28, 1994. SECY-90-016 provides enhanced fire protection criteria for evolutionary LWRs. SECY-93-087 recommends that the enhanced criteria be extended to include passive reactor designs. The Commission approved SECY-90-016 and SECY-93-087 in staff requirements memoranda. SECY-94-084, in part, provides criteria defining safe-shutdown conditions for passive LWR designs.

3. For 10 CFR 52.47(b)(1), the FPP should be consistent with the guidance of RG 1.206, Section C.II.1, "Inspections, Tests, Analyses, and Acceptance Criteria," and that contained in SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria," and 14.3.7, "Plant Systems – Inspections, Tests, Analyses, and Acceptance Criteria."

9.5.1.4 Technical Evaluation

The staff's evaluation of the FPP and system is based upon the information provided in the applicant's DCD, Revision 1, including Tier 1 and Tier 2.

The APR1400 FPS is classified as a non-safety-related system with the exception of the containment isolation function. The containment isolation valves and associated piping for the FPS are designed as safety-related (safety Class 2), seismic Category I, and quality group B.

The APR1400 FPS includes a seismic Category I fire-protection water supply system that supplies water to a seismic Category I fire hose and standpipe system in the reactor containment building, auxiliary building, and emergency diesel generator building (EDGB).

The staff based its review below on the guidance in RG 1.189.

9.5.1.4.1 Fire Hazard Analysis

The staff reviewed the applicant's fire hazard analysis, as provided in the DCD, to ensure that the applicant has demonstrated that the certified design will have the ability to perform safe shutdown functions and minimize radioactive material release to the environment in the event of a fire in conformance with RG 1.189. DCD Tier 2, Appendix 9.5A, "Fire Hazard Analysis," describes the APR1400 fire hazards analysis, DCD Tier 2, Appendix 9.5A.2, describes the fire hazard analysis methodology, and DCD Tier 2, Appendix 9.5A.3, provides the results of the fire hazard analysis. The applicant stated that the APR1400 fire hazards analysis establishes and evaluates all fire areas for the reactor containment building, auxiliary building, EDGB, turbine generator building, and compound building. The plant switchyard design is site-specific and not within the scope of the APR1400 design.

The purpose of the fire hazard analysis is as follows:

- Identify and evaluate the potential in-situ and transient fire hazards.
- Determine the effects of a fire in any location in the plant and the capability to safely shut down the reactor and minimize and control the release of radioactivity to the environment.
- Specify the appropriate measures for fire prevention, fire detection, fire suppression, and fire containment for each area containing SSCs important to safety in accordance with NRC guidelines and regulations.

In the fire hazards analysis provided in Appendix 9.5A, the staff noted that the radioactive release limits were indicated to be "below the 10 CFR Part 100 limits." The guidance in RG 1.189 states that the radioactive release limits should be "below the 10 CFR Part 20 limits." The staff issued RAI 84-8022 (ML15295A318), Question 09.05.01-01, requesting the applicant change this to indicate that the radioactive release limits state the limits are "below the 10 CFR Part 20 limits." In its response dated November 11, 2015 (ML15315A039), the applicant stated that the "10 CFR Part 100 limits," will be replaced with "10 CFR Part 20 limits." The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-01, resolved and closed.

The fire hazards analysis is based on an assessment of every fire area, using the defense in depth approach from RG 1.189. In its review the staff noted that in DCD Tier 2, Chapter 1, the applicant states:

> A standard site plot of the APR1400 is provided in Figure 1.2-1. The plot shows the scope of the design certification application.

The staff reviewed Figure 1.2-1, and found that the AAC gas turbine generator building and the two ESW and component cooling water heat exchanger (ESW/CCW HX) buildings are within the scope of the design certification. However, while reviewing Appendix 9.5A, the staff found that these buildings were not included in the fire hazard analysis even though the AAC gas turbine generator building is discussed in Section 9.5.1. The staff issued RAI 212-8246 (ML15258A010), Question 09.05.01-35, requesting the applicant include a fire hazard analysis for the AAC gas turbine generator building and the two ESW/CCW HX buildings. In its

response dated August 3, 2015 (ML16218A091), the applicant stated that DCD Tier 2, Appendix 9.5A will be revised to include a fire hazards analysis for the AAC gas turbine generator building and the ESW/CCW HX buildings. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 212-8246, Question 09.05.01-35, resolved and closed.

The fire hazard analysis, as provided in the DCD, is based on the existing design and uses all available current information. It is also based on the introduction of transient combustible to any area of the plant, subject to administrative controls. The fire hazard analysis methodology used by the APR1400 include the following:

- Safety-related equipment and components that could be used for the safe shutdown of the plant are identified by fire area or fire zone.
- Combustible materials that include in-situ and potential transient fire and explosion hazards, type of fire hazard, quantity, and the combustible loading that the material imposes on the fire area or zone are reviewed.
- The design basis fire for each fire area, which assumes no fire-suppression system actuation, is estimated based on the combustible loading and floor area.
- The fire detection and suppression provided for the fire area or zone are reviewed.
- The effects of the design basis fire on the capability to safely shut down the plant and the potential for the release of radioactive material are evaluated.
- The effects of an inadvertent actuation or rupture of suppression systems on the safe shutdown capability are evaluated.
- The effects of manual firefighting are evaluated.

The applicant defined a fire area as a portion of a building or plant that is separated from other areas by 3-hour-rated fire barriers (i.e., walls, floors, and ceilings) which contain the effects of a fire to within a single fire area. Fire-rated barriers include components such as reinforced concrete walls, floors, beams, joists, and columns. All penetrations in fire-rated barriers are protected with 3-hour-rated components such as penetration seals, fire doors, and fire dampers.

The applicant also defined a fire zone as a division of a fire area, typically based on fire-protection systems and structural features in the fire zone that provide an appropriate level of protection for the associated hazards. A fire zone is not necessarily isolated by complete fire barriers or fire-rated construction. A fire area may be divided into fire zones when it is not practicable or desirable to divide a fire area into multiple fire areas because of the plant design and layout such as inside containment.

The combustible loading, both in-situ and transient, in a fire area or fire zone are quantified to determine an equivalent fire severity in units of time.

The applicant described the fire-protection measures for each fire area in DCD Tier 2, Table 9.5A-2, "Fire Hazard Analysis Summary." The type of fire detection and fire suppression system is provided along with a description of the manual hose stations and portable fire

extinguishers that are available. Provisions for access and egress routes for firefighting and personnel egress is also indicated. Equipment that contains radioactive material, equipment or components that are available for a safe shutdown in the event of a fire are also indicated along with the anticipated combustible loading.

The DCD Tier 2, Section 9.5A.2.4, "Fire Protection System Integrity," applicant stated that

> (T)he design of an automatic fire-suppression system is evaluated to verify that safe shutdown and safety-related equipment cannot be rendered inoperable by an inadvertent operation of the fire-suppression system installed in a fire area.

In RAI 84-8022, Question 09.05.01-22, the staff requested the applicant to confirm that all firefighting systems, as required by GDC 3, are designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components. In its response dated November 11, 2015 (ML15315A039), the applicant stated DCD Tier 2, will be revised to state:

> The design of firefighting systems is evaluated to verify that their rupture or inadvertent operation does not significantly impair the safety capability of structures, systems, and components important to safety.

The staff finds that the response acceptable because the applicant's statement conforms with GDC 3. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-22, to be resolved and closed.

The applicant stated that the APR1400 is designed to meet the enhanced fire protection criteria designated in RG 1.189, Regulatory Position 8.2. The plant achieves safe shutdown with the assumption that fire will render all equipment in any one fire area inoperable, recognizing that post-fire reentry for repairs or operator actions will not be possible. Ventilation systems are provided so that smoke, hot gases, and fire suppressants do not migrate from one fire area to another and adversely affect safe shutdown capabilities, including operator actions. The MCR is excluded from this approach because of its physical configuration by providing an independent alternative shutdown capability, a RSR that is physically and electrically independent of the control room. Fire protection for redundant shutdown systems in the reactor containment building provides reasonable assurance that one shutdown division is free of fire damage.

In DCD Tier 2, Section 9.5A.2.5.1, "Criteria and Assumptions," the applicant stated:

> Similar to the assumptions for fire areas, if equipment is not in its desired position for continued operation, it is assumed operating.

In the staff's review of the DCD, the staff could not find any similar assumption made for fire areas. The staff issued RAI 84-8022, Question 09.05.01-23, requesting the applicant clarify what the assumptions for fire areas are as referenced in the above statement. In its response dated November 11, 2015 (ML15315A039), the applicant stated:

> [I]t is assumed that equipment that is not beneficial to safe shutdown will continue to operate, since no beneficial fire effects are credited.

The staff found the applicants response insufficient because it contradicts the guidance in RG 1.189, Regulatory Position 8.2, "Enhanced Fire Protection Criteria." One of the assumptions in this regulatory position is that new reactor designs should ensure that safe shutdown can be achieved by assuming that all equipment in any one fire area will be rendered inoperable by fire. The staff issued RAI 456-8566 (ML16096A310), Question 09.05.01-40, requesting the applicant to remove the sentence that indicates equipment that is not beneficial to safe shutdown will continue to operate. In its response dated May 11, 2016 (ML16132A136), the applicant stated that the sentence that indicates equipment that is not beneficial to safe shutdown will continue to operate will be removed. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 456-8566, Question 09.05.01-40, resolved and closed.

The applicant stated that the Gaseous Radwaste System design includes two gas analyzers with automatic control functions to preclude the buildup of an explosive mixture of hydrogen and oxygen. The staff issued RAI 538-8720, Question 11.03-12 (ML17037D278), requesting information if the applicant has planned use for a fixed water spray system for the charcoal delay beds. In its response dated March 17, 2017 (ML17076A138), the applicant stated that the Gaseous Radwaste System is designed to prevent the formation of an explosive mixture by monitoring and controlling the concentration of hydrogen and oxygen. Hydrogen and oxygen concentrations are maintained below the lower flammability limit. Dual instruments are provided to continuously monitor the concentrations. A high oxygen concentration alarm (for a concentration greater than 2 percent) is annunciated in the radwaste control room of the compound building. Operating personnel can mitigate the situation by closing the source of the oxygen or via nitrogen dilution or purge. A high-high oxygen concentration alarm (for a concentration greater than 4 percent) is annunciated in the MCR and the radwaste control room. Under this condition, nitrogen is automatically injected into the GRS to reduce the oxygen concentration. In case of fire outside the charcoal delay rooms, there is no large opening to allow propagation of fire from outside the room into these rooms. The access openings to the charcoal delay bed rooms for maintenance are normally closed by removable slabs, which do not allow propagation of fire. KHNP performed a fire hazard analysis and concluded that the design of the GRS charcoal delay beds have sufficient design features that a fire condition is unlikely to occur. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff is tracking this as a **Confirmatory Item (CI 11.03-12)**.

Because the fire hazard analysis has demonstrated that the certified design will have the ability to perform safe shutdown functions and minimize radioactive material release to the environment in the event of a fire in conformance with RG 1.189, the staff finds the design acceptable.

9.5.1.4.2 Fire Detection

The staff reviewed the DCD to ensure that automatic fire detection is provided for areas that contain or present an exposure fire hazard to SSC important to safety in conformance with RG 1.189. The applicant stated that fire detectors, which activate fire alarms, are provided for areas containing safety-related equipment, including the reactor containment building. In RAI 84-8022, Question 09.05.01-25, the staff requested that the applicant clarify a discrepancy in the DCD. In DCD Tier 2, Section 9.5A, the applicant stated that there is no fire detection inside containment. However, DCD Tier 2, Table 9.5A-2, indicates that there is fire detection inside containment. In its response dated November 11, 2015 (ML15315A039), the applicant

stated that there is detection in the reactor containment building and provided a markup to correct DCD Tier 2, Section 9.5A. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-25, resolved and closed.

Fire detectors in all fire areas or zones that provide early warning and actuate fire-suppression systems will be selected based on the combustible materials present; NFPA 72, "National Fire Alarm and Signaling Code," guidelines; and manufacturer recommendations.

Manual fire alarm pull stations are addressable and will annunciate locally in the vicinity of the pull station and in the MCR. All fire detection systems annunciate in the MCR and RSR and on local control panels.

The fire detection and alarm system is powered from a non-Class 1E 120 VAC distribution panel fed from a permanent non-Class 1E bus, which receives non-Class 1E onsite standby power from the alternate AC source in the event of LOOP. The central fire control panel contains backup batteries capable of supplying power to the detection system for 24 hours.

Because the proposed design conforms to RG 1.189 in that automatic fire detection is provided for areas containing or that present an exposure fire hazard to SSC important to safety, the staff finds the proposed automatic fire detection design acceptable.

9.5.1.4.3 Fire Protection Water Supply Systems

The staff reviewed the fire protection water supply system to ensure that it supplies the largest expected flow rate for a period of two hours as described in RG 1.189. The staff also reviews to ensure that water is supplied to at least two standpipes and hose connections for manual firefighting in areas of the plant containing equipment required for safe plant shutdown in the event of a SSE. The APR1400 design provides for two fire protection water supply systems. The first is a non-seismic system, what the applicant labels as the normal fire protection water supply system. The second is a seismic Category I system that provides fire protection water supply to areas of the plant that are required for safe plant shutdown following a SSE.

9.5.1.4.4 Normal Fire Protection Water Supply System

The applicant stated that the normal fire protection water supply system consists of water storage tanks, fire pumps, and piping to provide an adequate water supply to fire suppression systems and fire standpipe and hose stations in both safety-related and non-safety related areas.

The fire-protection water supply system is sized to contain sufficient water for a 2-hour operation of the largest design demand of any sprinkler system, plus a 1,900 L/min (500 gpm) manual hose stream allowance to support fire-suppression activities.

Two fresh water storage tanks are provided, each with a capacity of 435,000 gallons, of which 345,000 gallons are reserved for fire protection. RG 1.189 guidance states that NFPA 22, "Standard for Water Tanks for Private Fire Protection," is an acceptable method for the design of the water storage tanks. In RAI 84-8022, Question 09.05.01-14, the staff requested the applicant to indicate which NFPA standard will be used for the construction of the water storage tanks. In its response dated November 11, 2015 (ML15315A039), the applicant stated that NFPA 22 will be used. The staff finds the response acceptable because it follows

the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-14, resolved and closed.

The two tanks are separated so that the fire pumps can take suction from one or both tanks. Piping between the fire-protection water sources and the fire pumps is in accordance with NFPA 20, "Standard for the Installation of Stationary Pumps for Fire Protection." A failure of one tank or its piping cannot cause both tanks to drain. Each fresh water storage tank is automatically refilled from the raw water system in 8 hours.

The APR1400 design provides for three 50 percent capacity fire pumps and one jockey pump. One fire pump is driven by an electrical motor and the other two fire pumps are driven by diesel engines. Two of three fire pumps can provide system pressure and flow requirements to supply the largest design demand of any sprinkler system and 1,900 L/min (500 gpm) manual hose stream allowance to support fire-suppression activities. Each pump starts automatically on a progressively decreasing pressure signal inside the fire main in the following order:

- Jockey pump,
- Motor-driven pump, and
- Diesel-driven pumps.

The fire pumps are located in the yard, in a non-seismic, non-safety-related structure. The fire pump house is a steel-framed structure and is subdivided into three separate fire areas by 3-hour fire-rated barriers. Each diesel-driven fire pump and its associated controller, fuel tank, piping, and fittings are located in one of the fire pump areas. The electric-motor-driven fire pump is powered by a non-Class 1E bus.

The applicant stated that backup power is provided by the alternate AC power source and is electrically protected so that a fire in the fire pump house does not interrupt pump operation. The staff issued RAI 84-8022, Question 09.05.01-27, requesting that applicant clarify this statement since it implies that equipment in the fire area will survive the fire which is contradictory to the enhanced fire protection guidance in RG 1.189. In its response dated November 11, 2015 (ML15315A039), the applicant stated that the DCD will be revised to the following:

> Backup power is provided by the alternate ac power source and is electrically protected so that a fire in another fire area does not interrupt pump operation.

The staff finds this acceptable because it follows the enhanced fire protection guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-27, to be resolved and closed.

The fire-protection water supply piping is filled with water and pressurized by the jockey pump to allow immediate startup of a fire pump without water hammer effects. The jockey pump maintains system pressure in the yard main to avoid the startup of the main fire pumps in the absence of a fire.

A permanent cross-tie connection is provided for operators to use external water sources as an emergency backup water supply to the emergency containment spray backup system after a severe accident. In RAI 84-8022, Question 09.05.01-31, the staff requested the applicant to clarify how the FPS interfaces with the emergency containment spray backup system and what external water sources are used. In its response dated November 11, 2015 (ML15315A039), the applicant pointed to Section 19.2.4.2.3, "Emergency Containment Spray Backup System Performance," of the DCD which provided additional information on this system. The emergency containment spray backup system flow path is from external water sources (the reactor makeup water tank, demineralized water storage tank, fresh water tank, or the raw water tank), through the FPS line via the diesel-driven fire pump, to the emergency containment spray backup system line emergency connection located at ground level near the auxiliary building. This connection is shown on figure 9.5.1-1, "Fire Protection System Flow Diagram," sheet 4 of 9. The staff finds the response acceptable because the applicant provided information on how the FPS interfaces with the emergency containment spray backup system.

Because the as described normal fire water supply system supplies the largest expected flow rate for a period of two hours as described in RG 1.189, the staff finds the proposed design to be acceptable.

Seismic Category I Fire Protection Water Supply System

RG 1.189 guidance states that provisions should be made to supply water to at least two standpipes and hose connections to be used for manual firefighting is areas of the plant containing equipment required for safe plant shutdown in the event of a SSE. The applicant stated that the APR1400 design provides for a system that is in addition to the normal fire protection water supply system. The seismic Category I fire-protection water supply system provides a seismically designed water supply to seismic Category I standpipes and hose connections for manual firefighting in the containment building, auxiliary building, and EDGB. These buildings contain safety-related systems and components required for a safe shutdown in the event of a SSE.

The primary water supply to these standpipe and hose connections is the normal fire-protection water distribution system. Should a SSE cause the failure of the normal fire protection water supply system, the seismic Category I fire protection water supply system will supply water to these standpipes and hose connections. The normal fire-protection water supply line to the seismic Category I fire hose and standpipe system header contains a check valve that isolates the normal fire-protection water supply from the seismic Category I header upon loss of system pressure due to a seismic event.

The seismic Category I fire protection water supply system consists of two water storage tanks, each with a capacity of 18,000 gallons, and two 100 percent pumps which are located in the auxiliary building. This system can provide 284 L/min (75 gpm) at the specified pressure to any two fire hose stations in the reactor containment building, auxiliary building, or EDGB.

Because the proposed design conforms to RG 1.189 in that it ensures that two standpipes and hose connections for manual firefighting in areas containing equipment required for safe plant shutdown in the event of a SSE, the staff finds the proposed seismic Category I fire protection water supply system design to be acceptable.

Automatic Water Based Suppression Systems and Gaseous Suppression Systems

The staff reviewed the automatic suppression systems to ensure that these systems are installed as determined by the fire hazard analysis. The applicant stated that the selection of automatic water based suppression systems for each plant area is based on the fire hazards analysis. Automatic sprinkler systems will conform to the requirements of NFPA 13. "Standard for the Installation of Sprinkler Systems." Water systems are preferred, but the use of automatic water-based suppression in radiation areas is minimized because of the possible spread of contamination. Floor drains are provided in safety related areas to remove expected firefighting water as per the guidance in RG 1.189. The flooding effects due to rupture or inadvertent actuation of firefighting systems is addressed in DCD Tier 2, Section 3.4.

A clean agent suppression system is provided for the fire protection of the cables under the floors in the MCR habitability area, computer room area, and electrical equipment rooms where access for firefighting may be difficult. The system will be designed according to NFPA 2001, "Standard on Clean Agent Fire Extinguishing Systems."

Because the proposed design of the automatic suppression systems conforms to RG 1.189 in that it ensures these suppression systems are to be installed as determined by fire hazard analysis and that the systems will conform to the appropriate NFPA standard the staff finds the proposed designs acceptable.

Manual Suppression Systems

The staff reviewed the FPSs provided for manual fire suppression to ensure that manual fire-fighting capability is provided throughout the plant to limit the extent of fire damage. Standpipes, hydrants, portable equipment consisting of hoses, nozzles, and fire extinguishers should be provided for use by properly trained firefighting personnel. The applicant stated that the APR1400 design provides for Class III standpipe and hose stations in any area of the power block buildings that contains or presents a fire exposure hazard to equipment important to safety. This conforms to RG 1.189. The staff issued RAI 84-8022, Question 09.05.01-28, requesting the applicant clarify a discrepancy in the DCD. While the fire hazards analysis states that standpipe and hose stations are located in the compound building the DCD indicates that the compound building is not part of the power block. In its response dated November 11, 2015 (ML15315A039), the applicant stated that the DCD will be corrected to show the compound building is part of the power block. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-28, resolved and closed.

The Class III standpipe system provides 40 mm (1.5 in) and 65 mm (2.5 in) hose connections. Hose stations will be equipped with a maximum of 30.5 m (100 ft) of 40 mm (1.5 in) fire hose, and suitable nozzles. The Class III standpipes are designed and installed in accordance with NFPA 14, "Standard for the Installation of Standpipe and Hose Systems."

Fire hose and standpipe systems that are located in the reactor containment building, auxiliary building, and EDGB meet seismic Category I requirements. The primary water supply to hose and standpipe systems is the normal non-seismic fire-protection water distribution system. In the event of loss of the normal fire-protection water supply system following a seismic event, the seismic Category I fire-protection water supply system supplies these standpipes and hose connections.

Hydrants are provided on the yard main in accordance with the guidance of NFPA 24, "Standard for the Installation of Private Fire Service Mains." Hydrants are located at intervals of up to 76 m (250 ft) in accordance with RG 1.189. Curb boxes are provided for each hydrant's isolation valve.

Hose houses are provided at intervals of not more than 305 m (1,000 ft) along the yard main in accordance with RG 1.189.

Portable fire extinguishers are located and arranged in accordance with NFPA 10, "Standard for Portable Fire Extinguishers." Fire extinguishers are to be accessible, clearly marked to be prominently visible. They will also be readily accessible for use in high radiation areas but are not located within those areas unless the fire hazards analysis indicates that a specific requirement exists.

Because the proposed design of the manual fire suppression systems conforms to RG 1.189 in that it ensures these systems are to be installed throughout the plant and that the systems will conform to the appropriate NFPA standards, the staff finds the proposed designs acceptable.

Manual Firefighting Capabilities

The applicant stated that all aspects of the onsite fire brigade are COL information items. The staff finds this acceptable because manual firefighting capabilities as described in RG 1.189 deals with fire brigade personnel, staffing, equipment, training, prefire plans, and coordination with off-site firefighting resources. These COL information items are generally site specific.

Building Design and Passive Features

The staff reviewed the applicants building design and passive features to ensure that the descriptions of the types of materials used conform to GDC 3. According to GDC 3, noncombustible and heat resistant materials must be used wherever practical. The applicant stated that the APR1400 structures are composed of noncombustible material to the extent practicable. The power block structures use noncombustible or fire-resistant material including masonry, metal siding, and interior finishes. The selection of construction materials and the control of combustible materials are in accordance with the guidance of RG 1.189.

The applicant stated that some interior finish materials are of limited combustibles with the appropriate flame spread index in accordance with ASTM E-84, "Standard Test Method for Surface Burning." RG 1.189, Section 4.1, guidance states that interior finishes should be noncombustible or listed by an approving laboratory for not only flame spread, but also for potential heat release and critical radiant heat flux. In RAI 84-8022, Question 09.05.01-11, the staff requested that the applicant state that interior finishes meet the criteria in RG 1.189, Section 4.1. In its response dated November 11, 2015 (ML15315A039), the applicant stated that the DCD will be revised as follows:

> Interior finishes materials meet the requirements of NRC RG 1.189, Section 4.1.

The staff finds the response acceptable because it follows the guidance of RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-11, resolved and closed.

GDC 3 also states that SSCs important to safety must be designed and located to minimize the probability and effect of fires and explosions. The concept of compartmentalization meets GDC 3, in part, by using passive fire barriers to subdivide the plant into separate fire areas or fire zones. The applicant stated that the plant is subdivided into separate fire areas to confine the effects of fire to a single fire area. The applicant stated that a fire area is defined as a portion of a building or plant that is separated from other areas by 3-hour rated fire barriers (i.e., walls, floors, and ceilings) that contain the effects of fire within a single area. Some fire areas are subdivided into fire zones based on physical separation or location of plant equipment.

Three hour fire rated barriers are noncombustible and provide complete separation of redundant safe shutdown equipment, electrical cables, instrumentation and controls, except where other important requirements conflict with the need for separation, specifically:

- In the MCR, fire barriers separating redundant safety trains are not provided because it is impractical to completely separate the functions of the safety trains. Continuous occupancy of operators, the fire-detection systems, and clean agent suppression system are designed to provide reasonable assurance that an MCR fire will be rapidly detected and suppressed.
- In the RSR, fire barrier separation between redundant safety trains is not provided because the RSR is not required for safe shutdown unless a fire that brings about the evacuation of the MCR occurs.
- The reactor containment building is a single fire area. Fire barrier separation necessary to define a fire area is not practical throughout the containment area because there are other design requirements to be satisfied. Fire-protection features for redundant safe shutdown systems in the reactor containment building provide confidence that at least one of two divisions of safe shutdown systems is free of fire damage.

Because the applicants descriptions of the types of materials used and compartmentalization of the plant into fire areas conforms to GDC 3, the staff finds the proposed design acceptable.

9.5.1.4.5 Electrical Cable Design, Routing

The staff reviewed the DCD to ensure that the applicant's cable design, cable tray construction, and cable routing conform with the guidance in RG 1.189. The applicant stated that the insulating and jacketing materials for electrical cables, including fiber-optic cable will meet the fire and flame test requirements of IEEE Std. 1202, "IEEE Standard for Flame-Propagation Testing of Wire & Cable," which is in conformance with RG 1.189.

Metal cable trays are used throughout the plant. Rigid metal conduit or other metal raceways are used for selected cable runs. Flexible metallic tubing may be used in short lengths for equipment connections which is in conformance with RG 1.189.

Cables that are not needed for safe shutdown but have a common power source or common raceway with cables that are needed have coordinated short circuit protection so that an open, ground, or hot short of these cables does not affect the system with which the power source or raceway is shared. The applicant stated that spurious actuation by an associated circuit, whose fire-induced failure could affect shutdown, is not a concern for the APR1400 because of the fire barriers that separate redundant divisions, which is in conformance with RG 1.189

Because the applicant's description of the electrical cable, the cable tray design and cable routing conforms with the guidance in RG 1.189 the staff finds the proposed design acceptable.

Emergency Lighting

The staff reviewed the DCD to ensure that the applicant's emergency lighting design conforms to the guidance in RG 1.189. the applicant stated that emergency lighting is provided in selected areas for safe shutdown of the plant, restoring the plant to normal operation, firefighting, and safe movement of people to the access and egress routes during plant abnormal condition and loss of normal power supply.

The emergency lighting system is composed of emergency alternating current (ac) and emergency direct current (dc) lighting system. Emergency AC lighting is supplied from Class 1E buses. Isolation is provided from the Class 1E sources by a Class 1E isolation device located at the motor control center feed to the emergency lighting distribution panel. Emergency DC lighting system is composed of the lighting powered from the non-Class 1E 125Vdc station battery and the lighting powered by an individual 8 hours rated self-contained battery pack units.

Because the proposed design conforms to RG 1.189 in that emergency lighting is provided in areas of the plant needed to perform emergency operations and that there is lighting powered by individual 8-hour rated self-contained battery packs the staff finds the design acceptable.

9.5.1.4.6 Safe Shutdown Capability

The staff reviewed the DCD to ensure that the applicant's safe shutdown capability conforms to RG 1.189 in that one success path pf SCCs that can be used to bring the reactor to safe condition remains free of fire damage. The applicant stated that the fire safe shutdown analysis (FSSA) provides reasonable assurance that a fire at any location does not affect redundant safe shutdown components. The APR1400 has two separate and redundant safety divisions. One safety division can achieve safe shutdown from the MCR, which eliminates the need for operator activities that require operators to enter a fire-involved area.

The applicant stated that possible fire induced failures, including multiple spurious actuations, are addressed in post-fire safe-shutdown circuit analysis in accordance with the guidance of RG 1.189, Revision 2, which stipulates that any and all possible failures and spurious actuations caused by the failures, including combinations of multiple failures or operations that could prevent safe-shutdown, be addressed in the analysis. The applicant also stated that the circuit analysis will be done using a methodology similar to NEI 00-01 Revision 3, "Guidance for Post Fire Safe Shutdown." The staff issued RAI 84-8022, Question 09.05.01-19, requesting that the applicant reference a methodology from NEI 00-01 Revision 2, which is endorsed by RG 1.189. In its response dated November 11, 2015 (ML15315A039), and supplemented on May 10, 2016 (ML16131A858), the applicant stated that the detailed post fire safe shutdown circuit analysis will use a methodology that is endorsed by RG 1.189. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-19, resolved and closed.

The FSSA includes the effects of the worst-case spurious actuation. The staff issued RAI 84-8022, Question 09.05.01-18, requesting the applicant add to this statement that the FSSA also includes the effects of multiple spurious actuation. In its response dated November 11, 2015 (ML15315A039), and supplemented on May 10, 2016 (ML16131A858), the

applicant stated that the DCD will be revised to read that the FSSA includes the effects of multiple spurious actuations. The staff finds the revised response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-18, resolved and closed.

The FSSA is performed according to the following assumptions:

- Fire is not postulated to be concurrent with simultaneous, coincidental failures of safety systems, other plant accidents, or the most severe natural phenomena.
- Fire renders all equipment in any fire area (excluding the control room and reactor containment) inoperable, recognizing post-fire reentry for repairs and operator actions is not possible.
- Inside containment, cables for safe shutdown are separated to the extent practicable. In areas where the redundant safe shutdown cables do not meet the separation criteria of RG 1.189, at least one division is free of fire damage by fire protection measures.
- The FSSA demonstrates that one success path used to bring the reactor to safe shutdown conditions remains free of fire damage.

The staff issued RAI 212-8246, Question 09.05.01-39, requesting the applicant state whether the final fire hazards analysis will evaluate/consider the effects of spurious actuations caused by heat from a fire on cabinets that contained digital signal processing equipment and fiber optic cable. In its response dated December 31, 2015 (ML15365A317), supplemented on June 2, 2016 (ML16154A865), and October 24, 2016 (ML16298A382), the applicants stated that the final fire hazard analysis and FSSA is to be performed considering the effects of fire-induced spurious actuations that may result from heat or fire damage to digital I&C cabinets, if the external connections to those cabinets are made via fiber optic cables. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 212-8246, Question 09.05.01-39, resolved and closed.

Because the applicant's safe shutdown capability conforms to RG 1.189 in that one success path pf SCCs that can be used to bring the reactor to safe condition remains free of fire damage, the staff finds the design acceptable with respect to its safe shutdown capability.

Alternative and Dedicated Shutdown Capability - Control Room Fires

The staff reviewed the DCD to ensure that the control room FPP conforms with the guidance of RG 1.189, and that an alternate shutdown capability is provided in the event the MCR has to be evacuated due to a fire. The applicant stated that the control complex is separated from the other areas including the peripheral room of the technical support center by 3-hour fire-rated barriers. Automatic fire detection is provided in the MCR and also in raised-floor compartments. Smoke detectors are provided in the outside air intakes and the supply and return air ducts for the control room HVAC system. Upon detection of smoke in an outside air intake, the smoke damper in the outside air intake duct is closed automatically. Smoke detection is annunciated in the MCR and RSR. In case that smoke is detected in both outside air intakes, the smoke

dampers in the outside air intakes are closed automatically, and the operator manually places the system into recirculation mode without outside makeup air.

For a fire in the MCR, evacuation of the MCR is assumed and the RSR is used as the alternative shutdown capability. The RSR is located in a separate fire area on a different elevation of the plant and is therefore physically separated from the MCR. The RSR is also electrically isolated and provides redundant shutdown capability. A plant safe shutdown can be achieved using the independent controls in the RSR. No other operator manual actions or recovery actions are required for safe shutdown, which can be achieved from the RSR. A fire in the MCR is the only fire scenario that requires the RSR to be used. Shutdown from the MCR is accomplished for fires originating in all other fire areas.

Because the FPP for the MCR conforms to the guidance in RG 1.189, and that a RSR is provided which is in a separate fire area from the MCR, the staff finds the proposed design acceptable.

Containment

The staff reviewed the DCD to ensure that the FPP for containment conforms with the guidance of RG 1.189, in that the fire hazard analysis evaluates the effects of postulated fires within containment. The applicant provided a fire hazard analysis for the reactor containment building in DCD Tier 2, Section 9.5A.3. The applicant stated that the reactor containment building is considered one fire area which is divided up into 10 fire zones.

An automatic water spray systems is provided for the RCP motors. Spurious operation or rupture of the water spray systems may affect the availability of the RCPs, but the applicant stated that the capability to shut down the reactor is not impaired by the loss of any or all of the RCPs because these pumps are not needed for a safe shutdown.

A seismic Category I fire hose and standpipe system is provided in the reactor containment building for manual fire suppression. A seismic Category I fire-protection water supply system is provided in addition to the normal fire-protection water supply system.

Redundant trains of equipment and associated cables needed for safe shutdown located within the reactor containment building are separated or protected by fire wrap, a noncombustible radiant energy shield, or embedded in concrete.

Because the applicant provided a fire hazard analysis for the reactor containment building and provided fire protection features for postulated fires the staff finds the fire hazard analysis acceptable.

Cable Spreading Rooms

The staff reviewed the DCD to ensure that the FPP for the cable spreading rooms conforms with the guidance in RG 1.189. The staff noted that in Figure 9.5A-6, "Fire Barrier DBD – RCB/AB El. 137'-6"," the APR1400 design provides for two cable spreading rooms, one cable spreading room located on opposite sides of the MCR. Each cable spreading room is separated from other areas of the plant by 3-hour fire-rated barriers.

The staff noted in Figure 9.5A-6, that each cable spreading room has only one entrance. The guidance in RG 1.89 calls for two remote and separate entrances. The staff also noted that in

DCD Tier 2, Table 9.5.1-2 “APR1400 Fire Protection Program Conformance with NFPA 804,” that the COL applicant is responsible for providing the two remote and separate entrances to the cable spreading room. The staff issued RAI 84-8022, Question 09.05.01-29, noting that RG 1.189, Section 6.1.3, “Cable Spreading Room,” states in part that cable spreading rooms should have the following:

- at least two remote and separate entrances for access by fire brigade personnel,
- an aisle separation between tray stacks at least 0.9 m (3 ft) wide and 1.5 m (5 ft) high,
- hose stations and portable extinguishers installed immediately outside the room, and
- area fire detection.

In DCD Tier 2, Section 9.5.1, there is no mention of the fire protection features provided for the cable spreading rooms. DCD Tier 2, Table 9.5.1-2, (Sheet 57 of 70) indicates that the 4 items listed above are COL information items. The staff believes that these items, except the provision for portable fire extinguishers, should be part of the design certification. The applicant was requested:

- to designate these items, except the provision for portable fire extinguishers, as part of the design certification;
- to describe, clearly, in Table 9.5.1-2, (Sheet 57 of 70) which items are COL information items and which items are part of the design certification; and
- to provide a discussion in DCD Tier 2, Section 9.5.1, of the fire protection features the APR1400 offers for the cable spreading rooms.

In its response dated November 11, 2015 (ML15315A039), the applicant stated:

> The APR 1400 design does not contain cable spreading rooms. Instead, cables to the MCR are routed through the raised access floor areas and the cable spreading areas, which are separate fire areas from the MCR and have automatic detection and suppression equipment installed.

In a subsequent phone call with the applicant on February 17, 2016, the staff noted that in Section 9.5A.3.2.69, “F137-A01C: Cable Spreading Area,” the applicant states in part:

> These fire areas may contain cables from Channel A and C safety-related equipment. This is because cables serving the Train A area (e.g., electrical penetration area) at El. 13 ft 6 in go down to El. 120 ft 0 in, move horizontally to the Division I area, and move vertically up to the MCR area, which is located at elevation 156 ft 6 in. Therefore, separation between channels is not maintained in these areas.

In Section 9.5A.3.3.69, “F137-A01D: Cable Spreading Area,” the applicant states in part:

> These fire areas may contain cables from Channels B and D safety-related equipment. This is because cables serving the Train B area (e.g., electrical penetration area) at El. 137 ft 6 in go down to elevation 120 ft 0 in area, move horizontally to the Division II area, and move vertically up to the MCR area, which is located at El. 156 ft 6 in. Therefore, separation between channels is not maintained in these areas.

During the February 17, 2016, phone call the applicant stated that the information in Sections 9.5A.3.2.69, and 9.5A.3.3.69, is not correct in that these fire areas do not have cables from more than one safety related train in them. The applicant stated that a markup to the DCD correcting these sections would be provided. In the supplemental response dated April 22, 2016 (ML16113A449), the staff noted that there was no markup provided correcting the text in these two sections. Except for a figure provided, the response was identical to the original response dated November 11, 2015 (ML15315A039).

The staff issued RAI 500-8634 (ML16188A115), Question 09.05.01-42, requesting the applicant provide a markup for these two DCD sections correcting the information as stated in the February 17, 2016, phone call. In its response dated August 2, 2016 (ML16215A206), the applicant stated that the DCD will be corrected to state that these fire areas do not have cables from more than one safety related train in them. The staff finds the response acceptable because it follows the guidance in RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 500-8634, Question 09.05.01-42, resolved and closed.

Because the FPP for the cable spreading rooms conforms with the guidance in RG 1.189, the staff finds the design acceptable with respect to the cable spreading rooms.

Station Battery Rooms

The staff reviewed the DCD to ensure that the station battery rooms important to safety conform to the guidance in RG 1.189 in that they are provided with automatic fire detection and a ventilation system that will maintain hydrogen concentration below 2 percent. The applicant stated that each ventilation system of the Class 1E battery rooms limits hydrogen accumulation to less than 1 percent of the total volume of the battery area. A loss of the ventilation system will alarm in the MCR and a high hydrogen concentration in a battery room will also alarm in the MCR. An automatic fire detection system is installed in each battery room with provision for local alarm and annunciation in the MCR and RSR.

Because the proposed design conforms to the guidance in RG 1.189 in that automatic fire detection is provided and the ventilation system will maintain hydrogen concentration below 2 percent the staff finds the design acceptable.

9.5.1.4.7 Radwaste Building, Radwaste Storage Areas

The staff reviewed the DCD to ensure that the radwaste building storage areas and decontamination areas are separated from other areas by 3-hour rated fire barriers and that these areas have provisions for fire suppression. The applicant stated that the radioactive waste areas, storage areas, and decontamination areas are separated from other areas of the plant by fire barriers having at least 3-hour ratings. Automatic sprinklers or manual hose stations and portable extinguishers are used in all areas where combustible materials are located. Automatic fire detection annunciates and alarms in the MCR and alarms locally.

Ventilation systems in these areas are capable of being isolated to prevent the release of radioactive materials to other areas or the environment. Water from firefighting activities drains to liquid radwaste collection systems.

Materials that collect and contain radioactivity, such as spent ion exchange resins, charcoal filters, and HEPA filters, are stored in closed metal tanks or containers that are located in areas free from ignition sources or combustibles. These materials are protected from exposure to fires in adjacent areas as well.

In its review, the staff noted inconsistencies between DCD Tier 2, Section 9.5A-3, “Fire Hazard Analysis Results,” and DCD Tier 2, Table 9.5A-2, “Fire Hazard Analysis Summary.” The staff issued RAI 84-8022, Question 09.05.01-30, requesting the applicant review DCD Tier 2, Section 9.5A-3, and DCD Tier 2, Table 9.5A-2, and:

- Correctly indicate if the fire area is or is not a radiological area.
- Reconcile any differences between DCD Tier 2, Section 9.5A-3, and DCD Tier 2, Table 9.5A-2.

In its response dated November 11, 2015 (ML15315A039), and supplemented May 10, 2016 (ML16131A858), the applicant provided DCD markups correcting the above noted inconsistencies. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-30, resolved and closed.

Because the proposed design conforms to the guidance in RG 1.189 in that the radwaste building storage areas and decontamination areas are separated from other areas by 3-hour rated fire barriers and that these areas have provisions for fire suppression, the staff finds the design acceptable.

9.5.1.4.8 Reactor Cooling Pump Oil Collection

The staff reviewed the DCD to ensure that the RCP assembly is equipped with an oil collection system in conformance with RG 1.189 in that the system will have sufficient capacity to collect the total lube oil inventory of the RCP and the oil collection system will withstand a safe-shutdown earthquake. The applicant stated that the RCP assembly is equipped with an oil collection system to collect oil leakage and will be in accordance with RG 1.189. The oil collection system will be capable of collecting lube oil from all potential pressurized and unpressurized leakage sites in the RCP assembly. The oil collection system will be designed to withstand an SSE and the leaked oil will be collected and drained to an oil collection tank that can store the entire oil inventory of the RCP.

Because the RCP assembly is equipped with an oil collection system in conformance with RG 1.189 the staff finds the design acceptable.

9.5.1.4.9 Turbine Generator Building

The staff reviewed the DCD to ensure that the design of the turbine generator building conforms to the guidance of RG 1.189 in that fire barriers separating the turbine building from adjacent structures have 3-hour fire ratings and that these fire barriers maintain their structural integrity even in the event of a complete collapse of the turbine building. The applicant stated that the

turbine generator building is separated from the auxiliary building by a 3-hour rated fire barrier. In RAI 84-8022, Question 09.05.01-24, the applicant was requested to state that in the event of a complete collapse of the turbine structure that the fire barrier between the turbine building and the auxiliary building would maintain its structural integrity. In its response dated November 11, 2015 (ML15315A039), the applicant stated that the DCD would be revised as follows:

> The fire barrier that separates the turbine building from the auxiliary building will maintain its structural integrity even in the event of a complete collapse of the building structure.

The staff finds the response acceptable because it follows the guidance of RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-24, resolved and closed.

Because the 3-hour rated fire barrier separating the turbine building from the auxiliary building will maintain its structural integrity even in the event of a complete collapse of the turbine building the staff finds the design acceptable.

Station Transformers

The staff reviewed the DCD to ensure that any outdoor oil filled transformer is located at least 15.2 m (50 ft) distant from buildings, or building walls within 15.2 m (50 ft) of oil-filled transformers should be without openings and have a fire-resistance rating of at least 3 hours. The applicant stated that the separation distance between the main transformer (MT), unit auxiliary transformers (UAT), standby auxiliary transformers (SAT), and cables are as follows:

- The UATs are separated from each other and from the SATs and MT by a minimum distance of 15 m (50 ft.) or by a 3-hour-rating fire barrier.
- The isophase bus associated with the UATs is separated from the SATs by a minimum distance of 15 m (50 ft.) or by a 3-hour-rating fire barrier.
- The cables that are routed from the SATs to the switchgears are separated from the UATs and MT by a minimum distance of 15 m (50 ft.) or by a 3-hour-rating fire barrier.

The applicant stated that outdoor oil-filled transformers are separated from other buildings in accordance with the guidance of NFPA 804. The staff issued RAI 84-8022, Question 09.05.01-13, requesting that the applicant state that outdoor oil filled transformers are separated from other building in accordance with RG 1.189. NFPA 804 guidance allows building walls within 15.2 m (50 ft) of oil filled transformers to have a fire resistance rating of 2 hours. RG 1.189 guidance is for building walls within 15.2 m (50 ft) of oil filled transformers to have a fire resistance rating of 3 hours and also be without openings. In its response dated November 11, 2015 (ML15315A039), supplemented on April 22, 2016 (ML16113A449), the applicant stated that the DCD will be revised to state:

> Outdoor oil-filled transformers are separated from other buildings in accordance with the guidance of NRC RG 1.189. In order to meet the requirements of NRC RG 1.189, a 3-hour rated fire barrier, without openings, is in place between the transformers and the turbine building, which is located within 15.2 m (50 ft) of the transformers.

The staff finds the response acceptable because it follows the guidance of RG 1.189. The staff confirmed that the RAI response markup has been incorporated into Revision 1 of the DCD. Therefore, the staff considers RAI 84-8022, Question 09.05.01-13, resolved and closed.

Because any outdoor oil filled transformer located within 15.2 m (50 ft) of a building will be separated from that building by a 3 hour fire rated barrier without openings, the staff finds the design acceptable.

9.5.1.4.10 Diesel Generator and Diesel Fuel Oil Storage Areas

The staff reviewed the DCD to ensure that the diesel generator rooms and diesel fuel oil storage areas have automatic fire detection and are protected by an automatic suppression system in conformance with RG 1.189. the applicant stated that the APR1400 design has four EDGs, two located in the auxiliary building and two in the emergency generator building. The four diesel generators are separated from each other and from other areas of the plant by fire barriers that have fire resistance ratings of 3 hours. Each diesel generator is provided with fire detection and is also protected by an automatic pre action sprinkler system.

Each EDG is provided with a day tank that has a capacity 2078 L (549 gal). Each day tank is also located in a separate fire area with a fire resistance rating of 3 hours. Each day tank is provided with fire detection, is protected by an automatic pre action sprinkler system, and a dike that has the capacity to hold 110 percent of the day tank capacity.

The four EDG fuel oil storage tanks, one for each generator, are in underground vaults. One fuel oil storage tank on each side of the auxiliary building and two fuel oil storage tanks next to the emergency generator building. Each fuel oil storage tank is located in a separate fire area with a fire resistance rating of 3 hours. Each fuel oil storage tank area has fire detection and is also protected by an automatic pre action sprinkler system. The vault also conforms to NFPA 30, “Flammable and Combustible Liquids Code.”

Because the diesel generator rooms and diesel fuel oil storage areas have automatic fire detection and are protected by an automatic suppression system in conformance with RG 1.189, the staff finds the design acceptable.

9.5.1.4.11 Initial Test Program

Preoperational testing to demonstrate the proper manual and automatic operation of fire detection, alarm, suppression, and smoke control systems is described in DCD Tier 2, Section 14.2.12.1.85, “Fire Protection System Test.”

9.5.1.4.12 ITAAC

DCD Tier 1, Table 2.7.5.2-3, “Fire Protection System ITAAC,” identifies the APR 1400 design ITAAC related to the FPS. The applicant stated that the FPS is classified as a non-safety related system with the exception of the containment isolation function. Based on a graded approach commensurate with the safety significance of the FPS, the staff reviewed the proposed ITAAC and finds that they 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 AEA and NRC regulations.

9.5.1.4.13 Technical Specifications

DCD Tier 2, Chapter 16, "Technical Specifications," is not applicable to the FPS because there are no TSs associated with the system.

9.5.1.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.5(1)	The COL applicant is to establish a FPP, including organization, training, and qualification of personnel, administrative controls of combustibles and ignition sources, firefighting procedures, and quality assurance.	9.5.1
9.5(2)	The COL applicant is to address the design and fire protection aspects of the facilities, buildings and equipment, and a fire protection water supply system, which are site specific and/or are not a standard feature of the APR1400.	9.5.1
9.5(3)	The COL applicant is to describe the provided apparatus for plant personnel and fire brigades such as portable fire extinguishers, self-contained breathing apparatus, and radio communication systems.	9.5.1
9.5(4)	The COL applicant is to address the final FHA [fire hazard analysis] and FSSA based on the final plant design, including a detailed post-fire safe-shutdown circuit analysis.	9.5.1

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.5.1.6 Conclusion

The staff finds that the applicant's FPP design criteria are acceptable and meet the applicable requirements of 10 CFR Part 50 and 10 CFR Part 52, and conform to Commission policy contained in SECY-90-016. The staff finds that the applicant meets the guidelines of RG 1.189 and related industry standards. The applicant has demonstrated that safe shutdown can be achieved, even assuming that all equipment in any one fire area (excluding the control room and reactor containment) will be rendered inoperable by fire and that re-entry into the fire area for repairs and operator actions is not possible. The applicant's design has provided an independent alternative shutdown capability that is physically and electrically independent of the control room. The applicant's design provides fire protection for redundant shutdown systems in the reactor containment building that will ensure, to the extent practicable, that one shutdown division will be free of fire damage. Additionally, the applicant's design ensures that smoke, hot gases, or fire suppressants will not migrate into other fire areas to an extent that could adversely affect safe shutdown capabilities, including operator actions.

The applicant has demonstrated that SSCs important to safety are adequately protected from the effects of fires and explosions. The applicant's design uses noncombustible and heat resistant materials whenever practical and provides fire detection, suppression, and firefighting capabilities of appropriate capacity and capability to minimize the adverse effects of fire on SSCs important to safety.

The staff finds that ITAAC for the FPS provide reasonable assurance that the implementation of the FPP will be in accordance with the approved design and operational program descriptions, where applicable.

9.5.2 Communications Systems

9.5.2.1 Introduction

The following section contains the staff's review of the communications system (COMS). COMS are expected to provide reliable and effective communications inside buildings (intra-plant), between buildings (inter-plant), and with external locations (plant-to-offsite) during normal operation, maintenance, transient, fire, accident conditions including LOOP and security-related events.

The APR1400 COMS consists of the following subsystems:

- Paging phone system
- Evacuation alarm address system
- Public address system
- Sound powered telephone system
- Telephone System

- Plant time synchronizing system
- Local Area Network (LAN) and Virtual Private Network (VPN) system
- Wireless communication system
- Commercial Telephone
- Local law enforcement communications
- Emergency telephone system
- Satellite telephone system

9.5.2.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in Tier 1, Section 2.6.9, "Communication Systems."

DCD Tier 2: The applicant provided the DCD Tier 2 system description in Section 9.5.2, "Communications Systems," which is summarized here, in part, as follows:

The COMS provides plant-wide coverage for onsite or internal communications. The capability to initiate external communications to key local and federal entities is provided from the MCR and the RSS. The COMS also provides communication capabilities for security personnel.

The base station equipment such as radio transceivers, digital telephone channel banks, and switches of each subsystem are located in a Seismic Category Criteria I structure in separate rooms to avoid losing multiple communication capabilities during an accident or fire. The sound-powered system is distributed throughout the plant and does not require base station-type equipment. The emergency offsite communication interface system and security communication systems have equipment cabinets housing their dedicated telecommunication trunks, as well as dedicated radio equipment, located in an alternate secured location within the Safeguard or Nuclear Island Buildings.

ITAAC: The ITAAC associated with DCD Tier 2, Section 9.5.2 are given in DCD Tier 1, Table 2.6.9-1, "Communication Systems ITAAC."

Technical Specifications: There are no TSs associated with DCD Tier 2, Section 9.5.2.

9.5.2.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in NUREG-0800, Section 9.5.2, "Communications Systems," and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 9.5.2.

Requirements applicable to communications systems are as follows:

1. GDC 1, "Quality standards," as it relates to the design, fabrication, erection, and testing of SSCs to quality standards commensurate with the importance of the safety functions to be performed.

2. GDC 2, "Design bases for protection against natural phenomena," as it relates to the design of SSCs to withstand the effects of natural phenomena.

3. GDC 3, "Fire protection," as it relates to protection of SSCs from the effects of fires and explosions.

4. GDC 4, "Environmental and dynamic effects design bases," as it relates to the design of SSCs to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.

5. GDC 19. "Control room," as it relates to the provision of a control room from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions.

6. 10 CFR Part 50, Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," particularly Part IV.E(9), which requires the provision of at least one onsite and one offsite communications system, each with a backup power source and Part IV.D(1), as it relates to physical means for notifying local, State, and Federal officials and agencies.

7. 10 CFR 50.34(f)(2)(xxv), which requires the provision of an onsite Technical Support Center, and onsite Operational Support Center.

8. 10 CFR 50.47, "Emergency plans," paragraph (b)(8) as it relates to the provision and maintenance of adequate emergency facilities and equipment to support emergency response.

9. 10 CFR 50.55a, "Codes and Standards," which requires conformance to quality standards, ASME Codes and IEEE standards, and alternatives.

10. 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 AEA, and NRC regulations.

Acceptance criteria adequate to meet the above requirements are shown below:

1. Requirements of GDC 1 will be found acceptable if SSCs important to safety are designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified

as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these SSCs will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of SSCs important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

2. Requirements of GDC 2 will be found acceptable if SSCs important to safety are 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. The design bases for these SSCs shall reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

3. Requirements of GDC 3 will be found acceptable if SSCs important to safety are designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on SSCs important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these SSCs.

4. Requirements of GDC 4 will be found acceptable if SSCs important to safety are designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These SSCs shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

5. Requirements of GDC 19 will be found acceptable if equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls (I&C) to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.

6. Requirements of Appendix E to 10 CFR Part 50, Part IV.E(9), will be found acceptable if adequate provisions are made and described for emergency facilities and equipment, including: at least one onsite and one offsite communications system; each system shall have a backup power source.

7. Requirements of 10 CFR 50.34(f)(2)(xxv) and TMI Action Plan Item III A.1.2 will be found acceptable if provisions are made for an onsite Technical Support Center, an

onsite Operational Support Center, and, for construction permit applications only, a near-site Emergency Operations Facility.

8. Requirements of 10 CFR 50.47(b)(8) will be found acceptable if adequate emergency facilities and equipment to support the response are provided and maintained.

9. Requirements of 10 CFR 50.55a will be found acceptable if SSCs are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

10. Requirements of 10 CFR 52.47(b)(1) will be found acceptable if the DC application contains the proposed inspections, tests, analyses, and acceptance criteria (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 the NRC's regulations

11. RG 1.189, as it relates to communications systems to support fire protection of nuclear power plants.

12. NRC Bulletin 80-15, “Possible Loss of Emergency Notification System (ENS) with Loss of Offsite Power,” as it relates to provision of backup power for the ENS.

13. IEEE Std. 384-1992, “IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits,” as it relates to independence and isolation of Class 1E from non-Class 1E systems.

14. IEEE Std. 603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Generating Stations,” as it relates to design of safety systems.

9.5.2.4 Technical Evaluation

The communications system is reviewed with respect to the capability of the system and related plant design features to provide effective intraplant communications and effective plant-to-offsite communications during normal plant operations and during transient, fire, and accident conditions, including loss of offsite power.

For design certification (DC) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this SRP section in accordance with SRP Section 14.3, “Inspections, Tests, Analyses, and Acceptance Criteria.” The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

For a DC application, the review will also address COL information items and requirements and restrictions.

9.5.2.4.1 Description of Plant Communications System

The communication subsystems described in this section are classified as non-safety-related and are divided into two categories: plant communications systems and offsite communication systems. Plant communications systems consist of paging phone system, evacuation alarm address system, public address system and sound powered telephone system, telephone system, plant time synchronizing system, LAN and VPN systems, and wireless communication system. Offsite communication systems consist of commercial telephone, local law enforcement communications, emergency telephone system, satellite telephone system.

Paging Phone System

This system consists of handset stations and loud speaker assemblies throughout the plant. The stations each have one channel paging capability and multiple parties for simultaneous bidirectional voice communications between different areas. Paging phones are located at operator stations and near major equipment and stairways. Page and party lines are available for communication between the remote shutdown console room, MCR, and other areas that require operator action during emergency shutdown operations.

The party-line communication allows personnel to respond to voice pages or initiate party-line communication with certain recipients. Party line handsets are distributed throughout the plant at fixed locations for easy access. Noise-canceling headphones with directional microphones or acoustic booths are provided in plant areas that have high ambient noise conditions. The paging phone system serves as the backup evacuation alarm address system. This generates audio messages and broadcasts them over speakers during normal or emergency condition in conjunction with the evacuation alarm address system.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2, regarding the Paging Phone System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Evacuation Alarm Address

This system provides area alarm during radiation and fire accidents. It also provides public address capability. The system consists of the main amp, alarm speaker, and evacuation switch board. The alarm uses sirens located throughout the plant. The sirens and tone generator are manually activated from the evacuation switchboard.

The plant-wide alarm message provides a signaling tone to either alert the staff or provide status. A tone generator produces five warning tones: (1) pulse, (2) siren, (3) yelp, (4) warble, and (5) steady. Tones are activated by a number of external sources. Higher priority tones can be programmed to override those of lower priority. Beacon lighting is provided to complement the siren or tone in high noise areas. An automatic loudspeaker volume control is used for dedicated areas with a highly fluctuating noise levels. In case the normal system fails, the backup evacuation alarm broadcast system is manually initiated in conjunction with the paging phone system.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2, regarding the Evacuation Alarm Address, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Public Address System

Independent public address system is provided for the plant with provisions to merge the systems for "all call" operation. The system consists of control mixer, amplifiers, and loud speakers.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2, regarding the Public Address System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Sound-Powered Telephone Systems

This system provides a communication system between the following plant locations: MCR, TSC, refueling areas, turbine-generator operating deck, RSR, electrical and I&C equipment areas and other high maintenance active areas. It provides a backup communications mechanism during all modes of plant operations. Portable handsets are provided with sufficient cable and extensions to allow personnel to use the system at any point within the plant.

Sound-powered jacks are installed throughout the plant to help the testing and calibration of instrument and control circuits. The sound-powered jack locations include instrument racks, major equipment, start-up and overhaul operator stations, and refueling areas. A separate sound powered telephone system is interconnected by means of public addressing for direct communication between the refueling areas and the MCR. The sound powered telephone system is capable of simultaneous, bidirectional communication with three channels. The system consists of portable headsets with carrying cases and extension cords, jacks, a switching box for connecting different areas, and portable multichannel equipment. The sound powered telephone system for each zone has three channels. The zones can be interconnected via a switching box in the MCR.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 0, Section 9.5.2, regarding the Sound-Powered Telephone System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Telephone System

This system is a backup to the paging phone system. This system consists of desk-type telephones and signal addition units located throughout the plant and plant site. This system is available for allowing interplant communications during normal, abnormal, and accident conditions.

a. Private automatic branch telephone exchange

The plant private automatic branch telephone exchange (PABX) is connected to the offsite commercial telephone system and allows for normal and emergency communications. Emergency communication lines are connected directly to specific telephones located in critical areas of the plant, such as MCR, TSC, and security alarm stations. The PABX is interfaced to the plant wireless communication system. This allows personnel with plant radios to originate telephone communications if required.

b. Internal telephone

This system functions as a backup system for the paging phone system. It provides simultaneous bidirectional communications between various plant areas. Speakers located near each station emit an audible frequency and this provides the signal. A speaker and lamp are provided in high noise areas to alert the operator being called. Acoustic booths are also provided in these areas. The internal telephone locations include operator stations, major control panels, and operator's offices.

c. External telephone

This system provides a convenient means of communication between major buildings and offsite areas. Switching and distribution equipment for the external telephone system is compatible with the other neighbor unit.

d. PABX power source

The PABX is powered from the plant non-safety-related load group and consists of independent battery chargers and batteries for each PABX node. The batteries have the capability to operate the plant telephone system for approximately 16 hours following loss of normal alternating current (ac) power.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2, regarding the Telephone System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Plant Time Synchronizing System

This system consists of a master clock and subsidiary clocks. The master clock is located in the communication equipment room and subsidiary clocks are located throughout the plant. The master clock provides standard time synchronizing signals to necessary plant equipment.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2,regarding the Commercial Telephone System, supplements meeting the requirements of 10 CFR Part 50, Appendix E.

Local Area Network System and Virtual Private Network

The LAN system is a computer network. It consists of routers, backbone switches, workgroup switches, servers, clients, network interface cards, and fiber-optic/twisted pair cables. The plant LAN links up plant terminals with construction and the head office host computers. LAN system is located in the MCR, TSC, Operations Support Center (OSC), etc. The VPN system is a private network across public networks like the Internet. The VPN system provides plant with the capability of communicating to other units and the head office. Plant VPN links the plant computer terminals with the head office host computers. The COL applicant provides the LAN and VPN system (COL 9.5(8)).

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2, regarding the LAN and VPN System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Wireless Communication System

This system is designed to provide a stand-alone method of plant-wide communication between designated personnel equipped with, or having access to wireless two-way radios. This is the primary source of communications for emergency personnel. The wireless communication system is comprised of transmitters, receivers, antennas, amplifiers, and radio base station equipment. Antennas and amplifiers are distributed throughout the plant. Repeaters are used to allow seamless radio coverage throughout the plant. For areas that are not properly served by the primary antenna, other antennas and cables interconnecting the repeaters to the base station equipment are provided such that there is improved radio signal penetration. Radio coverage is provided throughout the plant, although radio usage in certain I&C areas is restricted due to potential electromagnetic interference (EMI) and radio frequency interference (RFI) considerations. These areas have posted warning signs. The wireless communication system is designed, installed, and tested so that I&C system circuits are not adversely impacted by EMI and RFI from transmitting sources.

The transmitters, receivers, antennas, amplifiers, and radio base station equipment are robust, highly reliable, and capable of withstanding the harsh environment of the facility. Physical separation of the cabinets increases protection against a single accident or fire from affecting multiple modes of communication throughout the plant.

The applicant has committed to conforming to the following regulatory guides and standards. Communication equipment used for fire protection activities are protected from exposure to fire damage in accordance with RG 1.189, "Fire Protection for Nuclear Power Plants," Revision 2. The fire brigade radio communication system is in accordance with RG 1.189. The fire brigade radio system consists of a base unit, mobile units, and portable units. The COL applicant is to provide the fire brigade radio system (COL 9.5(7)). The security radio system consists of a base unit, mobile units, and portable units. The COL applicant is to provide the security radio system which consists of a base unit, mobile units, and portable units (COL 9.5(12)). Applicant also commits that wireless communications equipment used with respiratory protective equipment will be designed and selected to conform with the requirements in RG 8.15, "Acceptable Programs for Respiratory Protection," Revision 1. It will also conform to the guidance provided in EPRI NP-6559, "Voice Communication Systems Compatible with Respiratory Protection," Electric Power Research Institute, November 1989.

The staff finds the information provided in APR1400 DCD Tier 2, Revision 1, Section 9.5.2, regarding the Wireless Communication System, supplements meeting the requirements of 10 CFR 50.47(b)(8).

Commercial Telephone

Plant-to-offsite communication during normal operation is through a commercial telephone system, with extensions installed at a limited number of locations throughout the plant. The system provides direct dialing to locations outside the plant and also between extensions within the plant.

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2 regarding the Commercial Telephone System, supplements meeting the requirements of 10 CFR Part 50, Appendix E.

Law Enforcement Communications

Radio or microwave transmitted two-way voice communication, either directly or through an intermediary, between local law enforcement authorities and the site as required by 10 CFR 73.55 (j)(4)(i) is provided on a 'site specific' basis due to the unique nature of each local law enforcement agency.

The COL applicant is to address the local law enforcement communications including dedicated conventional telephone and radio transmitted two-way communication system (COL 9.5(13)).

The staff finds the information provided in APR1400 DCD, Tier 2, Revision 1, Section 9.5.2 regarding Law Enforcement Communications, supplements meeting the requirements of 10 CFR Part 50, Appendix E, and 10 CFR 73.55 (j)(4)(i).

Emergency Telephone System

The emergency communication system uses two-way (incoming and outgoing) emergency communications from onsite to offsite facilities and agencies, a minimum of two independent communications links are provided. The onsite facilities provided with the emergency communications links are MCR, RSR, TSC, OSC, and the security alarm stations. The offsite facilities include the emergency operations facility (EOF), NRC resident office, and federal, state and local government agencies (including local law enforcement) as identified in the emergency response plan.

The two independent communications links are as follows:

1. Dedicated hotline telephones that provide direct communications to the selected locations in an off-hook condition. The provisions for hotline telephones are incorporated into the design of the onsite digital telephone subsystem.

2. Provisions for two-way radio communications via the portable wireless communication subsystem for personnel with access to specific wireless radios onsite and for the offsite personnel.

The COL applicant is to provide the emergency offsite communication system including dedicated hotline, local law enforcement radio equipment, and wireless communication system (COL 9.5(9)).

The staff finds the information provided in DCD Tier 2, Revision 1, Section 9.5.2, regarding the Emergency Telephone System, supplements meeting the requirements of 10 CFR Part 50, Appendix E, and 10 CFR 50.47(b)(8).

Satellite Telephone System

A satellite telephone system is connected to the plant telephone system to fulfill the needs after a beyond design basis external event. This system is tied directly into the plant telephone exchange (PBX) as an alternate source of outside telephone lines for the plant.

This system provides an automatic alternate communication path for outside connections to the public switched telephone network. The satellite telephone equipment includes a roof mounted antenna and transceiver.

The staff finds the information provided in DCD Tier 2, Revision 1, Section 9.5.2, regarding the Satellite Telephone System, supplements meeting the requirements of 10 CFR Part 50, Appendix E and 10 CFR 50.47(b)(8).

9.5.2.4.2 Analysis of Acceptance Criteria

Staff reviewed and evaluated the systems described above to ensure that they meet conformance to appropriate acceptance criteria. The results of this evaluation are discussed below.

10 CFR Part 50, Appendix E, Part IV.E(9), Emergency Facilities and Equipment

10 CFR Part 50, Appendix E, Part IV.E(9), requires that adequate provisions shall be made and described for emergency facilities and equipment including at least one onsite and one offsite communications system; each system shall have a backup power source.

One example of an offsite communications system which is described in the DCD would be the emergency telephone system. DCD Tier 2, Revision 1, Section 9.5.2.2.2.3, "Emergency Telephone System," states that in order to facilitate two-way (incoming and outgoing) emergency communications from onsite to offsite facilities/agencies, at least two independent communication links are provided. The onsite facilities provided with the emergency communication links are the MCR, RSS, TSC, OSC and the security alarm stations. The offsite facilities that are considered are the EOF, NRC resident office and Federal, State, and local government agencies identified in the emergency response plan, to be addressed by the COL applicant. The two independent communication links are as follows:

- Dedicated "hotline" telephones that provide direct communications to the selected locations when in an off-hook condition. The provisions for "hotline" telephones are incorporated into the design of the onsite digital telephone subsystem.
- Provisions for two-way radio communications via the portable wireless communication subsystem for personnel having access to specific wireless radios onsite and for the offsite personnel.

According to the DCD, the applicant defers to the COL applicant to provide the emergency offsite communication system including dedicated hotline, local law enforcement radio equipment, and wireless communication system as specified in COL i9.5(9). The COL applicant is also to provide the local law enforcement communications including dedicated conventional telephone and radio-transmitted two-way communication system as specified in COL 9.5(13).

APR1400 DCD, Tier 2, Revision 1, Section 9.5.2.1, "Design Bases," states:

> *The wireless communication system, paging phone system, alarm address system, telephone system, and sound powered telephone system provide onsite communications. The onsite communications systems have a backup power source.*

As stated above, paging phone system is an example of an onsite communications system which is described in the DCD. DCD Tier 2, Revision 1, Section 9.5.2.2.1.1, "Paging Phone System," states in part that paging phones "are located at operator stations, near major

equipment, and near stairways. Page and party lines are available for communication between the remote shutdown console room, MCR, and other areas that require operator action during emergency shutdown operations." It also states, "The paging phone system serves as the backup evacuation alarm address system. This generates audio messages and broadcasts them over speakers during normal or emergency condition in conjunction with the evacuation alarm address system." The section also states in part that a backup power source is provided for the offsite communication systems.

Section 9.5.2.1 also states,

> *The COL applicant is to provide a description of the offsite communication system that interfaces with the onsite communication system, including type of connectivity, radio frequency, normal and backup power supplies, and plant security system interface (COL 13.3(1)).*

However, staff looked to COL 13.3(1) and found that it did not state this information. Instead, COL 9.5(11) stated this. The staff issued RAI 245-8292, Question 09.05.02-01 (ML15288A063), requesting the applicant to clarify whether COL information items referenced in the APR1400 DCD, Section 9.5.2, are correctly identified. In its response to RAI 245-8292, Question 09.05.02-01 (ML16124B202), the applicant committed to correct the current COL 13.3(1) (referenced in DCD Tier 2, Subsection 9.5.2.1) to COL 9.5(5) in DCD Tier 2, Subsections 9.5.2.1(a) and 9.5.10, and Table 1.8-2. Staff finds the above response satisfactory and based on the above response, RAI 245-8292, Question 09.05.02-01, was previously tracked as a confirmatory item. The staff verified the proposed markups have been incorporated into Revision 1 of DCD Tier 2, Subsections 9.5.2.1(a) and 9.5.10 and Table 1.8-2. Therefore, the staff considers RAI 245-8292, Question 09.05.02-01, resolved and closed.

Back-up Power Source Discussion

APR1400 DCD, Tier 2, Revision 1, Section 9.5.2.1 states in part that the communication systems are normally powered using a permanent non-safety (PNS) bus. This bus is backed up by the alternate alternating current (AAC) source during a LOOP. The PNS bus is backed up further from one of the two dedicated 16 hour rated non-safety-related batteries (normal and standby) in case of either AAC Gas Turbine Generator (GTG) failure during a LOOP or Station Blackout (SBO) condition.

However, the applicant ultimately defers the design of the power source for both the onsite and offsite communication system, including backup power, to the COL stage. DCD, Tier 2, Chapter 1, Revision 1, COL 9.5(11), which states:

> The COL applicant is to provide a description of the offsite communication system that interfaces with the onsite communication system, including type of connectivity, radio frequency, normal and backup power supplies, and plant security system interface.

The staff finds it acceptable for the applicant to defer addressing the backup power source to the COL stage. Staff will review APR1400 COL applications to ensure that they meet the requirements of 10 CFR Part 50, Appendix E, Part IV.E(9) regarding backup power.

Testing procedures for Onsite and Offsite communication systems

10 CFR Part 50, Appendix E, Part IV.E(9) also states that all communication plans shall have arrangements for emergencies, including titles and alternates for those in charge at both ends of the communication links and the primary and backup means of communication. Where consistent with the function of the governmental agency, these arrangements will include:

a. Provision for communications with contiguous State/local governments within the plume exposure pathway EPZ. Such communications shall be tested monthly.

b. Provision for communications with Federal emergency response organizations. Such communications systems shall be tested annually.

c. Provision for communications among the nuclear power reactor control room, the onsite technical support center, and the emergency operations facility; and among the nuclear facility, the principal State and local emergency operations centers, and the field assessment teams. Such communications systems shall be tested annually.

d. Provisions for communications by the licensee with NRC Headquarters and the appropriate NRC Regional Office Operations Center from the nuclear power reactor control room, the onsite technical support center, and the emergency operations facility. Such communications shall be tested monthly.

According to DCD Tier 2, Chapter 1, Revision 0, COL 14.2(11), the COL applicant is to develop the test procedure for the communication system. The initial plant test program (ITP) is normally provided in Tier 2, Section 14.2. ITP addresses the applicant's plan for preoperational and initial startup testing. The test program consists of preoperational and initial startup tests, as described in RG 1.68. Preoperational tests consist of those tests conducted following completion of construction and construction-related inspections and tests, but before fuel loading. Such tests demonstrate, to the extent practicable, the capability of structures, systems, and components (SSCs) to meet performance requirements and design criteria. Initial startup tests include those test activities scheduled to be performed during and following fuel load activities. 10 CFR 50.34(b)(6)(iii), requires the applicant to provide plans for preoperational testing and initial operations. Also, section XI of Appendix B to 10 CFR Part 50, requires test programs to be established to assure that SSCs will perform satisfactorily in service.

DCD Tier 2, Section 9.5.2.4, states in part that preoperational testing is described in Section 14.2. However, there is no information on the ITP for the communication systems in Section 14.2. This is not acceptable and the applicant needs to provide the preoperational and initial startup tests, test specifications and procedures for the communication systems. Also, DCD Tier 1, Revision 0, Table 2.6.9-1, vaguely describes the inspections, tests, analyses, and associated acceptance criteria for the communication systems. But the information contained in the table is too vague and doesn't have detailed procedures for the tests or acceptance criteria for the tests.

The staff issued RAI 548-8822, Question 09.05.02-07 (ML17142A458), requesting the applicant to provide a detailed description of the applicant's Initial Test Program (ITP) in either Section 14.2 or 14.3 for all the communication subsystems and not just the ones needed for security communications. The description was to include individual pre-operational tests and initial startup test specifications for all communication subsystems which are described in DCD Tier 1,

Section 2.6.9, and Communication System ITAAC identified in Table 2.6.9.1. In its response to RAI 548-8822, Question 09.05.02-07 (ML17236A341), the applicant provided an attachment which provided the descriptions of preoperational tests for all the communication subsystems which are described in DCD Tier 1, Subsection 2.6.9. The applicant also committed to revising DCD Tier 2, Subsection 14.2.12.01, and Tables 14.2-1 and 14.2-7 to add the attachment. The staff finds the above response satisfactory since the applicant has committed to an initial test program for the communication systems as described in RG 1.68. Hence, RAI 548-8822, Question 09.05.02-07, is being tracked as a **Confirmatory Item**.

Based on the applicant's response for RAI 245-8292, Question 09.05.02-1 and RAI 548-8822, Question 09.05.02-7 and adequate provisions having been made and described for emergency facilities and equipment including at least one onsite and one offsite communications system with each system having a backup power source, the staff finds that the requirements of 10 CFR Part 50, Appendix E, Part IV.E(9) have been met pending the resolution of all confirmatory items.

10 CFR Part 50, Appendix E, Part IV.D(1), Notification Procedures

10 CFR Part 50, Appendix E, Part IV.D(1) requires a description of the administrative and physical means for notifying local, State, and Federal officials and agencies. DCD Tier 2, Revision 1, Section 9.5.2.2.2.3, "Emergency Telephone System," discusses the offsite emergency telephone system and identifies COL 9.5(9). Section 9.5.2.2.2.2, "Local Law Enforcement Communications," discusses radio or microwave transmitted two-way voice communication for law enforcement. This is evaluated in Section 13.6 of this report. Along with this, COL 9.5(13) and COL 9.5(5) further provide more information to support conformance to the Part IV.D(1) requirement. The staff finds the information in the DCD and in the COL information items acceptable in complying with the requirements of 10 CFR Part 50, Appendix E, Part IV.D(1), to provides descriptions of the administrative and physical means for notifying local, State, and Federal officials and agencies and of the agreements reached with these officials and agencies for the prompt notification of the public and for public evacuation or other protective measures, should they become necessary.

In summary, since the applicant provided a description of the emergency telephone system and the paging phone system and deferred the backup power requirements to the COL stage, and provided COL 9.5(9), 9.5(13) and 9.5(5), the staff finds that the requirements of 10 CFR Part 50, Appendix E, Part IV.E(9) and 10 CFR Part 50, Appendix E, Part IV.D(1), are met.

10 CFR 50.34(f)(2)(xxv), Emergency response facilities

10 CFR 50.34 (f)(2)(xxv) requires applicants to make provisions for an onsite Technical Support Center (TSC), an onsite Operational Support Center (OSC), and, for construction permit applications only, a near-site Emergency Operations Facility (EOF).

To satisfy the requirement, the application shall provide sufficient information to demonstrate that the required actions will be satisfactorily completed by the operating license stage. For those applicants subject to 10 CFR 50.34(f), information regarding the requirements of 10 CFR 50.34(f)(2)(xxv) and TMI Action Plan Item III A.1.2 will be found acceptable if provisions are made for an onsite TSC, an onsite OSC, and, for construction permit applications only, a near-site EOF. NUREG-0696, Appendix B to NUREG- 0718, NUREG-0737, and Supplement 1 to NUREG-0737 provide guidance relating to the design and implementation of

emergency response facilities (e.g., TSC, OSC, EOF). NUREG-0696, NUREG-0737, and Supplement 1 to NUREG-0737 provide guidance relating to occupancy and radiological habitability of vital areas (including the TSC), which aid in the mitigation of or recovery from an accident.

DCD Tier 2, Revision 0, Section 9.5.2.1 states in part, "[t]he emergency response facilities include the TSC, the operational support center (OSC), and the EOF in accordance with 10 CFR 50.34(f)(2)(xxv)." In the DCD, the applicant also states that, "[t]he COL applicant is to address the emergency response facilities (COL 13.1(1))." However, COL 13.1(1) does not address this requirement. Instead, COL 9.5(6) states,

> The COL applicant is to provide details of emergency response facilities and associated communication capabilities.

Similarly, COL 9.5(5) states,

> The COL applicant is to provide a description of the offsite communication system that interfaces with the onsite communication system, including type of connectivity, radio frequency, normal and backup power supplies, and plant security system interface.

The staff issued RAI 245-8292, Question 09.05.02-01 (ML15288A063), requesting the applicant to clarify whether COL information items referenced in the APR1400 DCD, Section 9.5.2, are correctly identified. In its response to RAI 245-8292, Question 09.05.02-01 (ML16124B202), the applicant committed to removing COL 13.1(1) and COL 9.5(6) provided in Subsections 9.5.2.1.b and 9.5.2.1.c. These will be removed and the following sentence will be added in lieu of COL 13.1(1): "Details for the features that are related to the design of emergency response facilities are described in Section 13.3." The staff verified that such description has been provided in DCD Tier 2, Revision 1, Section 13.3. Evaluation of the description is in Section 13.3 of this report. The applicant committed to remove COL 9.5(6) from DCD Tier 2, Table 1.8-2, and DCD Tier 2, Subsection 9.5.10. Staff finds the above response satisfactory and based on the above response, RAI 245-8292, Question 09.05.02-01, was previously tracked as a confirmatory item. The staff verified the proposed markups have been incorporated into Revision 1 of DCD Tier 2, Subsections 9.5.2.1.b, 9.5.2.1.c, and 9.5.10, and Table 1.8-2. Therefore, the staff considers RAI 245-8292, Question 09.05.02-01, resolved and closed.

DCD Tier 2, Revision 1, Section 13.3, "Emergency Planning," states in part, "The design features, facilities, functions, and equipment necessary for emergency planning are considered in the design bases for the standard plant." This section further describes the provisions made in the design for a TSC, OSC and EOF. In addition, it also talks about the various communication mediums between the TSC, OSC and EOF. This includes the emergency response data system (ERDS), voice and data communications and safety parameter display system (SPDS). here is also a description of the decontamination facilities. A detailed description and evaluation of the design and features of the TSC, OSC, and EOF are provided in Section 13.3, "Emergency Planning," of this report.

The staff finds the information provided in Section 13.3 of this report is sufficient to demonstrate the design's provision for an onsite Technical Support Center and an onsite Operational Support

Center. Based on the information in Section 13.3 of this report the staff finds that the requirements of 10 CFR 50.34(f)(2)(xxv) have been met.

10 CFR 50.47(b)(8), Equipment and Facilities to Support Emergency Response

The 10 CFR 50.47(b)(8) requires that adequate emergency facilities and equipment to support the emergency response are provided and maintained. Requirements of 10 CFR 50.47(b)(8) will be found acceptable if adequate emergency facilities and equipment to support the response are provided and maintained.

The onsite and, except as provided in 10 CFR 50.47(d), offsite emergency response plans for nuclear power reactors must meet the standards established in 10 CFR 50.47(b) and applicable requirements of Appendix E to 10 CFR Part 50. Compliance with these regulations is determined by using the guidance in RG 1.101, Revision 2, which endorses NUREG-0654/FEMA-REP-1, Revision 1, and through it NUREG-0396, and NUREG-0696. NUREG-0654/FEMA-REP-1, Revision 1, establishes an acceptable basis for NRC licensees and State, tribal and local governments to develop radiological emergency plans and procedures, and improve their overall state of emergency preparedness. NUREG-0696 discusses the facilities and systems to be provided by nuclear power plant licensees to aid the licensee's response to emergency situations. Additional guidance is provided in NUREG-0718, NUREG-0737, Supplement 1 to NUREG-0737, NUREG-0814, and Supplement 3 to NUREG-0654/ FEMA-REP-1, Revision 1.

Several communication systems are available to support emergency response. DCD Tier 2, Revision 1, Section 9.5.2.2.1.2, "Evacuation Alarm Address System," states in part that the system provides area alarm for radiation and fire accidents and also a public address capability. The evacuation alarm is provided using sirens located throughout the plant. The sirens and tone generator are manually activated from the evacuation switchboard. There are five different warning tones that can be produced by the tone generator. Similarly, DCD Tier 2, Revision 1, Section 9.5.2.2.1.1, "Paging Phone System," states in part that this system serves as the backup evacuation alarm address system and operates in conjunction with it. DCD Tier 2, Revision 1, Section 9.5.2.2.1.8, "Wireless Communication System," states in part that this subsystem is the primary source of communications for emergency personnel such as security and fire brigade. A detailed description the plant communication systems mentioned above is provided in section 9.5.2.4.1 of this report.

The emergency telephone system, is used for emergency communications from onsite to offsite facilities and agencies. This was described earlier in section 9.5.2.4.2 of this report. Similarly, the satellite telephone system provides an automatic alternate communication medium for outside connections to the public switched telephone network. COL 9.5(5), 9.5(7), 9.5(9), 9.5(12), and 9.5(13), further support 10 CFR 50.47(b)(8) requirements. Hence, the staff finds that there are adequate emergency facilities and equipment to meet the requirements of 10 CFR 50.47(b)(8).

DCD Tier 2, Revision 1, Section 13.3 states, "The design features, facilities, functions, and equipment necessary for emergency planning are considered in the design bases for the standard plant (References 1 through 5)." It further states, "The COL applicant is to develop the interfaces of design features with site-specific designs and site parameters (COL 13.3(1))." This section further describes the provisions made in the design for a TSC, OSC and EOF. In addition, it also describes the various communication mediums between the TSC, OSC and

EOF. This includes the ERDS, voice and data communications and SPDS. There is also a description of the decontamination facilities.

The staff finds the information provided and evaluated earlier in section 9.5.2.4.2 and in Section 13.3, of this report is sufficient to demonstrate that adequate emergency facilities and equipment to support the emergency response are provided and maintained. Hence the staff finds that the requirements of 10 CFR 50.47(b)(8) have been met.

General Design Criteria

10 CFR Part 50, Appendix A, GDC 1, requires SSCs important to safety to be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. A quality assurance program shall be established and implemented in order to provide adequate assurance that these SSCs will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of SSCs important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

10 CFR Part 50, Appendix A, GDC 2, requires SSCs important to safety are 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.

10 CFR Part 50, Appendix A, GDC 3, requires SSCs important to safety to be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room.

10 CFR Part 50, Appendix A, GDC 4, requires SSCs important to safety to accommodate the effects of and to be compatible with the environmental conditions associate with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant-accidents.

10 CFR 50.55(a)(1), requires that SSCs to be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

10 CFR Part 50, Appendix A, GDC 19, requires equipment at appropriate locations outside the MCR to be provided for prompt hot shutdown of the reactor with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures. DCD Tier 2, Revision 0, Section 9.5.2.1, “Design Bases,” states in part that while there is communication equipment located in the RSR, the communication equipment is not required to function for hot or cold shutdown of the reactor. The staff finds that the communications equipment does not serve a function to support prompt hot shutdown of the reactor. Hence, the staff concludes that the communication systems do not need to meet the requirements of 10 CFR Part 50, Appendix A, GDC 19.

DCD Tier 2, Revision 0, Section 9.5.2.1, “Design Bases,” states that the communication systems and components are selected and designed to operate within the following environments, as applicable:

a. Extremely noisy locations, up to 115 decibels (dB) sound pressure level

b. Ambient temperatures ranging from -30 °C to + 70 °C (-22 °F to + 158 °F)

c. Humid and oily locations

d. Hazardous areas (10 CFR Part 50, Appendix A, GDC 4)

e. Outdoors (where indicated)

f. Indoor areas with thick concrete walls or other obstructions

g. With personal wearing protective equipment

h. Areas having constant vibration

DCD Tier 2, Revision 0, Section 9.5.2.1 states, "Each communication system is designed in accordance with applicable codes and standards regarding environmental conditions, such as weather, moisture, noise level, electromagnetic interference (EMI), and radio frequency interference (RFI)." As stated in NUREG-0800, Section 9.5.2, typically communication systems will be composed of commercial equipment. As such, the equipment should be appropriately qualified commensurate with the safety significance of the equipment. Section 9.5.2 explains that the communication systems equipment are qualified for their application using the guideline of EPRI NP-5652, "Guideline for the Utilization of Commercial-Grade Items in Nuclear Safety-Related Applications" and EPRI TR-106439, "Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications."

DCD Tier 2, Revision 0, Section 9.5.2.1.g, "Codes and Standards," states that the following codes and standards as applicable are used for the design of the communication systems:

- IEEE Std. 269-2002, "IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets, Handsets, and Headsets"
- IEEE Std. 344-2004, "Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"
- IEEE Std. 487-2000, "IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations"
- IEEE Std. 1613-2003, "IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations"
- NFPA 70-2011, "National Electrical Code (NEC)"
- NFPA 72-2007, "National Fire Alarm Code"
- EPRI TR-102323-R3, "Guidelines for Electromagnetic Interference Testing of Power Plant Equipment"
- MIL-STD-810F, "Environmental Engineering Considerations and Laboratory Tests"
- IEEE/ANSI C63.12-1999, "American National Standard Recommended Practice for Electronic Compatibility Limits"

- ANSI/ANS-8.3-2003, "Criticality Accident Alarm System"
- NEMA 250-2004, "Enclosures for Electrical Equipment"
- ANSI/TIA-603-C-2004, "Land Mobile FM or PM - Communications Equipment - Measurement and Performance Standards"
- IEC61000-4-2-2008, "Electromagnetic Compatibility (EMC) Testing and Measurement Techniques- Electrostatic Discharge Immunity Test"
- IEC61000-4-3-2010, "Electromagnetic Compatibility (EMC) Testing and Measurement Techniques- Radiated, Radio Frequency, Electromagnetic Field immunity Test"
- IEC61000-4-5-2005, "Electromagnetic Compatibility (EMC) Testing and Measurement Techniques – Surge Immunity Test"

DCD Tier 2, Revision 0, Section 9.5.2.1, classifies the communication systems as non-Class 1E systems and, therefore, serve no safety-related functions. The staff finds that although these systems do not serve a safety-related function, it is important to safety, as it provides required communications capability during plant emergencies. Section 9.5.2.1 further states that communication systems are selected and designed in accordance with the guidance provided in 10 CFR Part 50 Appendix A, GDC 1, GDC 2, GDC 3, GDC 4, and GDC 19 to provide reasonable assurance that the facility can operate without undue risk to the health and safety of the public.

The staff issued RAI 245-8292, Question 09.05.02-02 (ML15288A063), requesting the applicant to clarify how the communication systems comply with the requirements of 10 CFR Part 50, Appendix A, GDC 2, GDC 3, and GDC 4. In its response to RAI 245-8292, Question 09.05.02-2 (ML15365A330), the applicant stated, "The APR1400 communication systems do not perform safety function(s), so they are classified as non-Class 1E and non-safety related (NSR) … none of the communication system SSCs are classified as a risk-significant SSC." Therefore, the communication systems are not necessarily required to comply with 10 CFR Part 50, Appendix A, GDC1, GDC 2, GDC 3, GDC 4, and GDC 19." The applicant also proposed to remove a portion of APR1400 DCD, Tier 2, Revision 0, Subsection 9.5.2.1 which stated, "However, communication systems are selected and designed in accordance with the guidance provided in 10 CFR Part 50 Appendix A, GDC 1, GDC 2, GDC 3, GDC 4, and GDC 19 to provide reasonable assurance that the facility can operate without undue risk to the health and safety of the public." The staff found the above response unsatisfactory since conformance to GDCs 1, 2, 3, and 4 is an acceptance criterion that need needs to be met even if the plant communication systems are non-safety related. The staff found that the applicant also did not provide sufficient information demonstrating the basis for not classifying the communication systems as risk-significant SSC. The availability of the communication systems is an implicit assumption in the APR1400 probabilistic risk assessment (PRA). The staff finds several risk important human actions that require operator action outside of the control room. This would implicitly assume the availability of the communication systems.

Therefore, the staff determined that RAI 245-8292, Question 09.05.02-02, was closed and unresolved. The staff issued RAI 491-8613, Question 09.05.02-04 (ML16147A396), requesting the applicant to justify why none of the communication system SSCs are classified as a risk-significant SSC and hence not needed to comply with the requirements of 10 CFR Part 50,

Appendix A, GDCs 2, 3, and 4. In its response to RAI 245-8292, Question 09.05.02-04 (ML16222A952), the applicant stated, "It will be reviewed in the next RAP expert panel meeting. The RAP (Reliability Assurance Program) expert panel meeting will be conducted after CAFTA PRA model develop [sic]. The next RAP expert panel meeting schedule is not decided yet, but it will be conducted within this year. If communication system is identified as a risk-significant SSC by RAP panel [sic], it will be added in DCD Tier 2, Table 17.1-1 (Risk-significant Within-Scope RAP SSCs)."

However, the applicant did not conduct a RAP expert panel for over a year and there was no indication from the applicant how they planned on resolving the RAI question. Therefore, the staff determined that RAI 491-8613, Question 09.05.02-04, was closed and unresolved. The staff issued RAI 548-8822, Question 09.05.02-06 (ML17142A458), requesting the applicant to clarify whether the RAP expert panel meeting had been conducted and based on the panel, had the communication systems been identified as risk-significant SSCs. In its response to RAI 548-8822, Question 09.05.02-06 (ML17242A321), the applicant stated that they would not be using the results of the RAP panel to make a decision on the risk-significance of the communication systems. Instead, in order to provide reliable and effective communications during normal and abnormal plant operations, the applicant would design the communication systems of the APR1400 to meet GDCs 1, 2, 3 and 4. The applicant also provided an attachment with its response which explains how the communication systems will meet GDCs 1, 2, 3, and 4. The applicant's commitments in the attachment for compliance with GDCs 1, 2, 3, and 4; and the respective staff evaluations of the commitments are described below.

Applicant committed that structures, systems, and components of the communication systems are designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Also, recognized codes and standards would be identified and evaluated to determine their applicability, adequacy, and sufficiency and supplemented or modified as necessary to assure a quality product in keeping with the required safety function. Since the COMS is designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed, the staff finds that the requirements of GDC 1 and 10 CFR 50.55(a)(1) have been met. Applicant committed that the portions of the COMS whose structural failure could reduce the functioning of seismic Category I SSCs to an unacceptable safety level or could result in incapacitating injury to occupants of the control room, would be designed to meet seismic Category II requirements in accordance with Subsection 3.2.1. Since portions of the COMS whose structural failure could adversely affect the function of Seismic Category I SSC are designed to Seismic Category II requirements, the staff finds that the requirements of GDC 2 have been met.

Applicant committed that the COMS is designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. The communication systems support safe shutdown and emergency response as well as coordinate on-site and off-site response in the event of fire. Also, the wireless communication system would be designed in accordance with RG 1.189, Regulatory Position 4.1.7, to provide plant-wide communication between designated personnel during fire conditions. DCD Tier 2, Revision 0, Section 9.5.2.2.1.8 also states in part that, "Communications equipment used for fire protection activities are protected from exposure to fire damage in accordance with RG 1.189." Since the COMS is designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions and due to the design commitments in accordance

with the requirements of RG 1.189 (Regulatory Position 4.1.7), the staff finds that the requirements of GDC 3 have been met. Applicant stated in its response that the COMS is not required to be protected against dynamic effects, including the effects of missile, pipe whipping, and discharging fluids. Since the COMS is not safety-related and does not affect any safety-related or risk-significant SSC, the staff finds that the COMS need not be credited for evaluating compliance with GDC 4. Based on the above evaluation, Staff finds that the response to RAI 548-8822, Question 09.05.02-06, is satisfactory. Applicant committed that DCD Tier 2, Subsection 9.5.2.3, will be revised to incorporate the information provided in the attachment. Hence, RAI 548-8822, Question 09.05.02-06, is being tracked as a **Confirmatory Item**.

Based on the commitments made by the applicant in its response to RAI 548-8822, Question 09.05.02-6; the design bases information in DCD Tier 2, Revision 0, Section 9.5.2.1; and the applicable codes and standards provided in DCD, Tier 2, Revision 0, Section 9.5.2.1.g; the staff finds that the requirements for compliance with the applicable GDC are met pending the resolution of all confirmatory items.

Compliance with Other Sections of 10 CFR

Compliance with 10 CFR 73.45(e)(2)(iii), “Performance capabilities for fixed site physical protection systems-communications subsystems,” is reviewed in Section 13.6, “Security,” of this report.

Compliance with 10 CFR 73.45(g)(4)(i), “Provide Communications Networks,” is reviewed in Section 13.6 of this report.

Compliance with 10 CFR 73.46(f), “Fixed Site Physical Protection Systems, Subsystems, Components, and Procedures – Communications Subsystems,” is reviewed in Section 13.6 of this report.

Compliance with 10 CFR 73.55(e), “Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage - Detection Aids,” is reviewed in Section 13.6 of this report.

Compliance with 10 CFR 73.55(f), “Communications Subsystems,” is reviewed in Section 13.6 of this report.

EMI/RFI Testing

10 CFR 52.47(a)(9) requires, in part, that for applications for light-water cooled nuclear power plants, an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application. The evaluation required by this section should include an identification and description of all differences in design features, analytical techniques, and procedural measures proposed for the design and those corresponding features, techniques, and measures given in the SRP acceptance criteria.

NUREG-0800, “Standard Review Plan,” Section 9.5.2, Revision 3, states in part to verify that communications equipment will be compatible with the electromagnetic interference (EMI) and radiofrequency interference (RFI) environment of the plant and that design measures have been taken such that there will be no interference between wireless communications systems and other plant equipment. RG 1.180, “Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems,” identifies

electromagnetic environment operating envelopes, design, installation, and test practices acceptable to the staff for addressing the effects of EMI, RFI, and power surges on I&C systems and components important to safety. While non-safety systems are not part of this regulatory guide, control of EMI/RFI from these systems is necessary to ensure that safety-related I&C systems can continue to perform properly in the nuclear power plant environment. When feasible, the emissions from non-safety-related systems should be held to the same levels as those from safety-related systems.

DCD Tier 2, Revision 0, Section 9.5.2.1, states that, "Each communication system is designed in accordance with applicable codes and standards regarding environmental conditions, such as weather, moisture, noise level, EMI, and radio frequency interference (RFI)." Similarly, Section 9.5.2.2.1.8 describes a standalone method for plant wide communication between designated personnel. The section states in part that radio coverage is provided throughout the plant, although radio usage in certain I&C areas is restricted due to potential EMI and RFI considerations. The design calls for posted warning signs in such areas and that the wireless communication system be designed, installed, and tested such that I&C system circuits are not negatively impacted by EMI and RFI from transmitting sources.

There was a need to understand how communication systems are tested in accordance with the procedure recommended by the equipment supplier to verify their operability under the predicted worst-case EMI/RFI environment. The staff issued RAI 245-8292, Question 09.05.02-3 (ML15288A063), requesting the applicant to clarify how communication systems are tested in accordance with the procedure recommended by the equipment supplier to verify their operability under the predicted worst-case EMI/RFI environment and also provide EMI/RFI barrier information for these systems. In its response to RAI 245-8292, Question 09.05.02-03 (ML 15365A330), the applicant stated that the wireless communication system is designed and tested to ensure that safety-related I&C systems are not negatively affected by EMI/RFI from the wireless communication system. EMI/RFI emissions of the wireless communication system are tested in accordance with RG 1.180. The applicant also committed to revising Section 9.5.2.2.1.8 to incorporate the design requirements of RG 1.180 for the wireless communication system. The following text would be added to this section: "EMI and RFI emissions of the wireless communication system are tested in accordance with RG 1.180." Since the wireless communication system would be tested in accordance with the provisions of RG 1.180, the staff found the above response satisfactory and RAI 245-8292, Question 09.05.02-03, was being tracked as a confirmatory item. The staff verified the proposed markups have been incorporated into Revision 1 of DCD Tier 2, Section 9.5.2.2.1.8. Therefore, the staff considers RAI 245-8292, Question 09.05.02-03, resolved and closed.

RG 1.180, states that the staff found EPRI TR-102323, "Guidelines for Electromagnetic Interference Testing in Power Plants," acceptable to address EMI/RFI for safety-related digital I&C systems in nuclear power plants. DCD Tier 2, Revision 0, Section 9.5.2.4, "Inspection and Testing Requirements," states, "The communication systems are inspected and tested prior to initial startup. Preoperational testing is described in Section 14.2. To verify the functionality of the systems by standby power and battery sources, the loss of ac power tests are performed. It will test communications among MCR, TSC, principal stats and emergency operation center, and radiological field assessment in conformal requirement of 10 CFR 50.47 (b)(6)." However, as stated earlier in section 9.5.2.4.2 of this report, there was no such information provided in section 14.2. Even though the applicant has committed to conform to RG 1.180, the staff needed to understand how the applicant will design and test the wireless communication system in accordance with RG 1.180. In its response to RAI 548-8822,

Question 09.05.02-07 (ML17236A341), the applicant provided an attachment which provided the descriptions of preoperational tests for all the communication subsystems which are described in Tier 1, Subsection 2.6.9. The applicant also stated in the response that I&C systems are designed, tested, qualified, and installed to conform with the requirements and guidance specified in RG 1.180, as described in DCD Tier 2, Subsections 7.1.2.5.3, 7.2.2.8, 7.3.2.8, and 7.9.2.11.

Based on the applicant's commitment that EMI/RFI emissions of the wireless communication system are tested in accordance with RG 1.180, the descriptions of the preoperational tests to be performed for the communication systems, and the commitments made in the responses to RAI 245-8292, Question 09.05.02-03 and RAI 548-8822, Question 09.05.02-07, the staff finds that requirements of EMI/RFI testing and 10 CFR 52.47(a)(9) are met.

Maximum Noise Condition Testing Criteria

10 CFR 52.47(a)(9) requires, in part, for applications for light-water cooled nuclear power plants, an evaluation of the standard plant design against the SRP revision in effect six months before the docket date of the application. The evaluation required by this section shall include an identification and description of all differences in design features, analytical techniques, and procedural measures proposed for the design and those corresponding features, techniques, and measures given in the SRP acceptance criteria. NUREG-0800, Section 9.5.2, requires verification that functional testing is planned under conditions that simulate the maximum plant noise levels generated during the various operating conditions, including fire and accident conditions, to demonstrate system capabilities.

DCD Tier 2, Revision 0, Section 9.5.2.1, states in part that the communication systems and components are selected and designed to operate in extremely noisy locations; up to 115 dB sound pressure level. DCD Tier 2, Revision 0, Section 9.5.2, also further states that each communication system is designed in accordance with applicable codes and standards regarding noise levels. In areas of high noise levels, acoustic booths and visual alerting are used. The section on paging phone system states in part that noise-canceling headphones with directional microphones or acoustic booths are provided in areas of the plant that are subject to high ambient noise conditions. DCD Tier 2, Revision 0, Section 9.5.2.2.1.2, “Evacuation Alarm Address System,” states in part that in areas with high noise levels, beacon lighting is provided to complement the siren or tone of the address system. An automatic loudspeaker volume control is used for dedicated areas with a highly fluctuating noise levels.

COL 14.2(11) stated, “[T]he COL applicant is to develop the test procedure of the communication system.” However, in the applicant's response to RAI 197-8176, Question 14.03.12-07, COL 14.2(11) was to be deleted. The staff issued RAI 548-8822, Question 09.05.02-07 (ML17142A458), requesting the applicant to resolve the inconsistency regarding COL 14.2(11) in the response provided by the applicant in RAI 491-8613, Question 09.05.02-05 versus the response for RAI 197-8176, Question 14.03.12-07. One response states that the COL information item will be deleted while the other response states that the COL information item will be revised. In its response to RAI 548-8822, Question 09.05.02-07 (ML17236A341), the applicant stated that in the response to RAI 97-8176, Question 14.03.12-07, COL 14.2(11) was deleted. In response to RAI 491-8613, Question 09.05.02-05, COL 14.2(17) was created.

In response to RAI 548-8822, Question 09.05.02-07, COL 14.2(17) was revised to state, "The COL applicant is to prepare the site-specific preoperational and startup test specification and test procedure and/or guideline for offsite communication system." This was provided in the attachment to the response and the applicant committed to revise DCD Tier 2, Subsection 14.2.13 and Table 14.2-7, and DCD Tier 1, Table 1.8-2, to incorporate the attachment. The staff finds the above response satisfactory and based on the above response, RAI 548-8822, Question 09.05.02-07, is being tracked as a **Confirmatory Item**.

Also, there was no information in DCD Revision 0, regarding the start-up or periodic testing of the communication systems in order to verify the adequacy of the communication systems capabilities in high noise operating conditions, including fire and accident conditions as required by GDC 4. As explained earlier in this report, the applicant's response to RAI 548-8822, Question 09.05.02-07 (ML17236A341), provided an attachment with descriptions of start-up and periodic testing for all the communication subsystems which are described in DCD Tier 1, Subsection 2.6.9. These tests are in accordance with RG 1.68. Based on the attachments provided by the applicant in its response to RAI 548-8822, Question 09.05.02-07, the staff finds that the communication systems and components are selected and designed to operate in extremely noisy conditions. Based on the above response, RAI 548-8822, Question 09.05.02-07, is being tracked as a **Confirmatory Item**.

Also, the ITAACs provided in DCD Tier 1, Revision 0, Table 2.6.9-1 were not clear as to what procedures would be followed to ensure that each communication system is capable of performing its intended function. More detail was required within the Communication Systems ITAACs in Table 2.6.9-1 for the staff to ensure compliance with the requirements of 10 CFR 52.47(b)(1). The staff issued RAI 548-8822, Question 09.05.02-07 (ML17142A458), requesting the applicant to provide more detailed ITAAC items addressing all of the communication subsystems and consequently revise DCD Tier 1, Table 2.6.9.1. In its response to RAI 548-8822, Question 09.05.02-07 (ML17236A341), the applicant provided an attachment which explains all the communication systems ITAAC and committed to revise DCD Tier 1, Section 2.6.9 and Table 2.6.9-1 to incorporate the information provided in the attachment. Since the applicant has provided the respective design commitments; inspections, tests and analyses; and acceptance criteria for each COM subsystem, the staff finds the above response is satisfactory. Based on the above response, RAI 548-8822, Question 09.05.02-07, is being tracked as a **Confirmatory Item**.

Based on the commitments provided by the applicant in the response to RAI 548-8822, Question 09.05.02-7, the staff finds that requirements of 10 CFR 52.47(b)(1) are met pending the resolution of all confirmatory items.

9.5.2.5 Combined License Information Items

Below is a list of applicable communication systems related COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.5(5)	A COL applicant is to provide a description of the offsite	9.5.2.2.1.7, 9.5.10

	communication system that interfaces with the onsite communication system, including type of connectivity, radio frequency, normal and backup power supplies, and plant security system interface.	
9.5(6)	The COL applicant is to provide the LAN and VPN system.	9.5.2.2.1, 9.5.10
9.5(7)	The COL applicant is to provide the fire brigade radio systems.	9.5.2.2.2.2, 9.5.10
9.5(8)	The COL applicant is to provide the local law enforcement communications including dedicated conventional telephone and radio transmitted two-way communication system.	9.5.2.2.2.3, 9.5.10
9.5(9)	The COL applicant is to provide the emergency offsite communication system including dedicated hotline, local law enforcement radio equipment, and wireless communication system.	9.5.2.2.3.2, 9.5.10
9.5(10)	The COL applicant is to provide the security radio system that consists of a base unit, mobile units, and portable units.	9.5.10
14.2(17)	The COL applicant is to prepare the site-specific preoperational and startup test specification and test procedure and/or guideline for offsite communication system.	14.2(13), Table 14.2-7

In its response to RAI 245-8292, Question 09.05.02-01 (ML16124B202), the applicant committed to removing the previous COL 13.1(1) and COL 9.5(6) which were provided in Subsections 9.5.2.1.b and 9.5.2.1.c. This was tracked as a confirmatory item. The staff verified the proposed markups have been incorporated into Revision 1 of DCD Tier 2, Table 1.8-2. Therefore, the staff considers RAI 245-8292, Question 09.05.02-01, resolved and closed.

9.5.2.6 Conclusion

The communication system includes all components for intraplant and plant-to-offsite communications. The scope of review of the communications system for the plant includes verification that offsite equipment is capable of providing for notification of personnel and

implementation of evacuation procedures, and verification that onsite communications are adequate in the event of an emergency. The basis for acceptance of the communication system in the review is conformance of the design, design criteria, and design bases to staff positions and industry standards and the ability of the system to provide effective communications between plant personnel in all vital areas during the full spectrum of accident or incident conditions under maximum potential noise levels. The staff concludes that the design of the communications system meets the staff's criteria and industry standards and is therefore acceptable pending the resolution of all confirmatory items as explained in Section 9.5.2.4 of this report.

9.5.3 Lighting Systems

9.5.3.1 Introduction

The sections below describe the staff's review of the plant lighting systems. The plant lighting systems must provide adequate lighting during all plant operating conditions such as normal, transients, fires, accidents, and loss of all AC power (i.e., SBO). The lighting systems include normal, emergency, and security lighting systems. This section of the report provides the staff's evaluation for the normal and emergency lighting systems for the APR1400 design. Section 13.6 of this report addresses security lighting.

9.5.3.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Section 2.6.8, "Lighting Systems." The plant lighting system is non-Class 1E and consists of the normal and emergency lighting systems. The normal lighting system provides illumination throughout the plant, and is powered from the non-Class 1E AC buses. The emergency lighting system is divided into emergency AC and DC systems. The emergency AC lighting system is powered from the Class 1E AC buses backed-up by the Class 1E EDGs. The emergency DC lighting system uses lighting fixtures powered from non-Class 1E station battery and self-contained battery pack unit. The emergency DC lighting fixtures equipped with self-contained rechargeable battery pack are powered from Class 1E or non-Class 1E AC in accordance with area designation. Their emergency illumination level is at least 0.1 foot-candle at the floor level for 8 hours. The emergency illumination levels in the MCR and RSR are a minimum of 10 foot-candle for 8 hours.

DCD Tier 2: The applicant provided a description of the lighting systems in DCD Tier 2, Section 9.5.3, "Lighting Systems," as summarized below.

The lighting systems are composed of normal, emergency, and security lighting systems (security lighting is addressed in detail in Section 13.6). The lighting systems are designed to maintain adequate illumination during normal and off-normal conditions including electrical equipment faults, LOOP, and SBO. The lighting systems are not required to mitigate the consequences of a design basis event, and as such, are non-Class 1E systems. The lighting systems provide adequate illumination levels, which are indicated illumination levels in NUREG-0700, "Human-System Interface Design Review Guidelines," and the Illuminating Engineering Society of North America (IESNA) lighting handbook, in various plant areas during normal and off-normal conditions. Exit sign lighting fixtures are provided at the egress routes. Portable lighting units are provided at designated areas for access and egress to areas where

emergency lighting is not installed. Supporting structures of lighting in safety-related areas are designed not to be damaged during or after a SSE.

Normal lighting system

The normal lighting system provides general illumination throughout the plant during normal plant operation. The system is energized from non-Class 1E 480 volts AC (VAC) buses and permanent non-safety (PNS) buses as long as power is available from the standby auxiliary transformers or unit auxiliary transformers. The normal lighting includes incandescent, fluorescent, high-pressure sodium, halogen, light-emitting diode (LED), and ceramic metal halide fixtures. The normal lighting is not available during LOOP, SSE, and SBO conditions. The normal lighting circuits are normally energized and require no periodic testing.

Emergency lighting system

The emergency lighting system is provided in areas required for safe shutdown of the plant, restoration of the plant to normal operation, firefighting, and safe movement of people to the access and egress routes during plant off-normal conditions and loss of the normal lighting system. The emergency lighting system is composed of emergency AC and emergency DC lighting systems. The emergency DC lighting provides illumination when the emergency AC lighting is lost. The emergency lighting is inspected and tested periodically.

The emergency AC lighting system is always turned on and combines with the normal lighting to provide adequate illumination levels that support operation and maintenance activities during normal plant operation. The emergency AC lighting system is provided in the MCR, radwaste control room, TSC, OSC, RSR, EDG room, Class 1E battery room, Class 1E switchgear room, and their access aisles for the safety-related equipment in these areas. The system is energized from Class 1E 480 VAC buses backed up by the Class 1E EDG and the non-Class 1E alternate AC (AAC) source. The non-Class 1E lighting circuits are electrically isolated from the Class 1E circuits by the use of isolation devices and separation distance as prescribed in the Institute of Electrical and Electronics Engineers Standard (IEEE Std.) 384-1992, "IEEE Std. Criteria for Independence of Class 1E Equipment and Circuits." The emergency AC lighting provides more than 10 foot-candles of illumination at the above designated areas.

The emergency DC lighting system is composed of the lighting powered from 8-hour rated non-Class 1E 125 volts DC (VDC) station batteries and the lighting powered by 8-hour rated self-contained battery pack units in accordance with RG 1.189. The emergency DC lighting fixtures, fed from the non-Class 1E 125 VDC station batteries, are provided in areas where emergency AC lights are provided. These fixtures are powered upon loss of emergency AC lighting power and provide more than 10 foot-candles of illumination. The emergency lighting fixtures equipped with self-contained battery pack units are provided in areas needed for operation of safe-shutdown equipment and for access and egress routes thereto, and are fed from receptacles for normal or emergency AC lighting. These fixtures automatically turn on upon loss of normal or emergency AC lighting power and provide more than 0.1 foot-candle of illumination at the areas where emergency AC lightings are provided. For firefighting, the self-contained battery lightings provide emergency lighting for safe movement of the personnel to the access and egress routes.

Security lighting system

The security lighting system is powered from offsite source by the 480 VAC buses and backed up by the AAC source upon LOOP. A minimum illumination level of 0.2 foot-candles is provided and measured horizontally at ground level in the isolation zones and appropriate exterior areas within the protected area. Per COL 9.5(14), the COL applicant is required to provide offsite power for the security lighting system.

ITAAC: The ITAAC associated with lighting systems are provided in DCD Tier 1, Section 2.6.8.2, Table 2.6.8-1, "Lighting Systems ITAAC."

Technical Specifications: There are no TSs for this area of review.

9.5.3.3 Regulatory Basis

No NRC general design criteria or other requirements directly apply to the performance of the lighting systems. However, the relevant NRC guidance applicable to the review of lighting systems are summarized below:

NUREG-0800, Section 9.5.3, "Lighting Systems" provides acceptance criteria for the lighting systems. The lighting systems are acceptable if they (1) provide adequate lighting in all areas of the plant during normal plant operations, (2) provide adequate emergency lighting during all plant operating conditions, including fire, transient, and accident conditions, (3) address the effect of the loss of all AC power (i.e., during an SBO) on the emergency lighting system, and (4) have adequate illumination levels conform to the illumination levels recommended in NUREG-0700.

NUREG-0700, Revision 2, "Human-system Interface Design Review Guidelines," as it relates to acceptable lighting levels. NUREG-0700 is based on the IESNA Lighting Handbook.

RG 1.75, Revision 3, "Criteria for Independence of Electrical Safety Systems," as it relates to the physical separation and electrical isolation that must be provided between safety-related and non-safety-related circuits to maintain the independence of safety related circuits and equipment so that the safety functions required during and following any design basis event can be accomplished. RG 1.75 endorses IEEE Std. 384-1992 with supplemental criteria.

9.5.3.4 Technical Evaluation

The staff reviewed the information in the APR1400 DCD Tier 2, Section 9.5.3, Table 9.5.3-1, "Plant Lighting Failure Modes and Effects Analyses," and Tier 1, Section 2.6.8, "Lighting Systems," pertaining to the normal and emergency lighting systems to determine whether, during all plant operation conditions, 1) the lighting in all plant areas and access routes to and from these areas is adequate in accordance with the acceptance criteria in NUREG-0800, Section 9.5.3, and 2) the lighting systems can operate without adversely impacting the operation, control, and maintenance of safety-related systems.

As reference, the lighting requirements for fire protection are evaluated in Section 9.5.1 of this report. The security lighting system is evaluated in Section 13.6 of this report. The adequacy of control lighting systems and features related to their effectiveness to support reliable human performance is evaluated in Chapter 18.0, "Human Factors Engineering," of this report.

9.5.3.4.1 Normal Lighting System

NUREG-0800, Section 9.5.3 recommends that the normal lighting system be capable of providing adequate station lighting in all plant areas and access routes during normal plant operations. In Section 9.5.3.1, "Design Bases," of the DCD Tier 2, the applicant stated that, during normal and off-normal conditions, the lighting systems provide adequate illumination levels for tasks and in work areas of the plant as specified in NUREG-0700 and IESNA lighting handbook. In RAI 164-8179 (ML15295A489), Question 09.05.03-02, the staff requested the applicant to provide the illumination levels for normal lighting for specified tasks and work areas as indicated in Table 12.1, "Nominal illumination levels for various tasks and work areas," and Table 12.10, "Range of recommended illuminances for inspection/assembly activities," of NUREG-0700, Section 12; and for all other areas/rooms of the plant that are required for control and maintenance of equipment and plant access routes during normal plant operations. In its response dated November 4, 2015 (ML15308A508), the applicant provided the normal illumination levels in units of lux for various plant areas. The staff noted that the illumination levels in some areas were lower than the levels recommended by NUREG-0700. Thus, in follow-up RAI 375-8466 (ML16028A035), Question 09.05.03-10, the staff requested the applicant to provide justification for the lower illumination levels. In its response dated March 10, 2016, to RAI 375-8466 Question 09.05.03-10 (ML16070A048), the applicant stated that the illumination levels as previously provided in units of lux are the typical values for representative areas in the plant. To avoid confusion, the applicant provided new illumination levels in units of foot candles. The staff found the applicant's response inadequate as the lower limits of the ranges of illumination levels in foot candles are lower than the levels recommended by NUREG-0700. Hence, in follow-up RAI 471-8581 (ML16117A251), Question 09.05.03-15, the staff requested the applicant to provide justifications for having illumination levels lower than the levels recommended by NUREG-0700 and to demonstrate that tasks can be accomplished with the lower illuminations. In its response dated June 23, 2016, to RAI 471-8581, Question 09.05.03-15 (ML16175A683), the applicant provided revised illumination levels for the MCR, RSR, and other in-plant areas of the plant. For the MCR, the applicant provided the following illumination levels:

- Reading:
    - Handwritten (pencil): 100 foot-candles
    - Printed or typed: 50 foot-candles
    - Video display unit: 10 foot-candles
- Writing and data recording: 100 foot-candles
- Maintenance and wiring areas: 50 foot-candles

The staff finds that the illumination levels for the reading, writing, data recording, and maintenance wiring areas in the MCR conform to Table 12.1 of NUREG-0700, and are, therefore, acceptable.

The applicant stated that the above illumination levels for reading, writing, data recording, and maintenance wiring areas in the MCR may be adjusted with the dimming control system in the

MCR to provide the optimal illumination for the task being performed. The controlled illumination level ranges in the MCR are as follows:

- Operator Console: 30-100 foot-candles
- Large Display Panel Area: 5-10 foot-candles
- Safety Console and Auxiliary Control Panel: 25-75 foot-candles

According to NUREG-0700, the illumination levels in the control room depend on the reflectance of the task background, the age of the operator, and the criticality of the task being performed. Based on this guidance of NUREG-0700, the staff finds that the illumination level ranges for the operator console and large display panel area are acceptable because the illumination levels can be adjusted to the maximum illumination of reading (100 foot-candles) and video display unit (10 foot candles) in the MCR based on the task being performed. The staff also finds the illumination level range for the safety console and auxiliary control panel acceptable because the maximum illumination (75 foot-candles) is higher than the recommended illumination level for auxiliary panel (50 foot-candles) in Table 12.1 of NUREG-0700 and adequate illumination is provided for the tasks.

In its response dated June 23, 2016, to RAI 471-8581, Question 09.05.03-15 (ML16175A683), the applicant provided an illumination level of 70 foot-candles for the RSR. The applicant stated in the response that 1) the RSR contains the remote shutdown console, table, instrument equipment, and printer and no seated operator stations, and 2) tasks such as reading (handwritten (pencil)), writing and data recording are not performed in the RSR. The staff notes that since the RSR includes a shutdown console and printer, work areas such as “panels, primary operating area,” “auxiliary panels” and tasks such as “reading (printed or typed),” as identified in NUREG-0700, Table 12.1, are to be considered. The staff finds that the illumination level (70 foot candles) for the RSR is higher than the recommended illumination level (50 foot-candles) for these above-mentioned work areas in Table 12.1 of NUREG-0700, and is, therefore, acceptable since adequate illumination is provided.

In its response dated June 23, 2016, to RAI 471-8581, Question 09.05.03-15 (ML16175A683), the applicant also provided the illumination levels for in-plant areas such as turbine generator building (50 foot-candles), laboratory (100 foot-candles), storage room (20 foot-candles), engineered safety features (ESF) equipment room (50 foot-candles), EDG building(50 foot- candles), fuel handling areas (FHAs) (50 foot-candles), reactor containment building (RCB) (50 foot-candles), and stairways and corridors (10 foot-candles). The staff finds that the illumination levels for the above-mentioned in-plant areas are consistent with the recommended levels in Table 12.1 of NUREG-0700, and therefore, are acceptable since adequate illumination is provided.

In Section 9.5.3.3, “Safety Evaluation,” of the DCD Tier 2, the applicant stated that the normal lighting, which is energized from non-Class 1E 480 Vac buses and PNS buses, is not available during LOOP, SSE, and SBO events. However, in its response dated March 10, 2016, to RAI 375-8466, Question 09.05.03-12 (ML16070A048), regarding the emergency lighting system as discussed in Section 9.5.3.4.2, the applicant stated that, during an SBO event, the normal lighting in the AAC GTG building provides adequate lighting after the AAC source restores power to the non-Class 1E 480 Vac bus located in the building. Since the normal lighting will turn back on after restoration of power from the AAC source in the event of an SBO, the staff

requested the applicant in follow-up RAI 499-8600 (ML16187A419), Question 09.05.03-17, to revise Section 9.5.3.3 of DCD Tier 2 to indicate that the normal lighting will be available after the AAC or backup power source provides power during an SBO event. In its response dated August 12, 2016, to RAI 499-8600, Question 09.05.03-17 (ML16225A411), the applicant revised DCD Tier 2, Section 9.5.3.3, to indicate the above-mentioned availability of the normal lighting in the AAC GTG building during an SBO. The staff finds the response acceptable since normal lighting will be available to provide adequate illumination for safe-shutdown operations in the AAC building during an SBO event. The staff confirmed that DCD Revision 1, contains the changes as committed to in the RAI response, and considers RAI 499-8600, Question 09.05.03-17, resolved and closed.

9.5.3.4.2 Emergency Lighting System

NUREG-0800, Section 9.5.3 recommends that the emergency lighting system be provided in all areas required for firefighting, control, and maintenance of equipment used for implementing safe shutdown of the plant during all plant operating conditions, and the access routes to and from these areas. The areas where the emergency AC lighting system is provided are listed in Section 9.5.3.2, Summary of Application, of this report. The staff noted that the applicant may not have identified all areas where emergency lighting systems should be provided. Thus, in RAI 204-8237 (ML15251A755), Question 09.05.03-05, the staff requested the applicant to identify other areas where emergency lighting systems are provided. In its response dated November 12, 2015 (ML15316A469), the applicant stated that the emergency AC and DC lighting systems are also provided in safety cooling equipment cubicles, fuel handling areas, RCB, ESW intake structure and pump house, and other ESF equipment areas. The applicant revised Section 9.5.3.2, “Design Description,” of the DCD Tier 2 to include these additional locations. The staff noted that the above areas do not include the AAC GTG building where equipment needed for implementing and maintaining safe shutdown of the plant during an SBO is located. Thus, in follow-up RAI 375-8466, Question 09.05.03-12, the staff requested the applicant to identify other areas required for implementing safe shutdown during an SBO event, where emergency lighting is provided. In the March 10, 2016 response (ML16070A048), the applicant stated that the AAC GTG building contains the emergency DC lighting from self-contained battery lighting fixtures. Based on the identification of the above locations where emergency lighting is provided, the staff finds that the applicant has provided emergency lighting systems in areas required for firefighting, control, and maintenance of equipment used for implementing safe shutdown of the plant during all plant operating conditions, and the access routes to and from these areas. Therefore, the staff considers RAI 375-8466, Question 09.05.03-12, resolved. The staff confirmed that DCD Revision 1 contains the changes as committed to in the RAI response, and considers RAI 204-8237, Question 09.05.03-5, resolved and closed.

NUREG-0800, Section 9.5.3 recommends that the effect of an SBO event on the emergency lighting system be addressed. In DCD Tier 2, Section 9.5.3.2, the applicant stated that the EDGs and the non-Class 1E AAC power source provide backup power for the emergency AC lighting system during a LOOP. However, DCD Tier 1, Section 2.6.8, only mentioned the EDGs as the backup power source for the emergency AC lighting system. Thus, in RAI 164-8179, Question 09.05.03-3, the staff requested the applicant to provide the backup power sources for the emergency AC lighting system during LOOP and SBO events. In response dated November 4, 2015 (ML15308A508), the applicant clarified that the EDGs and the AAC power sources energize the emergency AC lighting system via the Class 1E 480 VAC buses during a LOOP and an SBO, respectively. The staff verified in Section 8.3, “Onsite Power System,” and

8.4, "Station Blackout," of the DCD Tier 2 that the Class 1E 480 VAC buses are powered by the EDGs and the AAC power sources via the Class 1E 4.16 Kilovolts (KV) buses during a LOOP and an SBO, respectively. Therefore, the staff finds the applicant's response acceptable. The applicant revised DCD Tier 1, Section 2.6.8.1, and DCD Tier 2, Section 9.5.3.2, to include the above clarification. The staff confirmed that DCD Revision 1 contains the changes as committed to in the RAI response, and considers RAI 164-8179, Question 09.05.03-3, resolved and closed.

In Section 9.5.3.3, "Safety Evaluation," of the DCD Tier 2, the applicant stated that during LOOP, SSE, and SBO, the emergency AC lighting is interrupted until the power supply to the Class 1E AC buses is restored. During this period, the emergency DC lighting powered from the station battery or the individual self-contained battery pack provides adequate illumination for safe shutdown operations and for movement of personnel to the access and egress route. Since the self-contained battery pack lighting provides a minimum illumination of 0.1 foot-candle, the staff in RAI 164-8179, Question 09.05.03-4, requested the applicant to clarify whether both types of emergency DC lighting are used to provide adequate illumination during LOOP, SSE, and SBO; and to confirm that all safe-shutdown operations can be performed with the self-contained battery lighting only. In the November 4, 2015 (ML15308A508), response, the applicant stated that the emergency DC lighting powered from both the station battery and the individual self-contained battery pack provides illumination during LOOP, SSE, and SBO. The applicant further clarified that in areas where self-contained battery pack lighting fixtures only cannot provide sufficient illumination for safe-shutdown operations, emergency DC lighting fixtures fed from the station batteries are provided to ensure required illumination levels in those areas. The staff finds the applicant's response acceptable since both types of emergency DC lighting will be provided to ensure adequate illumination in areas required for safe shutdown operations during an SBO event. However, since the applicant's clarification was not incorporated in the DCD, the staff in follow-up RAI 375-8466, Question 09.05.03-11, requested the applicant to revise DCD Tier 2, Section 9.5.3, to incorporate the above clarification. In its response dated March 10, 2016 (ML16070A048), the applicant revised DCD Tier 2, Section 9.5.3.2, to include the above clarification. The staff confirmed that DCD Revision 1 contains the changes as committed to in the RAI response, and considers RAI 375-8466, Question 09.05.03-11, resolved and closed.

Based on the above, the staff finds that the applicant has adequately addressed the effect of an SBO on the emergency lighting system as the emergency DC and AC lighting will be available to provide adequate illumination during an SBO event. The staff also finds that the emergency lighting system conforms to NUREG-0800, Section 9.5.3.

RG 1.75, Regulatory Position C(1) recommends supplemental capability and testing criteria for an acceptable breaker or fuse that is automatically opened by fault current, in addition to the electrical isolation criteria provided in IEEE Std. 384-1992 for Class 1E isolation devices. In DCD Tier 2, Section 9.5.3.3, the applicant stated that isolation devices, as indicated in IEEE Std. 384-1992, are used to electrically isolate lighting circuits from Class 1E circuits, but did not provide the supplemental capability and testing criteria recommended by RG 1.75. In RAI 164-8179, Question 09.05.03-1, the staff requested the applicant to provide additional information about the isolation devices that will be used to electrically isolate the Class 1E circuits from the non-Class 1E lighting circuits; and to discuss conformance of the APR1400 design to RG 1.75 in regards to lighting systems. The staff also requested the applicant to add RG 1.75 and IEEE Std. 384-1992, Section 9.5.11, "References," in DCD Tier 2. In the November 4, 2015 (ML15308A508), response, the applicant stated that the isolation devices

between the Class 1E motor control centers (MCCs) and non-Class 1E lighting circuits are Class 1E molded case circuit breakers (MCCBs) with associated relay(s) and protective device(s). In addition, the applicant stated that the MCCBs' capabilities will be demonstrated with periodic testing performed in accordance with RG 1.75, Regulatory Position C(1). The applicant further stated that non-Class 1E cables feeding the emergency AC lighting circuits are routed on non-Class 1E raceways (e.g., trays, conduits) and are separated from the cables of Class 1E divisions by a minimum distance as indicated in IEEE Std. 384-1992. In addition, the applicant revised DCD Tier 2, Section 8.3.1.1.2.3, "System Independence," to include a statement that the isolation devices conform to Regulatory Position C(1) of RG 1.75 and Section 9.5.11 to add references of IEEE Std. 384-1992 and RG 1.75, respectively. Based on its review, the staff finds that the applicant has provided adequate electrical isolation between the non-Class 1E lighting circuits and the Class 1E circuits as the type and capabilities of the isolation devices and the minimum cable separation distance are in accordance with RG 1.75. However, the staff found that the applicant did not discuss details about the conformance to Regulatory Position C(1) of RG 1.75 in Section 8.3.1.1.2.3 with respect to isolation devices. Thus, in follow-up RAI 375-8466, Question 09.05.03-9, the staff requested the applicant to discuss the conformance of the isolation devices to RG 1.75 in DCD Tier 2, Section 9.5.3. In its response dated March 10, 2016 (ML16070A048), the applicant stated that the DCD Tier 2, Section 9.5.3.3 will be revised to refer to Section 8.3.1.1.2.3 for more details about the isolation devices. In a mark-up revision of DCD Tier 2, Section 8.3.1.1.2.3, which is included in its response dated January 26, 2016 (ML16026A490), the applicant provided a description of the periodic testing for the isolation devices. The staff finds the testing criterion in the mark-up consistent with Regulatory Position C(1) of RG 1.75. Therefore, the staff finds the applicant's response acceptable since details about the isolation devices are provided in Section 8.3.1.1.2.3 of the DCD Tier 2. The staff confirmed that DCD Revision 1 contains the changes as committed to in the RAI response, and considers RAI 375-8466, Question 09.05.03-9, resolved and closed.

In the DCD the applicant provided the seismic classification of the self-contained battery lights. The staff determined that other lighting fixtures located in the vicinity of safety-related equipment may adversely impact the safety-related equipment when subject to seismic loading of an SSE. Thus, in RAI 204-8237, Question 09.05.03-7, the staff requested the applicant to provide the seismic Category classification for all other lighting fixtures (normal, emergency ac, and emergency DC lighting systems) located in the vicinity of safety-related equipment. In its response dated November 12, 2015, to RAI 204-8237, Question 09.05.03-7 (ML15316A469), the applicant clarified that the lighting system equipment, including normal, emergency ac, and emergency DC lighting fixtures, located in safety-related areas is classified as seismic Category II. The seismic Category II lighting equipment is required not to impact safety-related equipment when subject to seismic loading of an SSE. The applicant further stated that lighting system equipment in other areas is classified as seismic Category III. The applicant also revised DCD Tier 2 Section 9.5.3.3, "Safety Evaluation," to incorporate the above-mentioned seismic classifications of lighting system equipment. The staff noted that the applicant did not define the term "safety-related areas," in its response or in DCD Tier 2 Section 9.5.3. Thus, in follow-up RAI 375-8466, Question 09.05.03-13, the staff requested the applicant to clarify the term "safety-related areas." In its response dated March 10, 2016 (ML16070A048), the applicant stated that the term "safety-related area" is applicable to areas containing equipment or structures required for safe shutdown (including accident mitigation), as mentioned in note No. (1) of DCD Tier 2, Table 3.2-1. Per DCD Tier 2, Table 3.2-1 (page 39 of 86), the MCR, the fuel handling area, the RCB, the auxiliary building, the component cooling water heat exchanger building, and the ESW building are safety-related areas where category II lighting

equipment is located. In addition, per DCD Tier 2, Section 3.2.1, “Seismic Classification,” lighting equipment in the MCR is designed to preclude a gross structural failure resulting from an SSE that could result in incapacitating injuries to personnel in the MCR. The staff finds that since lighting equipment located in safety-related areas is seismic Category II, lighting fixtures located in the vicinity of safety-related equipment required for safe shutdown (including accident mitigation) will not impact the safety-related equipment when subject to a seismic loading of an SSE. Therefore, the staff finds the responses acceptable since safety-related equipment required for safe shutdown and accident mitigation will not be impacted by lighting fixtures during an SSE, and as such, the safety-related equipment will be able to perform their intended function. The staff confirmed that DCD Revision 1, contains the changes as committed to in the RAI response, and considers RAI 204-8237, Question 09.05.03-7, resolved and closed.

In DCD Tier 2, Table 3.2-1 (page 39 of 86), lighting equipment/fixtures in both the EDG building and the RSR are classified as seismic Category III. The staff noted that since the EDG building and the RSR contain safety-related equipment required for safe shutdown, they are safety-related areas, as discussed above and, as such, lighting equipment in these areas would be classified as seismic Category II. Hence, in follow-up RAI 471-8581, Question 09.05.03-16, the staff requested the applicant to explain the seismic classification of the EDG building and the RSR where lighting equipment may impact safety-related equipment in their vicinities when subject to seismic loading of an SSE. In its response dated June 10, 2016, to RAI 471-8581 (ML16162A055), Question 09.05.03-16, the applicant stated that lighting equipment in the EDG building and the RSR are seismic Category II equipment, and revised DCD Tier 2,Table 3.2-1, (page 39 of 86) to incorporate this information. The applicant also confirmed that lighting equipment in all safety-related areas is classified seismic Category II. Since lighting equipment in all safety-related areas including the EDG and RSR meets seismic Category II requirements not to impact safety-related equipment when subject to seismic loading of an SSE, the staff finds that the applicant has adequately addressed the seismic classification of lighting equipment in safety-related areas. The staff confirmed that DCD Revision 1, contains the changes as committed to in the RAI response, and considers RAI 471-8581, Question 09.05.03-16, resolved and closed.

In Section 9.5.3.4, “Inspection and Testing Requirements,” of the DCD Tier 2, the applicant stated that the emergency lighting is inspected and tested periodically. In RAI 204-8237, Question 09.05.03-8, the staff requested the applicant to identify the programs that will address inspection and testing of the emergency AC and DC lighting systems. In its response dated November 13, 2015 (ML15317A366), the applicant stated that the emergency lighting is inspected and tested in accordance with the plant operating and maintenance procedures that are identified in DCD Tier 2, Section 13.5.2, “Operating and Maintenance Procedures.” The staff noted that in DCD Tier 2, Section 13.5.2, the COL applicant is required to develop operating and maintenance procedures, but no specific COL information item is related to procedures for emergency lighting system. Hence, in follow-up RAI 375-8466, Question 09.05.03-14, the staff requested the applicant to provide the COL information item(s) that address the procedures for the emergency lighting system in DCD Tier 2, Section 9.5.3. In its response dated March 10, 2016 (ML16070A048), the applicant revised DCD Tier 2, Section 9.5.3.4, to include COL 13.5(6) for the operating and maintenance procedures related to the emergency lighting system. The staff finds the change acceptable. Based on this information, the staff finds that the applicant has adequately addressed maintenance of the emergency lighting system since the emergency lighting system will be inspected and tested periodically in accordance with the program to be developed by the COL applicant. Therefore, the staff finds the applicant responses acceptable. The staff confirmed that DCD Revision 1,

contains the changes as committed to in the RAI responses, and considers RAI 204-8237, Question 09.05.03-8, and RAI 375-8466, Question 09.05.03-14, resolved and closed.

9.5.3.4.3 Security Lighting System

The security lighting system is evaluated in Section 13.6 of this report. This section only discusses a discrepancy, which the staff noted in DCD Tier 2, Sections 9.5.3, 9.5.10, “Combined License Information,” and 1.8.1, “Combined License Information” [sic] regarding the normal power supply for the security lighting system.

In DCD Tier 2, Section 9.5.3.2, the security lighting is powered by offsite power and backed up by the AAC power source upon LOOP, while in Section 9.5.10 and Table 1.8-2, the COL applicant is required to provide “electric power” for the security lighting system. In RAI 204-8237, Question 09.05.03-6, the staff requested the applicant to modify the statement “electric power” to “offsite power” for consistency. In its response dated November 12, 2015, the applicant stated that the term “electric power” will be revised to “offsite power” in DCD Tier 2, Section 9.5.10 and Table 1.8-2 for the security lighting system. The staff finds that the applicant has adequately addressed the issue as the normal power supply for the security lighting system is offsite power in the DCD. The staff confirmed that DCD Revision 1 contains the change as committed to in the RAI response, and considers RAI 204-8237, Question 09.05.03-6 resolved and closed.

9.5.3.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.5(11)	The COL applicant is to provide security lighting for the protected area barrier and isolation zones and normal offsite power for all the exterior security lighting systems.	9.5.3.2, 9.5.10

The staff finds the COL information items to be acceptable. The staff finds that no additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for this system.

9.5.3.6 Conclusion

The staff reviewed the APR1400 normal and emergency lighting systems against the guidelines of the NUREG-0800, Section 9.5.3, and NUREG-0700, Section 12. Based on the above technical evaluation, the staff concludes that the normal and emergency lighting systems provide adequate illumination in all areas of the plant and access routes to these areas during

all plant operating conditions such as normal, transient, fire, accident, and SBO conditions, as recommended by NUREG-0800 and NUREG-0700. Therefore, the staff concludes that the normal and emergency lighting systems are acceptable because they provide adequate illumination in accordance with the guidance in NUREG-0800, Section 9.5.3, and NUREG-0700, Section 12.

9.5.4 Emergency Diesel Engine Fuel Oil System

9.5.4.1 Introduction

The emergency diesel engine fuel oil system (EDEFOS) provides a separate and independent fuel oil supply train to each EDG, and has sufficient storage capacity to support a minimum of 7 days of operation of each of the four Class 1E EDGs at continuous power rating without replenishment of fuel. Each EDEFOS is comprised of a storage tank, a day tank, transfer pumps, and related piping and controls.

9.5.4.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.2, “Emergency Diesel Generator System,” describes the principal performance characteristics and safety functions of the EDG s and their supporting systems, and includes Table 2.6.2-1, “Emergency Diesel Generator System Piping List,” Table 2.6.2-2, “Emergency Diesel Generator Systems Component List,” and Table 2.6.2-3, “Emergency Diesel Generator System ITAAC.”

DCD Tier 1, Section 2.6.2, Items 8a and 8b state that each diesel fuel oil transfer pump have sufficient net positive suction head and is capable of transferring oil from the diesel fuel oil storage tank to its corresponding day tank at sufficient pressure and flow to cover the maximum demand at EDG continuous rated load while simultaneously increasing day tank level.

Section 2.6.2, Items 9 and 10, state that each EDG has fuel storage capacity to provide fuel to its EDG for a period of seven days with the EDG supplying the power requirements for the most limiting design basis event. Each day tank provides fuel oil for at least 60 minutes plus a minimum additional margin of 10 percent at EDG rated load. Other items in this section state the design requirements for the ASME Section III and seismic Category I portions of all of the EDG support systems.

DCD Tier 2: The DCD Tier 2, Section 9.5.4, “Emergency Diesel Engine Fuel Oil System,” and Figure 9.5.4-1, “Emergency Diesel Engine Fuel Oil System Flow Diagram,” provide the EDEFOS system description, which is summarized, in part, as follows:

The EDEFOS provides for the required storage capacity and continuous supply of fuel oil to each of the four Class 1E EDGs. Each EDG has its own dedicated and independent EDEFOS as described in DCD Tier 2, Section 9.5.4. Diesel fuel for each EDG is supplied by fuel oil transfer pumps from a fuel oil storage tank to a fuel oil day tank. The EDEFOS is designed to provide storage capacity of at least a seven day supply of fuel oil, plus margin for periodic testing, for the operation of the EDG at its continuous rating.

ITAAC: DCD Tier 1, Table 2.6.2-3, provides ITAAC requirements for the EDGs. Item 1 of this table requires verification of the functional arrangement of the overall EDG. Table 2.6.2-3 provides specific requirements for the diesel fuel oil transfer pumps (Item 8.a, 8.b and 11), fuel

oil storage tank (Item 9), and fuel oil day tank (Item 10). In addition, there are other ITAAC that apply generally to the overall EDG design.

Technical Specifications: DCD Tier 2, Chapter 16, TS 3.8.1, "AC Sources – Operating," provides EDG TS requirements. Surveillance Requirements (SR) 3.8.1.4 through 3.8.1.6, 3.8.3.1, 3.8.3.3 and 3.8.3.5 provide day tank and storage tank requirements. Limiting Conditions for Operation (LCO) for the EDEFOS are given in Chapter 16, LCO 3.8.3, "Diesel Fuel Oil, Lube Oil, and Starting Air." In addition, TS 5.5.13, "Diesel Fuel Oil Testing Program," provides requirements for a program to ensure the quality of the diesel fuel oil.

9.5.4.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are specified in NUREG-0800, Section 9.5.4, "Emergency Diesel Engine Fuel Oil Storage and Transfer System," and are summarized below. Other areas of review (other SRP sections) that include interfaces with this SRP section are identified in NUREG-0800, Section 9.5.4.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods, without loss of capability to perform their safety functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to the capability of shared systems and components important to safety between units to perform required safety functions.

4. GDC 17, "Electric power systems," as it relates to the capability of the EDEFOS to meet independence and redundancy criteria.

5. 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the verification that the EDEFOS design meets quality group classification per RG 1.26 and seismic Category per RG 1.29 for safety and non-safety related portions of the system.

2. For GCD 4, acceptance is based on the verification that the EDEFOS design has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

3. For GDC 5, acceptance is based on the verification that sharing of EDEFOS systems and components in multiple-unit plants does not impair the ability to perform their safety functions.

4. For GDC 17, acceptance is based on the verification that the EDEFOS are independent and a single failure of any one EDEFOS will only affect its associated EDG.

5. For 10 CFR 52.47(b)(1), acceptance criteria is based on the verification that the EDEFOS meets corrosion control criteria per RG 1.137, Revision 2, "Fuel-Oil System for Emergency Power Supplies," and inspections, tests, analyses, and acceptance criteria in SRP Section 14.3 and 14.3.7.

9.5.4.4 Technical Evaluation

The staff reviewed the APR1400 EDEFOS in accordance with NUREG-0800, Section 9.5.4, Revision 3. The staff also reviewed supplemental information that the applicant provided in letters dated November 13, 2015 (ML15317A521), March 4, 2016 (ML16064A044), June 21, 2016 (ML16173A470), and July 19, 2016 (ML16201A211). The APR1400 includes four safety related (Class 1E) EDGs and their respective support systems such as fuel oil, lube oil, engine cooling water, starting air, and combustion air intake and exhaust systems. The staff's acceptance of the EDEFOS is based on the system design being in compliance with the requirements of the GDCs specified above.

9.5.4.4.1 GDC 2, Design bases for protection against natural phenomena

As indicated in DCD Section 9.5.4.1, "Design Bases," the EDEFOS is designed and fabricated to codes consistent with the quality group classification assigned by RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," and the seismic Category assigned by RG 1.29. SRP 9.5.4 recommends essential portions, including the isolation valves separating essential and nonessential portions, are classified Quality Group C and seismic Category I. DCD Table 3.2-1, defines the EDEFOS components as Quality Group C. DCD Tier 2, Figure 9.5.4-1 has designated the safety related components and piping for the EDEFOS as Quality Group C, seismic Category I, except for a portion of the piping leading to vents, fill connections, and drains, which is Quality Group D and seismic Category II or III. The applicant has stated in DCD Tier 2, Section 9.5.4.4, "Safety Evaluation," that there are sufficient features and administrative controls to be taken on these lines to protect against possible damage from vehicles, tornadoes, hurricanes, tsunamis, missiles, floods, extreme cold temperatures, and accidental contaminations.

There are four EDG units for the APR1400 and each EDG provides Class 1E power to one of the four independent Class 1E buses during a LOOP. Two EDGs are located in the auxiliary building and two EDGs in the EDGB. The two EDG units in the auxiliary building are separated so they are on opposite sides of the building in a mirror-like configuration. The seismic Category I EDGB houses the other two EDG units and supporting equipment in two separate compartments. Each EDG compartment is designed to be physically separated to provide protection from fire, aircraft, missiles, and the environment. The EDGB and auxiliary building are both classified as seismic Category I, allowing them withstand the effects of natural

phenomena including earthquakes, tornadoes, hurricanes, floods, and external missiles, as described in DCD Tier 2, Sections 3.3, 3.4, and 3.8.

The EDEFOS has four diesel fuel storage structures, separate from EDG, containing storage tank and pumps, two in the auxiliary building and the other two in the EDGB. Each diesel fuel storage structure is a reinforced, missile-protected underground vault separated into an oil storage bay and an equipment area. As shown in Figure 1.2-20. “General Arrangement Auxiliary Building El. 63’-0”, Sections A-A and B-B,” the oil storage bay is separated from the equipment area by a partial-height wall such that oil spill upon tank rupture is contained within the oil storage bay. The oil storage bay contains a diesel fuel oil storage tank and necessary piping. The seismic Category I portions of EDEFOS fuel oil piping, located between the diesel fuel storage structure and the EDGs in auxiliary building and EDGB, are routed in concrete pipe chases to contain any possible contamination arising from fuel oil leakage.

Each EDEFOS contains two 100 percent motor-driven fuel oil transfer pumps for each EDG and each pump is capable of transferring oil from the diesel fuel oil storage tank to its corresponding day tank. The fuel oil transfer pumps take suction from the fuel oil storage tanks through duplex fuel oil strainers. Each fuel transfer pump is capable of transferring oil from the diesel fuel oil storage tank to its corresponding day tank at sufficient pressure and flow to cover the maximum demand. The fuel transfer pumps are located in the fuel oil storage tank structure in such a way that sufficient NPSH is available under all design conditions, including a pump runout.

The diesel fuel oil storage tank has the capacity to store a minimum of seven days of fuel oil and delivers it to the EDG as required to operate the EDG at its continuous rating, and each day tank provides fuel oil for at least 60 minutes plus a minimum additional margin of 10 percent for each EDG when loaded to the continuous rating.

As indicated in DCD Tier 2, Section 9.5.4.2.2.5, “Diesel Fuel Oil Day Tanks,” the day tank elevation provides assurance that there is adequate NPSH on the engine-driven fuel oil pump (not shown in Figure 9.5.4-1 as part of design) at all times. Whenever the oil level of a fuel oil day tank is low, one diesel fuel oil transfer pump supplies diesel fuel oil from the diesel fuel oil storage tank to the diesel fuel oil day tank until the day tank level is sufficient. In the event that one diesel fuel oil transfer pump fails to start or trips in a train, the other pump in the train is automatically started.

The overflow and drain connections on the day tanks are piped back to the diesel fuel oil storage tanks. The fuel oil storage tanks and day tanks have one fill line and one vent line that terminate outside and are exposed to the outside air. The fill and sample lines of fuel oil storage tanks are locked-closed with isolation valves, and their connections are capped and locked to prevent entry of moisture. The fuel oil storage tanks are vented (with flame arrester) to atmosphere, and the end of the vent lines is placed at an elevation higher than the maximum flood level.

Therefore, the safety-related equipment of the EDEFOS is protected from floods, natural phenomenon missiles, and interaction with non-seismic systems in the vicinity. The non-safety fill connections contain seismic I isolation valves to avoid potential damage to safety-related SSCs in the event of a design basis earthquake and withstand SSE seismic loads without incurring a structural failure that permits interaction with the safety-related portions of the EDEFOS. Based on the above assessment, the staff finds the EDEFOS design conforms to the quality group classification and seismic Category guidance of RG 1.26 and RG 1.29,

respectively. Therefore the applicant has demonstrated the EDEFOS is designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed as required under 10 CFR 50.55a(a)(1).

9.5.4.4.2 GDC 4, Environmental and dynamic effects design bases

Each EDG train is located in a dedicated room or compartment in the EDGB or auxiliary building. There are four separate and independent trains of the EDGs so that the consequences of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks upon an EDEFOS do not lead to a loss of more than one EDG. Each EDG has a separate and independent EDEFOS. Therefore, based on the redundancy of EDG's and separation of EDG locations minimizing impact on multiple EDG's, the staff through engineering judgment finds that the EDEFOS meets the requirements of GDC 4. Therefore the applicant has demonstrated the EDEFOS has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

9.5.4.4.3 GDC 5, Sharing of structures, systems, and components

DCD Tier 2, Section 9.5.4 describes the EDG has its own independent EDEFOS. For the EDEFOS design, diesel fuel for each EDG is supplied by fuel oil transfer pumps from a fuel oil storage tank and fuel day tank. Each APR1400 unit has four independent EDGs, each with a separate and independent EDEFOS that is not shared with other EDG. Furthermore, since the APR1400 design is a single nuclear unit, there is no sharing among nuclear power units. Therefore, the staff finds that the EDEFOS meets the requirements of GDC 5.

9.5.4.4.4 GDC 17, Electric power systems

As stated above, each EDG has a separate and independent EDEFOS. Therefore, a single failure in any one EDEFOS will affect only its associated EDG. This arrangement meets the guidelines specified in SRP Section 9.5.4. The EDEFOS design features, including redundancy and independence, and the provisions for testing the system capability support the requirement for an onsite electric power system to assure post-accident safe shutdown and, therefore, meet the requirements of GDC 17.

Other Design Considerations

SRP Section 9.5.4 acceptance criteria recommends the use of ANSI/ANS-59.51-1997, "Fuel Oil Systems for Safety-Related Emergency Diesel Generators," specifying that each EDG shall have onsite fuel oil storage sufficient to operate the diesel generator following any design-basis accident and LOOP for either seven days, or the time required to replenish the oil from sources outside the plant site following any limiting design-basis accident without interrupting the operation of the diesel, whichever is longer.

The EDEFOS is designed to provide storage capacity of at least a seven day supply of fuel oil for the operation of the EDG at its continuous rating, plus a margin to allow for periodic testing for each diesel engine, in accordance with ANSI/ANS 59.51. The seven-day fuel inventory requirement is controlled by TS 3.8.3. In addition, EDEFOS is capable of being filled with fuel oil from an external source within seven days following an event, without interruption of diesel engine operations. Each day tank also provides fuel oil for at least 60 minutes plus a minimum additional margin of 10 percent at EDG rated load.

Prior to adding or refilling fuel oil to fuel oil storage tanks, the fuel oil storage structures are heated up and maintained at a suitable temperature above the cloud point of fuel oil. The heat up is done using electric unit heaters, and the overall maintenance process is described in the fuel oil program. The staff finds this meets the guidance of RG 1.137.

The applicant has stated in DCD Tier 2, Section 9.5.4.1, the active components of the EDEFOS are tested during plant operations. Provisions are made to allow in-service inspection of components to be carried on at an interval specified in the ASME B&PV)Code, Section XI, “Rules for In-Service Inspection of Nuclear Power Plant Components.” This meets the acceptance criteria of SRP Section 9.5.4.

RG 1.137, Revision 2, and SRP Section 9.5.4, Revision 3, provide guidelines for corrosion control and the initial and continuing quality of fuel oil for the EDEFOS. DCD Tables 1.9-1, “APR1400 Conformance with Regulatory Guides,” and 1.9-2, “APR1400 Conformance with the Standard Review Plan,” indicate that the design conforms to this guidance with no exceptions. The applicant addressed these topics in DCD Subsection 9.5.4 and in the TS and Bases (Subsections 5.5.13, 3.8.3, and B 3.8.3). According to DCD Subsection 9.5.4, the exterior surfaces of the fuel oil storage tanks, day tanks, and piping will be painted with a primer and finish coat system for corrosion protection. The guidance for external coatings in RG 1.137, Revision 2, is that their use should follow the requirements of National Association of Corrosion Engineers (NACE) International NACE Standard Practice (SP) 0169-2007, “Control of External Corrosion on Underground or Submerged Metallic Piping Systems.” SP0169-2007 lists acceptable types of external coatings and the standards to which those coatings should conform. In addition, SP0169-2007 provides recommendations for assessing the need for coatings and cathodic protection, as well as technical practices for implementing cathodic protection.

The applicant did not propose cathodic protection for the exterior of tanks or piping. The staff finds this acceptable because the tanks and piping are designed to be inside underground structures (surrounded by air) and not directly buried. Cathodic protection is not applicable under these conditions. The staff’s guidance for external protection of piping and tanks that are underground (not buried) is to apply coatings, as described most recently in license renewal ISG (LR-ISG-2015-01, “Changes to Buried and Underground Piping and Tank Recommendations”). Although the absence of cathodic protection is consistent with staff guidance for the proposed design, it was not clear to the staff that the safety-related coatings in the EDEFOS will follow all of the relevant guidance in RG 1.137, Revision 2. Operating experience has shown that external corrosion can occur even in underground vaults, as described in LR-ISG-2015-01. Therefore, in RAI 355-8438 (ML15362A446), Question 09.05.04-8, the staff requested that the applicant state in the DCD that the system will follow the guidance in RG 1.137, Revision 2, for corrosion protection for the external surfaces of underground piping, tanks, and other components.

The applicant responded to Question 09.05.04-8 in the June 21, 2016 letter (ML16173A470). The response proposed a new COL information item, COL 9.5(16), which would require a COL applicant to identify the applicable codes and standards for the external coating on the underground piping in accordance with the guidance in RG 1.137, Revision 2. The proposal includes revisions to DCD Subsections 9.5.4.2.2.6 and 9.5.10. The staff finds this acceptable because RG 1.137, Revision 2 contains guidance acceptable to the staff for corrosion protection of underground piping in fuel oil systems for emergency power supplies. These changes to Subsections 9.5.4.2.2.6 and 9.5.10 were incorporated into Revision 1 of the DCD as proposed.

For the external tank coatings, the applicant stated in the June 21, 2016 letter (ML16173A470), that the external surfaces of the tanks are designated Service Level II according to the guidance in RG 1.54, Revision 2. The response proposed a corresponding change to DCD Subsection 9.5.4.4.e and the addition of RG 1.54, Revision 2 to the list of references in Subsection 9.5.11. RG 1.54 does not have specific guidance for Service Level II coatings, which are not safety-related. However, ASTM D5144, "Standard Guide for Use of Protective Coating Standards in Nuclear Power Plant," which RG 1.54 identifies as a top-level standard that provides detailed guidance through reference to other standards. Standard D5144 provides factors to consider for Service Level II coatings. The staff finds this acceptable because the performance of the external tank coatings is not directly related to a safety function. The tanks will be in a space with a safety-related ventilation system, so the air is designed to be non-corrosive. However, if significant corrosion does occur it can be detected by the internal inspections required by the ASME Code. Failure of the coatings can be detected by visual inspection, and coating debris potentially resulting from external coating failure would not interfere with the function of safety-related equipment. The changes described above to Subsections 9.5.4.4.e and 9.5.11 were incorporated into Revision 1 of the DCD as proposed. Based on these changes, and the changes to DCD Subsections 9.5.4.2.2.6 and 9.5.10, described in the preceding paragraph, the staff considers RAI 355-8438, Question 09.05.04-8, resolved and closed.

DCD, Revision 1, Subsection 9.5.4.5, "Inspection and Testing Requirements," states that inspection of the EDEFOS piping will be performed according to the ASME B&PV Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components." This is acceptable because the piping is designed according to ASME B&PV Code, Section III, "Rules for Construction of Nuclear Facility Components." As stated in RG 1.137, Revision 2, Position C7, ASME B&PV Code, Section XI applies to fuel oil system components designed according to ASME B&PV Code, Section III. The initial submittal of the DCD did not identify the inspection requirements for the storage tanks and day tanks. Therefore, in RAI 355-8438, Question 09.05.04-9, the staff requested that the applicant confirm that the storage tanks and day tanks will be inspected according to ASME B&PV Code, Section XI, in conformance with RG 1.137, Revision 2. The applicant responded in a letter dated March 4, 2016 (ML16064A044). The response confirmed that the safety-related components and piping of the EDEFOS are designed in accordance with Section III, Subsection ND (for Class 3 components) of the ASME B&PV Code, and that inspection of these items will be performed according to ASME B&PV Code, Section XI. The response proposed revisions to the inspection and testing requirements of DCD Subsections 9.5.4.5; 9.5.5.4, 9.5.6.4, and 9.5.7.4. The revisions clarify that the ASME B&PV Code, Section XI inservice inspection applies to components and piping designated ASME B&PV Code Class 3. The staff finds this acceptable because it conforms to the guidance in RG 1.137, Revision 2 for adequate inspection of safety-related diesel fuel oil systems. These revisions to Subsections 9.5.4.5, 9.5.5.4, 9.5.6.4, and 9.5.7.4 were incorporated into Revision 1 of the DCD as proposed. Therefore, the staff considers RAI 355-8438, Question 09.05.04-9, resolved and closed.

DCD Subsection 9.5.4, as supplemented by Enclosure 5 to the applicant's November 13, 2015, letter (ML15317A521), which responded to the staff's email of August 19, 2015, also states that inspection on the interior surfaces of the tanks will be performed at least once every 10 years when the tanks are emptied and cleaned. The staff finds this acceptable because it conforms to the guidance in RG 1.137, Revision 2. This revision of DCD Subsection 9.5.4 was incorporated into Revision 1 of the DCD as proposed.

The applicant addresses fuel oil quality and cleanliness in TS 5.5.13, TS 3.8.3, TS Bases Section 3.8.3, and DCD Subsection 9.5.4. For properties of the fuel oil (Grade 2D), the TS and DCD Subsection 9.5.4 reference American Society for Testing and Materials (ASTM) International ASTM D975-13, “Standard Specification for Diesel Fuel Oils.” The staff finds it acceptable to reference D975-13 because that is the version endorsed in RG 1.137, Revision 2. The initial submittal of the DCD references D975-10, which does not conform to RG 1.137, Revision 2. Changing the reference in DCD Subsection 9.5.4 from D975-10 to D975-13 is based on enclosure 5 to the applicant’s November 13, 2015, letter (ML15317A521). This change to the references in Subsection 9.5.4was incorporated into Revision 1 of the DCD as proposed. As stated in DCD Subsection 9.5.4, the fuel oil in the storage tank and day tanks is periodically sampled to verify quality according to the “Diesel Fuel Oil Testing Program” in Section 5.5.13 of the TS. Adding the name of the sampling program and identifying it as a TS with the corresponding section number is based on enclosure 5 to the applicant’s November 13, 2015 (ML15317A521), letter. The staff finds this acceptable because it clarifies the basis for the sampling requirements. This additional description of the sampling program in Subsection 9.5.4 was incorporated into Revision 1 of the DCD as proposed.

With respect to fuel testing prior to addition of new fuel oil into the storage tanks, the applicant states in DCD Subsection 9.5.4.5 that samples will be tested for specific gravity, flash point, viscosity, and water and sediment content in accordance with ASTM D975 limits and ASTM D1298-12 (for specific gravity). The initial submittal of the DCD referenced ASTM D975 for specific gravity, which is not adequate because D975 does not address specific gravity. Identifying ASTM D1298 for measurement of specific gravity is based on enclosure 5 to the applicant’s November 13, 2015 (ML15317A521), letter. Identification of ASTM D1298 in Subsection 9.5.4 was incorporated into Revision 1 of the DCD as proposed. The staff finds this acceptable because it is consistent with RG 1.137, Revision 2, the STS Bases, and the APR1400 proposed TSs Bases. The requirement to measure flash point of new fuel samples prior to adding the new fuel to the storage tanks is based on the applicant’s response in the March 4, 2016, letter to RAI 355-8438, Question 09.05.04-10 (ML16064A044),. The response proposed replacing “cloud point,” as originally proposed, with “flash point” in DCD Subsection 9.5.4.5. The staff finds this change acceptable because it makes the sampling requirement consistent with TS 5.5.13.a.2 and RG 1.137, Revision 2, which require testing of flash point, and not cloud point, prior to adding the new fuel to the storage tanks. The change from “cloud point” to “flash point” in DCD Subsection 9.5.4.5 was incorporated into Revision 1 of the DCD as proposed. Therefore, the staff considers RAI 355-8438, Question 09.05.04-10, resolved and closed.

The proposed TS 5.5.13, “Diesel Fuel Oil Testing Program,” Item b, requires verification that the remaining properties of the new fuel oil are within the limits for ASTM 2D fuel oil within 31 days after adding the new fuel oil to the storage tanks. The staff finds this acceptable because it is consistent with the STS and Position C.13.3 of RG 1.137, Revision 2. The requirement for the periodic testing of the fuel oil for particulate content to follow ASTM D6217-11, “Standard Test Method for Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration,” is based on the applicant’s March 4, 2016, response to RAI 355-8438, Question 09.05.04-11 (ML16064A044). ASTM D6217-11 is the method listed in RG 1.137, Revision 2, C.13.1 and C.13.8. However, the application originally proposed the use of ASTM D5452-12, “Standard Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration,” in the APR1400 TS Bases for SR 3.8.3.3. The staff finds changing the ASTM test method from D5452-12 to D6217-11, acceptable because it makes the TS Bases consistent with the current staff guidance as documented in RG 1.137, Revision 2. These changes to the TS

Bases and reference list for SR 3.8.3.3 were incorporated into Revision 1 of the DCD as proposed. Therefore, the staff considers RAI 355-8438, Question 09.05.04-11, resolved and closed.

In order to minimize degradation of the fuel oil, DCD Subsection 9.5.4.5, as proposed in enclosure 5 of the applicant's November 13, 2015 (ML15317A521), letter, states that accumulated moisture and sediment will be removed via the sump drain in accordance with SR 3.8.3.5 in the TS. The initial submittal stated that the moisture and sediment would be removed periodically, which is inconsistent with the TS requirement. The staff finds replacing "periodically" with a reference to the TS acceptable because it makes DCD Subsection 9.5.4.5 consistent with the TS. Addition of the TS reference to Subsection 9.5.4 was incorporated into Revision 1 of the DCD as proposed. However, the proposed DCD revisions in the applicant's November 13, 2015 (ML15317A521), letter also contained potential inconsistencies between the DCD Subsection 9.5.4 and the TS. The applicant clarified these issues and proposed changes to the TS and DCD Subsection 9.5.4.5 in response to RAI 355-8438, Question 09.05.04-12. The response was provided in the applicant's July 19, 2016, letter and included the following clarifications and proposed DCD changes:

- Revision of TS Section 5.5.13, "Diesel Fuel Oil Test Program," to clarify that testing of stored fuel applies to both storage tanks and day tanks.
- Revision of TS SR 3.8.1.5 and 3.8.3.5 to require that accumulated water and sediment (rather than only water) are checked for and removed from storage tanks, day tanks, and engine mounted tanks.
- The response explains that water and sediment are removed at the same time because sediment can obstruct the oil flow from the tank and it is difficult to remove only the water.
- Revision of DCD Subsection 9.5.4.5 to change the timing of water and sediment removal. Rather than "periodically," the DCD would say the water and sediment are removed according to Surveillance Requirement 3.8.3.1 and 3.8.3.5.

The staff finds the proposed changes acceptable because they clarify the APR1400 requirements to check for and remove accumulated water and sediment from the EDEFOS, and because the proposed changes would meet the requirements in the STS and the guidance in RG 1.137. These changes were incorporated into Revision 1 of the FSAR as proposed. Therefore, the staff considers RAI 355-8438, Question 09.05.04-12, resolved and closed.

The staff also notes that the APR1400 design is in accordance with the recommendations of NUREG/CR-0660 regarding tank-bottom drains. DCD Tier 2, Section 9.5.4.2.2.1 indicates that fittings are provided for tank level instrumentation, venting, sampling, and water removal. Flanged openings are provided as manholes for access to the tank interior and the tank bottom is constructed so that a low-point sump exists for collection and drainage of any water or sediment that may be present.

The SRP Section 9.5.4, Paragraph 9.5.4 I.1.G, specifies that the design include the capability to detect and control system leakage, including isolating system portions in the event of excessive leakage or component malfunction. DCD Section 9.5.4.1 specifies,

> The EDEFOS is designed to be capable of detecting and controlling system leakage by putting appropriate monitors and confining fuel oil leaks and spills in and around the system, components and structures.

The EDEFOS is located inside the auxiliary building or EDGB, with the exception of the outside fill and vent connections. The outside fill locations only contain fuel during the filling operation. Supply and branch lines have isolation valves that can be operated to minimize the impact of leaks. Each diesel fuel oil storage tank is located inside a concrete structure to contain oil spills, and it is equipped with a level transmitter and vent line with a flame arrester. Buried fuel oil system piping is inspected by means of a visual examination at each end of the buried piping for evidence of leakage. The staff, however, was unable to determine the design, qualification, and location for these monitors from the submitted documents and issued RAI 152-8006 (ML15227A002), Question No. 09.05.04-4, requesting additional descriptions of the EDEFOS leakage detection and control system. In its response dated September 14, 2015 (ML15257A428), the applicant stated that each diesel fuel oil storage tank room has a dedicated sump with level switch. Upon reaching a setpoint level, an alarm will be activated in the MCR to alert the operator; therefore, the EDEFOS can be monitored continuously. However, since the applicant did not fully address the RAI question with respect to the control of fuel oil leakage, the staff issued follow-up RAI 448-8557 (ML16081A016), Question 09.05.04-13, requesting the applicant to confirm the sump has adequate capacity to confine the full content of the fuel oil storage tank or to describe the measures to control the leakage and/or transfer excess fuel oil from the sump. In its response dated April 22, 2016 (ML16113A410), the applicant stated that although the sump is not sized to confine the full contents of the diesel fuel oil storage tank, walls are placed around each tank to a height that will confine the full contents. Also, a manual valve is provided in the piping between the diesel fuel oil storage tank, and the sumps are provided with two automatic sump pumps to cycle the oil back into the tank; therefore, the full contents of the diesel fuel oil storage tank can be pumped through the sump without spilling outside of the diesel fuel storage tank vault. The staff finds the RAI response adequate, as appropriate measures are provided to isolate and contain fuel oil leakage. The staff subsequently confirmed Revision 1 of the DCD have been revised to adequately describe the design features utilized to contain oil spills.

The day tank is automatically filled from the storage tank on a day tank low level signal. According to DCD Section 9.5.4.6, the storage tanks and day tanks have high level and low level alarms, and the fuel oil strainers and filters have high differential pressure alarms. Each of these is a local alarm at the EDG control panel, and there is a common trouble alarm in the MCR that includes all of these alarms. This design is in accordance with ANSI/ANS-59.51 and SRP Section 9.5.4.

Each EDEFOS is designed to minimize the potential for exposure to ignition sources, such as open flames and hot surfaces. The day tank and storage tank are located in separate rooms away from the diesel engine. Flame arresters are installed in the vent lines at the fuel oil storage and day tanks to prevent potentially explosive mixtures from igniting. This meets the guidelines of SRP Section 9.5.4.

SRP Section 9.5.4 I.1.I states that an applicant should identify the available and acceptable sources of fuel oil, including the means of transporting oil and recharging the fuel oil storage tank, following a design basis accident to enable each redundant diesel generator system to supply uninterrupted emergency power for as long as required. This is addressed in DCD by inclusion of COL 9.5(10) in Section 9.5.10 as follows:

> The COL applicant is to specify that adequate and acceptable sources of fuel oil are available, including the means of transporting and recharging the fuel storage tank, following a design basis accident.

SRP Section 9.5.4, Paragraph 9.5.4.III.6.A specifies that each fuel oil storage tank has a stick gauge connection for determining its fuel level. The fuel oil system is equipped with adequate level indication and alarms to monitor the level and operation of the fuel oil system. In addition, a level indicator, located near the fill connection on diesel fuel oil storage tank, allows the operator to monitor tank level during the filling operations to prevent overfilling of the tank.

DCD Tier 1, Section 2.6.2, Items 8.a and 8.b, state that each diesel fuel oil transfer pump have sufficient net positive suction head and is capable of transferring oil from the diesel fuel oil storage tank to its corresponding day tank at sufficient pressure and flow to cover the maximum demand at EDG continuous rated load while simultaneously increasing day tank level. Section 2.6.2, Items 9 and 10, state that each EDG has fuel storage capacity to provide fuel to its EDG for a period of seven days with the EDG supplying the power requirements for the most limiting design basis event and each day tank provides fuel oil for at least 60 minutes plus a minimum additional margin of 10 percent at EDG rated load. Other items in this section state the design requirements for the ASME Section III and seismic Category I portions of all of the EDG support systems.

Based on the above, the staff finds other design considerations as discussed in SRP 9.5.4, including ANSI/ANS 59.51 and RG 1.137 related to the EDEFOS are properly addressed in the design.

9.5.4.4.5 Initial Plant Test Program

DCD Tier 2, Chapter 14.2, Section 14.2.12.1.86 (EDG) and 14.2.12.1.88 (EDG support systems) focuses on the initial testing program for the EDGs. The staff evaluated this section to determine whether or not it contains adequate detail to inform the initial test program. Section 14.2.12.1.88, in particular, includes operability tests to demonstrate that the EDG fuel oil system provides a reliable and adequate supply to each EDG. System components and piping are tested to pressures designated by ASME Section III Class 3. Inspection and functional testing are performed prior to initial operation as described in Section 14.2; thereafter, the system is periodically tested along with the complete EDG system in accordance with the TS as described in Chapter 16.

The DCD Tier 2, Section 9.5.4.5, “Inspection and Testing Requirements,” states

> (T)he operability of EDEFOS may be demonstrated during tests of the emergency diesel generator, or testing may be performed by operation of the system in recirculation mode (bypassing day tank) and sending fuel through the recirculation line back to the fuel oil storage tank.

In addition, Section 14.2.12.1.88 contains an operability test to demonstrate the operation of the fuel oil recirculation system. The staff is unable to locate any description of this recirculation mode in Section 9.5.4 or Figure 9.5.4-1. Therefore, the staff issued RAI 152-8006, Question 09.05.04-3, requesting the applicant to describe the recirculation system and operating mode and update the DCD accordingly. In its response, the applicant proposed a revision to DCD Tier 2, subsection 9.5.4.5 to state the use of the day tank overflow line during

recirculation mode. The staff finds the response adequate and subsequently confirmed the above changes have been incorporated into Revision 1 of the DCD.

9.5.4.4.6 ITAAC

The staff reviewed the ITAAC in the DCD to verify that it meets SRP Section 14.2 acceptance criteria. The staff found that in Tier 1, Table 2.6.2-3, "Emergency Diesel Generator System ITAAC," the applicant would use the phrase "Report Exists" rather than provide specific design details. The use of "Report Exists" is not always sufficient for verification that the "As-built" components installed in the plant will be able to perform their safety function. The acceptance criteria of a "report exists" (i.e., design calculations, etc.) would provide confirmation that the components and system is properly sized and designed to meet its demand, however use of a report would not verify the actual installed components and system would perform its safety function. Therefore, the staff issued RAI 152-8006, Question No. 09.05.04-5, requesting the applicant to define how use of "report exists" in Table 2.6.2-3 will be sufficient to verify as-built design following the completion of its installation or construction activities at its final location at the plant site. In its response dated September 14, 2015, the applicant stated that the capacity of the fuel oil storage tank, fuel oil transfer pump, and fuel oil day tank will be based on the fuel consumption rate provided by the EDG supplier. Consequently, the fuel consumption rates and capacity information were deleted from Table 9.5.4-1 "Emergency Diesel Engine Fuel Oil System Component Data." The deletion of this information, however, does not address the original RAI question as to how design commitments can be verified against as-built configurations ITAAC. Consequently, the staff issued a follow-up RAI 459-8573 (ML16105A299), Question 09.05.04-14, requesting the applicant to identify the designed fuel consumption rates and capacity of the fuel oil storage tank, fuel oil transfer pump, and fuel oil day tank in Table 9.5.4-1 and to provide the proper acceptance criteria in Table 2.6.2-3 (ITAAC) to confirm that the as-built conditions meet the design commitments. In the response to the subject follow-up RAI, the applicant proposed a revision to Table 9.5.4-1 to restore the deleted information as bracketed to denote that they are conceptual design information. In addition, the applicant also proposed a revision to Table 2.6.2-3 to indicate that an analysis will be performed to determine fuel oil storage capacity and EDG fuel consumption, and an inspection will be performed to verify that the as-built fuel oil storage tank's capacity bounds the analysis. The staff subsequently confirmed the above have been incorporated into Revision 1 of the DCD. Based on the above, the staff finds that the applicant has provided the adequate ITAAC and properly addressed the requirements of 10 CFR 52.47(b)(1).

As shown in Item 1 in DCD Tier 1, Table 2.6.2-3, the ITAAC contains a design commitment to perform inspection of the as-built functional arrangement of the EDG system as described in the Design Description of Subsection 2.6.2.1 and in Tables 2.6.2-1 and 2.6.2-2. Acceptance criteria for Item 1 of ITAAC requests confirmation that the functional arrangements are in accordance with Subsection 2.6.2.1. However, Subsection 2.6.2.1 does not include functional arrangement information and the design details of Subsection 2.6.2.1 are already verified by use of other items in the ITAAC. In addition, Tables 2.6.2-1 and 2.6.2-2 contain information related to seismic Category and ASME classification, but do not include functional arrangement information. Therefore, it is not clear how the acceptance criteria to verify as-built functional arrangement can be achieved. In addition, Tier 1 does not contain any figures showing the functional arrangement to inspect or verify. The staff issued RAI 152-8006, Question 09.05.04-6, requesting the applicant to provide functional arrangement of the EDEFOS to allow for the review of the ITAAC design commitment. In its response, dated September 14, 2015, the applicant proposed a revision to the applicable DCD Tier 1

documentation, which provided the appropriate design description, drawing, and ITAAC related to the EDEFOS for the staff to be able to confirm that design commitments of the EDEFOS are met. The staff finds the RAI response adequate and subsequently confirmed the above have been incorporated in Revision 1 of the DCD.

9.5.4.5 Combined License Information Items

The following is a list of applicable COL information items and descriptions.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.5(12)	The COL applicant is to identify the applicable codes and standards for the external coating on the underground piping in accordance with NRC RG 1.137.	9.5.4.2.2.6, 9.5.10
9.5(13)	The COL applicant is to specify that adequate and acceptable sources of fuel oil are available, including the means of transporting and recharging the fuel storage tank, following a design basis accident.	9.5.4.5, 9.5.10

COL 9.5(16) requires a COL applicant to identify the applicable codes and standards for the external coating on the underground piping in accordance with RG 1.137, Revision 2. As discussed above in the previous subsection, the staff finds this acceptable because it conforms with RG 1.137, Revision 2 guidance for corrosion protection of underground piping and tanks in fuel oil systems for emergency power supplies, including following NACE International SP0169-2007. The applicant proposed this COL information item in response to RAI 355-8438, Question 09.05.04-8. Therefore, the proposed COL 9.5(16) is being tracked as part of **Confirmatory Item MCB-9.5.4-6.**

9.5.4.6 Conclusions

Contingent upon closure of the confirmatory item identified above, the staff finds the APR1400 EDEFOS design acceptable and in compliance with regulations, as stated in the GDC of 10 CFR Part 50, Appendix A. This conclusion is based on the staff's technical evaluation that the DCD meets the requirements of GDC 2, GDC 4, GDC 5, GDC 17, and 10 CFR 52.47(b)(1) for the EDEFOS.

9.5.5 Emergency Diesel Engine Cooling Water System

9.5.5.1 Introduction

The Emergency Diesel Engine Cooling Water System (EDECWS) is designed to provide a separate and independent system providing cooling water to the EDG. The EDECWS maintains the temperature of the diesel engine within an optimum operating range during standby and full-load operations thereby providing fast starting, load-accepting capability, and reduced thermal stresses. The system includes all valves, heat exchangers, pumps, and piping up to the EDG interface. Portions of the EDECWS are safety-related, as identified below. The following subsections provide the staff's review of this system.

9.5.5.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.2, "Emergency Diesel Generator System," describes the principal performance characteristics and safety functions of the EDG s and their supporting systems, and includes Table 2.6.2-1, Table 2.6.2-2, and Table 2.6.2-3.

DCD Tier 2: The DCD Tier 2, Section 9.5.5, "Emergency Diesel Engine Cooling Water System," and Figure 9.5.5-1, "Emergency Diesel Engine Cooling Water System Flow Diagram," provide the EDECWS system description, which is summarized, in part, as follows:

Each EDG has its own dedicated and independent cooling water system as described in DCD Tier 2, Section 9.5.5. The EDECWS provides cooling water to the engine. Portions of the EDECWS are housed within their respective diesel engine compartments, receiving heat from components essential for proper operation of the EDG and transferring heat to the component cooling water (CCW) system, as a heat sink.

ITAAC: DCD Tier 1, Table 2.6.2-3 provides ITAAC requirements for the EDGs. Item 1 of this table requires verification of the functional arrangement of the overall EDG system. Although Tables 2.6.2-1 and 2.6.2-2 contain a list of components and piping provided with the EDECWS, there is no specific ITAAC requirements for the EDECWS. Therefore, the current design does not provide for any verification of the functional arrangement of the safety-related EDECWS. The resolution of this item is discussed in Section 9.5.5.4 of this report.

Technical Specifications: DCD Tier 2, Chapter 16, TS 3.8.1 through TS 3.8.3 provide EDG requirements. There are no specific TS requirements for the cooling water system. Cooling water system requirements are implied with overall EDG operability.

9.5.5.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are specified in NUREG-0800, SRP Section 9.5.5, "Emergency Diesel Engine Cooling Water System," and are summarized below. Other areas of review (other SRP sections) that include interfaces with this SRP section are identified in NUREG-0800, Section 9.5.5.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods without loss of capability to perform their safety functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to the capability of systems and components important to safety shared between units to perform required safety functions.

4. GDC 17 "Electric power systems," as it relates to the capability of the EDECWS meet independence and redundancy criteria.

5. GDC 44, "Cooling water," as it relates to the design of a cooling system with suitable redundancy to transfer heat to an UHS under normal operating and accident conditions.

6. GDC 45, "Inspection of cooling water system," as it relates to available design provisions to permit periodic inspection of safety-related system components and equipment.

7. GDC 46, "Testing of cooling water system," as it relates to available design provisions to permit appropriate functional testing of safety-related systems or components for structural integrity, leak-tightness, operability, and performance of active components and system capability function as intended under accident conditions.

8. 10 CFR 52.47(b)(1), which requires that a design certification application contains 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the verification that the EDECWS design meets quality group classification per RG 1.26 and seismic Category per RG 1.29 for safety and non-safety related portions of the system.

2. For GCD 4, acceptance is based on the verification that the EDECWS design has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

3. For GDC 5, acceptance is based on the verification that sharing of EDECWS systems and components in multiple-unit plants does not impair the ability to perform their safety functions.

4. For GDC 17, acceptance is based on the verification that the EDECWS are independent and a single failure of any one EDECWS will only affect its associated EDG.

5. For GDC 44, acceptance is based on the verification that the EDECWS are independent and redundant such that a single active component failure in the EDECWS will not result in a loss of heat transferring capability from more than one EDG.

6. For GDC 45, acceptance is based on the verification that provisions are made to ensure periodic inspection is performed for the EDECWS.

7. For GDC 46, acceptance is based on the verification that periodic performance testing is performed for the EDECWS.

8. For 10 CFR 52.47(b)(1), acceptance criteria is based on the verification that the EDECWS meets corrosion control criteria per RG 1.137 and inspections, tests, analyses, and acceptance criteria in SRP Section 14.3 and 14.3.7.

9.5.5.4 Technical Evaluation

The staff reviewed the design description of the EDECWS in the DCD for the APR1400 in accordance with NUREG-0800, Section 9.5.5, Revision 3. The APR1400 consists of four EDGs and their respective support systems such as fuel oil, lube oil, engine cooling water, starting air, and combustion air intake and exhaust systems. The staff's acceptance of the EDECWS design is based on the system design being in compliance with the requirements of the GDCs specified above.

Each EDECWS is subdivided into the low-temperature (LT) water subsystem and the high-temperature (HT) water subsystem. The non-safety-related portion is the preheating water circuit of HT water subsystem, which consists of an electric preheater and a preheating pump that are active during engine standby and a water treatment skid to treat the coolant quality by adding corrosion inhibitor. The rest of the system is safety-related with heat exchangers to provide the necessary cooling for the diesel engine coolant and lubricating oil to maintain normal operating conditions.

9.5.5.4.1 GDC 2 Design bases for protection against natural phenomena

In accordance with the guidance in RG 1.26 and RG 1.29, the safety-related portions of the EDECWS should be classified as Quality Group C and seismic Category I. If a nonsafety-related system's failure can adversely affect a safety-related system, that system should be classified as seismic Category II. Nonsafety-related systems whose failure cannot adversely affect a safety-related system should be classified as seismic Category III. DCD Tier 2, Figure 9.5.5-1 shows the interface between the nonsafety-related pre-heat water system and the safety-related portions of the HT cooling water system. The nonsafety-related preheat water heat exchanger and water treatment skid of the EDECWS are classified as seismic Category II and Quality Group D. Figure 9.5.5-1 shows that the pre-heat water system contains a valve to isolate nonsafety-related from safety-related system that is classified as Seismic II and quality group D. The staff issued RAI 101-8007 (ML15295A492), Question 09.05.05-1, requesting the applicant to verify whether this classification is sufficient to prevent failure due to interaction between the two systems or whether it should be Seismic I/Quality group C. In its response dated September 15, 2015 (ML15258A717), the applicant confirmed that the isolation valve is indeed classified as seismic Category I and quality Group C and proposed a revision to DCD Tier 1 and Tier 2 documentation accordingly. The staff subsequently confirmed the proposed revisions have been incorporated into Revision 1 of the DCD.

There are four EDG units for the APR1400 and each EDG provides Class 1E power to one of the four independent Class 1E buses during a LOOP event. Two EDGs are located in the auxiliary building and two EDGs are in the EDGB. The two EDG units in the auxiliary building are separated so that they are on opposite sides of the building in a mirror-like configuration. The seismic Category I EDGB houses the other two EDG units and supporting equipment in two

separate compartments. Each EDG compartment is designed to be physically separate to provide protection from fire, aircraft, missiles, and the environment.

The EDGBs and auxiliary building are both classified as seismic Category I, allowing them to withstand the effects of natural phenomena including earthquakes, tornadoes, hurricanes, floods, as well as external missiles, as described in DCD Tier 2, Sections 3.3, and 3.8. Therefore, all four EDECWS are protected from internal and external hazards. The non-safety portion of the EDECWS, including the preheating and water treatment system, is classified as seismic Category II to avoid potential damage to safety-related SSCs in the event of a design basis earthquake and can withstand a SSE seismic loads without incurring structural failure that permits deleterious interaction with the safety-related portions of the EDECWS. Based on the above assessment, the staff finds the EDECWS design conforms to the quality group classification and seismic Category guidance of RG 1.26 and RG 1.29, respectively, and thus fulfills the requirements of GDC 2. Therefore the applicant has demonstrated the EDECWS is designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed as required under 10 CFR 50.55a(a)(1).

9.5.5.4.2 GDC 4, Environmental and dynamic effects design bases

The staff reviewed the DCD to ensure that the design precludes the loss of multiple EDGs due to dynamic or environmental effects. Each EDG train is located in a dedicated room or compartment in the EDGB or the auxiliary building. There are four separate and independent trains of EDGs, and each EDG has a separate and independent EDECWS, so that the consequences of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks upon an EDECWS do not lead to a loss of more than one EDG. Therefore, based on the redundancy of EDGs and separation of EDG locations for minimizing impact on multiple EDGs, the staff finds that the EDECWS meets the requirements of GDC 4. Therefore the applicant has demonstrated the EDECWS has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental or dynamic effects.

9.5.5.4.3 GDC 5, Sharing of structures, systems, and components

DCD Tier 2, Section 9.5.5, describes each EDG as having its own dedicated and independent EDECWS. EDECWS receives heat from components essential for proper operation of the diesel engines and additional parts of the system and transfers the heat to the CCW system heat sink. Each APR1400 unit has four independent EDGs, each with a separate and independent EDECWS that is not shared between other EDGs or other nuclear units. Therefore, the staff finds that the EDECWS meets the requirements of GDC 5.

9.5.5.4.4 GDC 17, Electric power systems

As described in DCD Tier 2, Section 9.5.5, each EDECWS is subdivided into the low-temperature (LT) water subsystem and the high-temperature (HT) water subsystem, which is shown in DCD Tier 2, Figure 9.5.5-1.

The LT water subsystem is a closed-loop cooling system designed to transfer heat from the supercharging air cooler and the engine lube oil system to the CCW system. The LT water subsystem consists of an engine-driven LT water pump, two supercharging air coolers, an LT water expansion tank, an LT/CCW heat exchanger, a lube oil/LT water heat exchanger, and a three-way thermostat valve. The engine-driven LT water pump drives water through the cold side of the lube oil/LT water heat exchanger to cool lube oil. Part of the water from the LT water

pump is circulated to two supercharging air coolers to cool the compressed combustion air. Water leaving the lube oil/LT water heat exchanger and the two supercharging air coolers outlet are circulated to the hot side of the LT/CCW heat exchanger cooled by the CCW. The LT water after LT/CCW heat exchanger is returned to the suction of the LT water pump.

The HT water system is also a closed-loop cooling system designed to transfer heat from the engine and turbocharger to the CCW system. The HT system consists of an engine-driven HT water pump, two turbochargers, a three-way thermostat valve (recommendation of NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability"), an HT/CCW heat exchanger, an HT water expansion tank, a preheating HT water pump, an electric heater, and a lube oil / preheating water heat exchanger. As described in DCD Tier 2, Section 9.5.5.2.2, "System Operation," the HT water flows from the engine-driven HT water pump into the cylinder block to cool the cylinder liners and cylinder heads. Part of the cooling water is circulated to the cooling chamber of the turbochargers. After cooling the turbochargers and cylinder heads, the water flows through the thermostatic valve, which controls cooling water temperature by diverting flow either back to HT water pump inlet or through the HT/CCW heat exchanger.

In order to meet the requirements of GDC 17 an applicant may include the provision that each EDG has a separate and independent EDECWS, and also implement the recommendations specified in NUREG/CR-0600. The APR1400 design provides for separate and independent EDECWS and the recommendations of NUREG/CR-0660 have been met in that three-way thermostatic valves are used to direct engine water to the bypass or heat exchanger as recommended. However, the DCD lacks a clear description of these three-way thermostatic valves; therefore, the staff issued RAI 101-8007, Question 09.05.05-4, requesting additional details on operation and location of the 3-way valves. In its response dated September 15, 2015, the applicant stated that, for both LT/CCW and HT/CCW heat exchangers, the three-way thermostatic valves split cooling water flow so that only as much water passes through the heat exchangers as needed to maintain proper water outlet temperature. The remainder bypasses the heat exchangers and returns directly to the water pump so that the total flow to the water pump and the engine remains essentially constant regardless of the ambient temperature of engine loading. The applicant proposed the above clarification in DCD Tier 2 documentation, and the staff subsequently confirmed the clarification has been incorporated in Revision 1 of the DCD.

In addition, DCD Tier 2, Section 8.3.1.1.3, "Class 1E Emergency Diesel Generators," indicates the EDG controls and monitoring instrumentation as installed are free-standing, floor-mounted panels, with exception of the sensors and other equipment that are necessarily mounted on the EDG or its associated piping. These panels are designed for their normal vibration environment and are qualified to seismic Category I requirements. Alarms are separately annunciated on the local control panel, which also signals an EDG common trouble alarm in the MCR and RSR. System capability is tested each time the EDG is operated. The EDECWS design features, including redundancy and independence, and the provisions for testing the system capability support the requirement for an onsite electric power system to assure post-accident safe shutdown and, therefore, meet the requirements of GDC 17.

9.5.5.4.5 GDC 44, Cooling water

SRP Section 9.5.5 lists the guidelines for the applicant to meet the requirements of GDC 44 including the provisions for redundancy, independent and separation to ensure the heat transfer

function of the EDECWS for the EDGs is maintained under transient or accident conditions.. The application describes that each EDECWS contains a LT/CCW water heat exchanger and HT/CCW water heat exchanger cooled by component cooling water which transfers heat from EDG during operation. Each EDG has an independent and separate EDECWS, such that a single active component failure will not result in a loss of more than one EDG, allowing unaffected EDGs to perform system safety functions. Therefore, the staff concludes that the EDECWS meets GDC 44.

9.5.5.4.6 GDC 45, Inspection of cooling water system

SRP Section 9.5.5 lists the guideline for the applicant to meet the requirement of GDC 45 including the provision for periodic inspection of the EDECWS. The staff finds that the applicant has met these guidelines, since the DCD states that the provisions are made to allow for periodic inspection of safety-related components and equipment. The layout of the piping and components provides sufficient space to permit inspection, cleaning, maintenance, and repair of the system. Therefore, the staff concludes that the EDECWS meets GDC 45.

9.5.5.4.7 GDC 46, Testing of cooling water system

SRP Section 9.5.5 lists the guidelines for the applicant to meet the requirements of GDC 46 including the provisions for functional testing of the EDECWS system and components. The staff finds that the applicant has met these guidelines, since the application states the system operability is tested along with the complete EDG system during regularly scheduled tests in accordance with the TS as described in Chapter 16. This testing demonstrates the performance of active components, leak tightness, operability, and the capability of the system to function as intended under accident conditions. Therefore, the staff concludes that the EDECWS meets GDC 46.

The applicant also met other guidelines of SRP Section 9.5.5 as follows:

> Adequate volume is available to maintain system water level and pump net positive suction head without refill, assuming expected water loss over a seven-day period of engine operation .

The staff was unable to verify whether the system has sufficient seven-day inventory to support functional performance and requested the applicant to confirm whether the system volume is sufficient to maintain the seven-day period of engine operation in RAI 101-8007, Question 09.05.05-2. In its response dated September 15, 2015, the applicant confirmed that the water volume between the normal operating water level and the low level alarm is adequate for a seven-day period of diesel engine operation and proposed a revision to DCD Tier 2 documentation accordingly. The staff subsequently confirmed the above revision has been incorporated into Revision 1 of the DCD.

> Instrumentation and control features permit operational testing of the system and assure that normal protective interlocks do not preclude engine operation during emergency conditions.

The diesel engine is equipped with sufficient instrumentation and alarms to monitor the operation of the cooling water system. The high-high temperature alarm (jacket water out) initiates a diesel engine trip if the diesel engine is in the test mode to prevent damage to the diesel engine. If this type of alarm is received during an emergency mode (e.g., LOOP, LOCA),

the trip signal is locked out and the diesel engine continues to run. A high-high alarm in the emergency condition alerts the operator to prepare to switch over to the redundant EDG. DCD Tier 1, Section 2.6.2 further states that, when running in a test mode, an EDG is capable of responding to an automatic start signal. This meets the SRP Section 9.5.5 guidelines which state that normal protective interlocks do not preclude engine operation during emergency conditions.

9.5.5.4.8 Initial Test Program

The staff evaluated Tier 2, Section 9.5.5.4, to determine whether or not it contains adequate detail to inform the initial test program. DCD Tier 2, Section 9.5.5.4, states that inspection and functional testing are to be performed prior to initial operation as described in Section 14.2; thereafter, the system is periodically tested along with the complete EDG system in accordance with the TSs as described in Chapter 16. DCD Tier 2, Chapter 14.2, Section 14.2.12.1.86, and 14.2.12.1.88 focused on the EDGs. Section 14.2.12.1.88, in particular, includes operability tests for EDG cooling water system to keep the pump warm, operation of cooling system heaters and cooling system alarms. System components and piping are tested to pressures designated by ASME Section III Class 3. Inspection and functional testing are performed prior to initial operation as described in Section 14.2; thereafter, the system is periodically tested along with the complete EDG system in accordance with the TSs as described in Chapter 16. The staff finds these proposed testing standards and strategies to be an acceptable means to verify that the system will perform as described in DCD Tier 2, Section 9.5.5.

9.5.5.4.9 ITAAC

The staff reviewed the ITAAC in the DCD to verify that it meets SRP Section 14.2 acceptance criteria. DCD Tier 1 does not contain any figures showing the functional arrangement of the EDECWS, and, as stated in Section 9.5.5.2 of this report, although Tables 2.6.2-1 and 2.6.2-2 contain a list of components and piping provided with the EDECWS, there are no specific ITAAC requirements for the EDECWS. As such, the design does not provide for any verification of the functional arrangement of the safety-related EDECWS. Therefore, the staff issued RAI 152-8006, Question 09.05.04-6, requesting the applicant to provide functional arrangement drawings to allow acceptable closure of the ITAAC design commitment. In its response dated September 14, 2015, the applicant proposed revisions to the applicable DCD Tier 1 documentation to provide the appropriate design description, drawing, and ITAAC related to the EDECWS. The staff subsequently confirmed the revised documentation has adequate information to allow the staff to verify the as-built configuration of the EDECWS system. Therefore, the staff finds that the applicant has properly addressed the requirements of 10 CFR 52.47(b)(1).

9.5.5.4.10 Technical Specifications

DCD Tier 2, Chapter 16, TS 3.8.1 through TS 3.8.3 provide EDG requirements. There are no specific TS requirements for the EDECWS. Cooling water system requirements are implied with overall EDG operability. Therefore, the staff finds this in conformance with NUREG-1432, Revision 4.0, April 2012, “Standard Technical Specifications, Combustion Engineering Plants.”

9.5.5.5 Combined License Information Items

No applicable COL information items were identified in the DCD.

9.5.5.6 Conclusion

The staff finds the APR1400 EDECWS design acceptable and in compliance with regulations, as stated in the GDC of 10 CFR Part 50, Appendix A. This conclusion is based on the staff's technical evaluation that the DCD meets the requirements of GDC 2, GDC 4, GDC 5, GDC 17, GDC 44, GDC 45, GDC 46, and 10 CFR 52.47(b)(1) for the EDECWS.

9.5.6 Emergency Diesel Engine Starting Air System

9.5.6.1 Introduction

The Emergency Diesel Engine Starting Air System (EDESS) is designed to provide fast-start capability for the diesel engine by using compressed air to rotate the diesel engine until combustion begins and the diesel engine accelerates under its own power. Following is the staff's evaluation of the proposed design.

The EDESS consists of two redundant sets of equipment, each completely independent of the other for successful operation. A cross-connecting line with a normally closed valve is provided between the two redundant starting air systems. Each set of equipment is composed of a motor-driven compressor package, an air receiver, valves, instrumentation and control system, piping, and devices to crank the engine. The EDESS has boundary divisions between a safety-related portion downstream of and including the check valve on the air compressor discharge, and the remaining nonsafety-related portion.

9.5.6.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.2, "Emergency Diesel Generator System," describes the principal performance characteristics and safety functions of the EDGs and their supporting equipment, and includes Table 2.6.2-1, Table 2.6.2-2, and Table 2.6.2-3.

DCD Tier 1, Section 2.6.2, Item 12 states that the starting air system receiver tanks of each EDG have a combined air capacity for five starts of the EDG without replenishing air to the receiver tanks.

DCD Tier 2: DCD Tier 2, Section 9.5.6, "Emergency Diesel Engine Starting Air System," and Figure 9.5.6-1, "Emergency Diesel Engine Starting Air System Flow Diagram," provide the EDESS system description, which is summarized, in part, as follows:

Each EDG has its own dedicated and independent EDESS. The EDESS consists of two redundant sets of equipment, each completely independent of the other for successful operation. A cross-connecting line with a normally closed valve is provided between the two redundant starting air systems. Each set of equipment is composed of a motor-driven compressor package, an air receiver, valves, instrumentation and control system, piping, and devices to crank the engine. The EDESS has boundary divisions between a safety-related portion downstream of and including the check valve on the air compressor discharge, and the remaining nonsafety-related portion.

ITAAC: DCD Tier 1, Table 2.6.2-3, provides ITAAC requirements for the EDGs. Item 1 of this table requires verification of the functional arrangement of the overall EDG. Tables 2.6.2-1 and 2.6.2-2 contain a list of components and piping provided with the EDESS. Table 2.6.2-3 provides specific requirements for the starting air receivers (Item 13). In addition, there are

other ITAAC that apply generally to the overall EDG design. Detailed evaluation of ITAAC can be found in Section 14.3 of this report.

Technical Specifications: DCD Tier 2, Chapter 16, TS 3.8.1 provides EDG requirements. Limiting Conditions for Operation for the EDESS are given in TS 3.8.3 with SR to verify each DG air start receiver pressure.

9.5.6.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are specified in NUREG-0800, SRP Section 9.5.6, "Emergency Diesel Engine Starting System," and are summarized below. Other areas of review (other SRP sections) that include interfaces with this SRP section are identified in NUREG-0800, Section 9.5.6.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods without loss of capability to perform their safety functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of externally and internally generated missiles, pipe whip, and jet impingement forces of pipe breaks.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to the capability of systems and components important to safety shared between units to perform required safety functions.

4. GDC 17, "Electric power systems," as it relates to the capability of the EDESS to meet independence and redundancy criteria.

5. 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the verification that the EDESS design meets quality group classification per RG 1.26 and seismic Category per RG 1.29 for safety and non-safety related portions of the system.

2. For GCD 4, acceptance is based on the verification that the EDESS design has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

3. For GDC 5, acceptance is based on the verification that sharing of EDESS systems and components in multiple-unit plants does not impair the ability to perform their safety functions.

4. For GDC 17, acceptance is based on the verification that the EDESS are independent and a single failure of any one EDESS will only affect its associated EDG.

5. For 10 CFR 52.47(b)(1), acceptance criteria is based on the verification that the EDESS meets corrosion control criteria per RG 1.137 and inspections, tests, analyses, and acceptance criteria in SRP Section 14.3 and 14.3.7.

9.5.6.4 Technical Evaluation

The staff reviewed the design description of the EDESS in the DCD for the APR1400 in accordance with NUREG-0800, Section 9.5.6, Revision 3. The APR1400 consists of four EDGs and their respective support systems such as fuel oil, lube oil, engine cooling water, starting air, and combustion air intake and exhaust systems. The staff's acceptance of the EDESS design is based on the system design being in compliance with the requirements of the GDCs specified above.

The EDESS consists of both safety-related and a nonsafety-related portions. The nonsafety-related portion is downstream of and including the check valve on the air compressor discharge. The safety-related portion of the system is from, and including, the air receiver inlet check valve through the air receiver and discharge piping up to the connection at the engine interface as shown in DCD Tier 2, Figure 9.5.6-1.

As stated in DCD Section 9.5.6.2.1, "General Description," a nonsafety-related motor-driven air compressor is provided for each starting air receiver. The air compressor package/skid consists of a compressor, a compressed air cooling fan, an air dryer, and a filter. Relief valves in the compressor package, on the overspeed air receiver tank, and the starting air receiver tank protect the starting air system from over pressurization. Each compressor compresses ambient air from within the engine room and then discharges compressed air. The heat of compression is removed by an air cooling fan. To minimize the accumulation of moisture, the EDESS is equipped with a multi-stage drying and filtering unit located in-line between the air cooling fan and the receiver tank to supply air. Each starting air receiver is equipped with a set of pressure switches that automatically control the operation of the air compressor on its associated train, starting the compressor on low pressure and stopping the compressor on high pressure.

For normal operations, ambient air is taken from the engine room, compressed, dried, filtered, and stored in air receiver tanks. The starting air receivers are tanks with capacity for five start attempts of the EDG without recharging the receivers. The EDESS capacity is determined as follows: duration of each cranking cycle is approximately three seconds (consisting of two to three engine revolutions) or air start requirements (per engine start) provided by the engine manufacturer are used, whichever air start requirements are more demanding. Two starting air receiver tanks for each EDG provide storage capacity that is sufficient to allow five successful diesel engine starts without the use of the compressor. Safety relief valves are provided for receiver over-pressure protection.

9.5.6.4.1 GDC 2, Design bases for protection against natural phenomena

In accordance with RG 1.26 and RG 1.29, the safety-related portion of each EDESS is classified as Quality Group C and seismic Category I as shown in DCD Tier 1, Table 2.6.2-1, and DCD Tier 2, Table 3.2-1. The air compressor skids and the portion of the EDESS up to the air receiver inlet check valves are not safety related; however, their failure could adversely affect a

safety related system. They are, therefore, classified as Quality Group D, and seismic Category II. This classification is also shown on Figure 9.5.6-1 of DCD.

There are four EDG units for the APR1400 and each EDG provides Class 1E power to one of the four independent Class 1E buses during a LOOP event. Two are located in the auxiliary building and two in the EDGBs. The two EDG units in the auxiliary building are separated so they are on opposite sides of the building in a mirror-like configuration. The seismic Category I EDGB houses the other two EDG units and supporting equipment in two separate compartments. Each EDG compartment is designed to be physically separate to provide protection from fire, aircraft, missiles, and the environment. The EDGB and auxiliary building are designed to withstand the effects of internal and external hazards. The seismic Category I building is designed to withstand the effects of natural phenomena including earthquakes, tornadoes, hurricanes, floods, and external missiles, as described in DCD Tier 2, Sections 3.3, and 3.8.

Based on above, the safety-related equipment of the EDESS is protected from floods, natural phenomenon missiles, and interaction with non-seismic systems in the vicinity. The nonsafety portion of the system, including the air dryer packages and the starting air compressors, are classified as seismic Category II to avoid potential damage to safety-related SSCs in the event of a design basis earthquake and can withstand a SSE seismic loads without incurring structural failure that permits deleterious interaction with the safety-related portions of the EDESS. Because the design conforms to the guidance of RG 1.26 and 1.29, the staff finds that the EDESS meets the requirements of GDC 2.

9.5.6.4.2 GDC 4, Environmental and dynamic effects design bases

Each EDG train is located in a dedicated room or compartment in the EDGB or the AB. There are four separate and independent trains of EDGs, and each EDG has a separate and independent EDESS, so that the consequences of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks upon an EDESS do not lead to a loss of more than one EDG. All pressure lines of an EDESS division are located in the room or compartment supporting only that division. Therefore, a failure of any pressure line will only have the potential impact on the function of the SSCs in that division. There are no high- or moderate-energy lines in the EDGB whose failure could alter the function of more than one EDESS. Therefore, based on the redundancy of EDGs and separation of EDG locations for minimizing impact on multiple EDGs, the staff finds that the EDESS meets the requirements of GDC 4. Therefore the staff had determined that the applicant has demonstrated the EDESS has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

9.5.6.4.3 GDC 5, Sharing of structures, systems, and components

DCD Tier 2, Section 9.5.6 describes each EDG as having its own dedicated and independent EDESS. Each EDESS consists of two redundant sets of equipment, each completely independent of the other for successful operation. The set of equipment is a motor-driven compressor package, an air receiver, valves, instrumentation and control system, piping, and devices to crank the engine. A cross-connecting line with a normally closed valve is provided between the two redundant starting air systems. DCD Tier 2, Figure 9.5.6-1, shows the cross-connecting line, but does not show any normally closed valve to isolate the redundant air system. Therefore, the staff issued RAI100- 8008 (ML15226A001), Question 09.05.06-1,

requesting the applicant to provide the location of the normally closed valve and update Figure 9.5.6-1 accordingly. In its response dated September 11, 2015 (ML15254A290), the applicant confirmed that a cross-connecting line with a normally closed valve is provided between the two motor-driven compressor packages and proposed a revision of the EDESS description and Figure 9.5.6-1 as appropriated. The staff subsequently confirmed the proposed revisions have been incorporated into Revision 1 of the DCD. Since each EDG is supplied with a dedicated and independent EDESS, and starting air systems are not shared between nuclear power units, the staff finds that the requirements of GDC 5 are met.

9.5.6.4.4 GDC 17, Electric power systems

The staff reviewed the EDESS to ensure that no single failure will have a negative effect on multiple EDGs. Each EDG has a dedicated EDESS with two air compressors, two air dryers, two filters, and two air receivers. The starting air receiver capacity for each redundant diesel engine is sufficient for a minimum of five successful engine starts without the use of the air compressor. Relief valves in the compressor package, on the overspeed air receiver tank and the starting air receiver tank, protect the starting air system from over pressurization. Starting air system alarms are annunciated separately on the local control panel as well as on an EDG common trouble alarm in the MCR and RSR.

Each air compressor package/skid consists of a compressor, a compressed air cooling fan, an air dryer, and a filter. The air dryer dries starting air to a dew point of not more than 10 C (50 °F) when installed in a normally-controlled 21 °C (70 °F) environment; otherwise, the starting air dew point is controlled to at least 5.5 °C (10 °F) less than the lowest expected ambient temperature. Air driers are refrigerant type in accordance with the recommendations of NUREG/CR-0660. Each air receiver is furnished with inlet/outlet shutoff valves, pressure gauge, drain valve with provisions for the periodic blowdown or automatic blowdown of accumulated moisture and foreign material in the air receivers, safety valve, and sensing element for low pressure alarm.

DCD Section 9.5.6.2.1 indicates that the layout of the piping and main components provides the space required to permit inspection, cleaning, maintenance, and repair of the system.

The system minimizes the potential for air leakage by incorporating welded and flanged connections. The capability to isolate system or piping components is provided, if required to maintain the system safety function. This includes the isolation of portions of the system for excessive leakage or component malfunction.

The EDESS design features, including redundancy and independence, and the provisions for testing the system capability support the requirement for an onsite electric power system to assure post-accident safe shutdown. The staff has determined that a single failure in any one of the systems will affect only its own diesel generator and, therefore the EDESS meets the requirements of GDC 17.

9.5.6.4.5 Initial Plant Test Program

The staff evaluated Tier 2, Section 9.5.6.4, to determine whether or not it contains adequate detail to inform the initial test program. DCD Tier 2, Section 9.5.6.4, “Inspection and Testing Requirements,” states inspection and functional testing are performed prior to initial operation as described in Section 14.2. The system is periodically tested along with the complete EDG system in accordance with the TSs as described in Chapter 16. This testing demonstrates the

performance of active components, leak tightness, operability, and the capability of the system to function as intended under accident condition.

This testing also demonstrates the starting air system has sufficient volume available to perform five consecutive starts of its EDGs; starting air compressors operability; starting pneumatic controls; and starting air alarms, interlocks, and automatic operation. For the above reasons, the staff finds that the initial plant testing program is acceptable. A more detailed review of the initial plant testing program can be found in Chapter 14 of this report.

9.5.6.4.6 ITAAC

The staff reviewed the ITAAC in the DCD to verify that it meets SRP Section 14.2 acceptance criteria. DCD Tier 1, Table 2.6.2-3, ITAAC Item 1, requires verification of the as-built functional arrangement (including support systems). However, the staff found that the DCD did not contain any figures showing the functional arrangement of the EDESS. Therefore, the staff issued RAI 100-8008, Question 09.05.06-2, requesting the applicant to provide the functional arrangement of the EDESS to allow for the review of the ITAAC design commitment. In its response dated September 11, 2014 (ML15254A290), the applicant proposed a revision to DCD Tier 1 documentation as appropriate to add the required figure, and the staff subsequently confirmed the changes have been incorporated into Revision 1 of the DCD. The proposed documentation revision provides adequate information to allow the staff to verify the as-built configuration of the EDESS system. Therefore, the staff finds that the applicant has properly addressed the requirements of 10 CFR 52.47(b)(1).

9.5.6.4.7 Technical Specifications

The staff reviewed the DCD to determine that TS were provided for the EDESS. DCD Tier 2, Chapter 16, TS 3.8.3 provides limiting conditions of operation and surveillance requirements related to EDG starting air. SR 3.8.3.4 requires each EDG air start receiver pressure to be ≥ [[40.77 kg/cm^2G (580 psig)]].

Paragraph E.1 of the bases for this requirement (B 3.8.3) states that with starting air receiver pressure less than [[40.78 kg/cm^2G (580 psig)]], sufficient capacity for five successive EDG start attempts does not exist. However, as long as the receiver pressure is greater than [[8.79 kg/cm^2G (125 psig)]], there is adequate capacity for at least one start attempt, and the EDG can be considered OPERABLE while the air receiver pressure is restored to the required limit. A period of 48 hours is considered sufficient to complete restoration to the required pressure prior to declaring the EDG inoperable.

Each starting air receiver is equipped with a set of pressure switches that automatically control the operation of the air compressor on its associated train, starting the compressor on low pressure and stopping the compressor on high pressure. Pressure gauges are located on the tanks for local indication. A separate pressure switch on the local control panel alarms if the starting air receiver pressure falls below the allowable set value. Controls for starting the EDG system are discussed in DCD Tier 2, Section 8.3, and the EDG emergency trips are discussed in DCD Tier 2, Chapter 16, B 3.8.1.

9.5.6.5 Combined License Information Items

No applicable COL information items were identified in the DCD.

9.5.6.6 Conclusion

The staff finds the APR1400 Emergency Diesel Engine Starting Air System design acceptable and in compliance with regulations as stated in the general design criteria of 10 CFR Part 50, Appendix A. This conclusion is based on the staff's technical evaluation that the DCD meets GDC 2, GDC 4, GDC 5, GDC 17, and 10 CFR 52.47(b)(1) for the EDESS.

9.5.7 Emergency Diesel Engine Lubrication System

9.5.7.1 Introduction

The APR1400 includes four safety-related (Class 1E) EDGs. Each EDG has a separate and independent emergency diesel engine lubricating oil system (EDELS). During engine operation the EDELS stores and delivers clean lubricating oil to the EDG, its bearings and crankshaft, turbocharger bearings, and other moving parts. By means of heaters, the EDELS delivers warmed oil to the engine during standby to provide fast-starting and load-accepting capability. Following is the staff's evaluation of the proposed design.

9.5.7.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.2, "Emergency Diesel Generator System," describes the principal performance characteristics and safety functions of the EDG s and their supporting systems, and includes Table 2.6.2-1, Table 2.6.2-2, and Table 2.6.2-3.

DCD Tier 1, Section 2.6.2, Item 13, states that each lube oil makeup tank provides lube oil to its respective EDG for seven continuous days of rated full-power operation. Other items in this section state the design requirements for the ASME Section III and seismic Category I portions of all of the EDG support systems.

DCD Tier 2: DCD Tier 2, Section 9.5.7, "Emergency Diesel Engine Lubrication System," and Figure 9.5.7-1, "Emergency Diesel Engine Lubrication System Flow Diagram," provide the EDELS system description, which is in summarized, in part, as follows:

Each EDG has a separate, independent lubrication system consisting of lube oil/LT water heat exchanger, lube oil / preheating water heat exchanger, full-flow filter, engine-driven lube oil pump, three-way thermostat valve, prelube oil pump, lube oil makeup tank, controls, and instrumentation. The EDELS stores a minimum of seven days of lubricating oil and delivers it to the EDG as required for continuous operation.

ITAAC: DCD Tier 1, Table 2.6.2-3, provides ITAAC requirements for the EDGs. Item 1 of this table requires verification of the functional arrangement of the overall EDG. Tables 2.6.2-1 and 2.6.2-2 contain a list of components and piping provided with the EDELS. Table 2.6.2-3 provides specific requirements for the lubrication makeup tank (Item 12). In addition, there are other ITAAC that apply generally to the overall EDG design.

Technical Specifications: DCD Tier 2, Chapter 16, TS Section 3.8.1, "AC Sources – Operating," provides EDG requirements. Surveillance requirement (SR) 3.8.3.2 provides lube oil storage requirements. Limiting Conditions for Operation (LCO) for the EDELS is given in Chapter 16, LCO 3.8.3, "Diesel Fuel Oil, Lube Oil, and Starting Air."

9.5.7.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are specified in NUREG-0800, Section 9.5.7, "Emergency Diesel Engine Lubrication System," and are summarized below. Other areas of review (other SRP sections) that include interfaces with this SRP section are identified in NUREG-0800, Section 9.5.7.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods without loss of capability to perform their safety functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to the capability of systems and components important to safety shared between units to perform required safety functions.

4. GDC 17, "Electric power systems," as it relates to the capability of the EDELS to meet independence and redundancy criteria.

5. 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the verification that the EDELS design meets quality group classification per RG 1.26 and seismic Category per RG 1.29 for safety and non-safety related portions of the system.

2. For GCD 4, acceptance is based on the verification that the EDELS design has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

3. For GDC 5, acceptance is based on the verification that sharing of EDELS systems and components in multiple-unit plants does not impair the ability to perform their safety functions.

4. For GDC 17, acceptance is based on the verification that the EDELS are independent and a single failure of any one EDELS will only affect its associated EDG.

5. For 10 CFR 52.47(b)(1), acceptance criteria is based on the verification that the EDELS meets corrosion control criteria per RG 1.137 and inspections, tests, analyses, and acceptance criteria in SRP Section 14.3 and 14.3.7.

9.5.7.4 Technical Evaluation

The staff reviewed the design description of the EDELS in the DCD for the APR1400 in accordance with NUREG-0800, Section 9.5.7, Revision 3. The APR1400 includes four safety-related (Class 1E) EDGs and their respective support systems such as fuel oil, lube oil, engine cooling water, starting air, and combustion air intake and exhaust systems. The staff's acceptance of the EDELS design is based on the system design being in compliance with the requirements of the GDCs specified above.

9.5.7.4.1 GDC 2, Design bases for protection against natural phenomena

The staff reviewed to determine that, as required by GDC 2, the EDELS is protected against natural phenomena. In accordance with SRP 9.5.7, the safety-related portion of each EDELS is classified as Quality Group C and seismic Category I as shown in DCD Tier 1, Table 2.6.2-1 and DCD Tier 2, Section 9.5.7. DCD Tier 2, Figure 9.5.7-1 designates the nonsafety-related preheat lube oil portion and lube oil makeup tank of the EDELS as seismic Category II and Quality Group D.

There are four EDG units for the APR1400, and each EDG provides Class 1E power to one of the four independent Class 1E buses during a LOOP event. Two are located in the auxiliary building and two in the EDGB. The two EDG units in the auxiliary building are separated so they are on opposite sides of the building in a mirror-like configuration. The seismic Category I EDGB houses the other two EDG units and supporting equipment in two separate compartments. Each EDG compartment is designed to be physically separate to provide protection from fire, aircraft, missiles, and the environment. The EDGBs and auxiliary building are both classified as seismic Category I, allowing them to withstand the effects of natural phenomena including earthquakes, tornadoes, hurricanes, floods, as well as external missiles, as described in DCD Tier 2, Sections 3.3, and 3.8.

Based on the above, the staff finds that the safety-related equipment of the EDELS is protected from floods, natural phenomenon missiles, and interaction with non-seismic systems in the vicinity. The nonsafety portion of the system, including the lube oil preheating system, are classified as seismic Category II to avoid potential damage to safety-related SSCs in the event of a design basis earthquake and can withstand a SSE seismic loads without incurring structural failure that permits deleterious interaction with the safety-related portions of the EDELS. Therefore, the staff finds the EDELS meets the requirements of GDC 2.

9.5.7.4.2 GDC 4, Environmental and dynamic effects design bases

Each EDG train is located in a dedicated room or compartment in the EDGB or auxiliary building. There are four separate and independent trains of the EDGs, and each EDG has a separate and independent EDELS, so that the consequences of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks upon an EDELS do not lead to a loss of more than one EDG. Therefore, based on the redundancy of EDGs and separation of EDG locations minimizing impact on multiple EDGs, the staff finds that the EDELS meets the requirements of GDC 4. Therefore, the staff has determined that the applicant has demonstrated the EDELS has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

9.5.7.4.3 GDC 5, Sharing of structures, systems, and components

DCD Tier 2, Section 9.5.7 describes each EDG as having its own dedicated and independent EDELS. For the EDELS design, lubricating oil is stored and delivered to the diesel engine, its bearings and crankshaft, turbocharger bearings, and other moving parts during engine operation. Each unit has four independent EDGs, each with a separate and independent EDELS that is not shared between other diesel generators or other nuclear units. Therefore, the staff finds that the EDELS design meets the requirements of GDC 5.

9.5.7.4.4 GDC 17, Electric power systems

GDC 17 requires the EDELS to meet independence and redundancy criteria such that a single failure of any one EDELS will only affect its associated EDG. The guidelines of SRP Section 9.5.7 also specify that EDELS operating pressure, temperature differentials, flow rate, and heat removal rate external to the engine must be in accordance with the engine manufacturer. Also, 10 CFR 52.47(b)(1) requires that an APR1400 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 APR1400 is built and will operate in accordance with the design certification, the provisions of the AEA, and NRC regulations.

Each diesel engine contains an engine-driven lube oil pump, which draws oil from the engine lube oil sump tank and discharges it through the lube oil/LT water heat exchanger to the engine. The engine lube oil lubricates and cools various engine components. The oil flows through a full-flow filter before entering the engine. A pressure-regulating valve on the oil header maintains proper oil pressure by relieving excess oil back to the lube oil sump tank. When in the standby mode, the system maintains a minimum oil temperature and provides preheating lubrication system to facilitate quick engine starting. Each EDG has a separate and independent lubricating system.

DCD Section 9.5.7.2.1, “General Description,” describes a lube oil/LT water heat exchanger. However, Figure 9.5.7-1 does not show this heat exchanger and piping configuration, including heat sink. Figure 9.5.7-1 also contains off-sheet connectors titled, Lube Oil Pipe “A” and Lube Oil Pipe “B,” but does not provide any additional information regarding these piping connections. In addition, DCD Section 9.5.7.2.2, “System Operation,” states, “The three-way thermostat valve splits the lube oil flow so only as much water passes through the heat exchanger as needed to maintain the proper lube oil outlet temperature. The remainder bypasses the heat exchanger and returns directly to the water pump so that the total lube oil flowing through the pump and engine remains essentially constant regardless of the ambient temperature of engine loading.” The staff is unable to locate any three-way thermostat valve that splits the lube oil flow, nor any water pump or heat exchanger bypass on Figure 9.5.7-1. The staff issued related RAI 101-8007, Question 09.05.05-3, and RAI 100-8008, Question 09.05.06-2, requesting the applicant to provide details of the design, classification and location of these components, and update figures accordingly. In its respective responses, dated September 15, 2015 (ML15258A717), and September 11, 2015 (ML15254A290), the applicant proposed revisions to design drawings that resolved the staff’s questions by providing adequate information for the staff to review and accept the EDELS design. The staff subsequently confirmed the changes have been incorporated into Revision 1 of the DCD.

SRP Section 9.5.7 specifies that, in meeting the GDC 17 requirements, the onsite lubricating oil storage capacity for each diesel engine needs to be sufficient for seven days of operation. In accordance with ANSI/ANS-59.52, DCD Tier 2, Section 9.5.7.2.1 indicates the lube oil makeup tank, which has sufficient capacity for seven continuous days of the EDG rated full-power operation, is provided with individual fill, drain, and vent lines located outdoors. Makeup to the engine lube oil sump tank by gravity is manually initiated from the lube oil makeup tank.

During diesel engine operation, the engine-driven pump draws oil from the engine lube oil sump tank and delivers it through the lube oil/LT water heat exchanger to the engine. The oil flows through a full-flow filter before entering the engine. The lube oil/LT water heat exchanger provides the necessary cooling to dissipate heat from the engine coolant and lubricating oil.

In standby mode, the motor-driven prelube oil pump draws oil from the engine sump tank and delivers it through the lube oil/preheating water heat exchanger and the full-flow filter to the engine. The lube oil/preheating water heat exchanger keeps the lubricating oil warm. During engine operation, the prelube oil pump is shut down. Prelubrication of the engine with warm lubricating oil provides for rapid, reliable starting and load capability while minimizing bearing wear.

NUREG/CR-0660 also cautions against pre-lube periods exceeding five minutes unless approved by the diesel manufacturer. SRP 9.5.7, Section III.3.F and G, which is based on NUREG/CR-0660, states the same caution. However, DCD Tier 2, Section 9.5.7.2.1 only states that, while in standby the motor-driven, prelube oil pump draws oil from the engine sump tank and delivers it through the lube oil/preheating water heat exchanger and the full-flow filter to the engine. Therefore, the staff issued RAI 186-8009 (ML15253A006), Question 09.05.07-1, requesting the applicant to clarify that the EDELS is in compliance with the guidelines presented in SRP 9.5.7 Section III.F and G. In its response dated October 28, 2015 (ML15301A897), the applicant proposed a revision to DCD Tier 2, Section 9.5.7.2.2, to clarify that the prelube time interval prior to manual starting of the EDG is limited to three to five minutes unless otherwise recommended by the diesel engine manufacturer. The staff found this to be in conformance with NUREG/CR-0660 and, therefore, acceptable. The staff subsequently confirmed the change has been incorporated into Revision 1 of the DCD.

The diesel engine crankcase is vented to the atmosphere through the roof of the building via a lube oil separator. The engine lube oil sump tank is vented to the atmosphere through the roof. The crankcase is equipped with blowout panels to prevent high pressures from damaging the diesel engine. Lubricating oil leakage is detected by routine surveillance, low-level alarm in the lube oil sump tank, and low engine inlet pressure and alarm. System leakage into the lube oil system through the lube oil/LT water heat exchanger is minimized by the normal operating pressure of the lube oil being higher than the LT water pressure. Oil leakage from the diesel engine is collected in a sump in the EDG room.

The lube oil in the lube oil makeup tank is periodically inspected to determine the purity of the oil. Parameters are monitored, including viscosity, neutralization number, and percentage of water. Any accumulated water detected in the bottom of the makeup tank is removed. If degradation of the oil is detected, the oil is drained out for disposal.

DCD Tier 2, Section 9.5.7.5, “Instrumentation Requirements,” provides the instrumentation requirements. Alarms are separately annunciated on the local control panel, which also signals

an EDG common trouble alarm in the MCR and RSR. The following temperature, pressure, and level annunciate when it exceed setpoints.

a. Low lube oil temperature at the inlet of the full-flow filter

b. High lube oil temperature at the inlet of the full-flow filter

c. High differential pressure of full-flow filter

d. Low lube oil makeup tank level

e. High lube oil makeup tank level

f. Low-low lube oil level in the lube oil sump

g. Low pressure for lube oil at the engine inlet during preheating and normal operation

h. High pressure for the crankcase

i. Low-low pressure for lube oil at the engine inlet

The diesel engine is equipped with both temperature and pressure monitoring systems with separate alarm and trip switches to alert the operator of abnormal operating conditions. During standby, low prelube oil pressure and low HT water temperature are alarmed to alert the operator to take corrective action. If a trip setpoint is exceeded while the diesel engine is operating during the test mode, an alarm is annunciated and a diesel engine trip automatically shuts down the diesel engine to prevent incurring any damage. However, if such an alarm is received during the emergency mode (i.e., LOOP or LOCA), the trip is locked out and the diesel engine continues to run. The alarms alert the operator to prepare to switch over to the redundant EDG. This meets the SRP Section 9.5.7 guidelines which state that normal protective interlocks do not preclude engine operation during emergency conditions.

Each EDELS is independent and physically separated from the other EDELS and support a single EDG; therefore a single failure in any EDELS component will affect only its own diesel generator, as specified in ANSI/ANS-59.52. Based on the above review and the features provided for the EDG, the staff finds the EDELS meets the requirements of GDC 17 in that any postulated failure will not affect multiple EDGs.

9.5.7.4.5 Initial Plant Test Program

The staff evaluated Tier 2, Section 9.5.7.4, to determine whether or not it contains adequate detail to inform the initial test program. DCD Tier 2, Chapter 14.2, Sections 14.2.12.1.86 and 14.2.12.1.88 focused on the initial testing requirements of the EDGs. Section 14.2.12.1.88, in particular, includes operability tests for lube oil prelube pump, lube oil heaters, lube oil alarms and lube oil transfer pump components. System components and piping are tested to pressures designated by ASME Section III Class 3. Inspection and functional testing are performed prior to initial operation as described in Section 14.2; thereafter, the system is periodically tested along with the complete EDG system in accordance with the TSs, as described in Chapter 16. The staff finds these proposed tests to be an acceptable means to provide assurance that the EDELS system will perform as described in DCD Tier 2,

Section 9.5.7. A more detailed evaluation of the initial test program can be found in Chapter 14 of this report.

9.5.7.4.6 ITAAC

The staff reviewed DCD Tier 1, Section 2.6.2, and ITAAC to determine whether they have been included in accordance with the requirements of 10 CFR 52.47(b)(1). The existing ITAAC do not verify whether the EDELS is installed in accordance with design, and will operate in accordance with the design; i.e., EDELS operating pressure, temperature differentials, flow rate and heat removal rate are in accordance with the engine manufacturer’s recommendations and thus ensure reliable EDELS operation. Therefore, the staff issued RAI 152-8006, Question 09.05.04-6, requesting the applicant to provide an ITAAC in DCD Tier 1 for the EDELS and supporting functional arrangement drawings to allow acceptable closure of ITAAC design commitment. In its response dated September 14, 2015, the applicant proposed revisions to the applicable DCD Tier 1 documentation to provide the appropriate design description, drawing, and ITAAC related to the EDELS. The staff subsequently confirmed the proposed changes have been incorporated into Revision 1 of the DCD. The documentation revision provides adequate information to allow the staff to verify the as-built configuration of the EDELS system. Therefore, the staff finds that the applicant has properly addressed the requirements of 10 CFR 52.47(b)(1).

9.5.7.4.7 Technical Specifications

The staff reviewed the DCD to ensure that TS were provided for the EDELS. DCD Tier 2, Chapter 16, TS Section 3.8.1 “AC Sources – Operating,” provides EDG requirements. Surveillance requirement (SR) 3.8.3.2 provides lube oil storage requirements of greater than or equal to a 7-day supply. Limiting Conditions for Operation (LCO) for the EDELS is given in Chapter 16, LCO 3.8.3, “Diesel Fuel Oil, Lube Oil, and Starting Air,” which states that the lube oil subsystem shall be within limits for each of the required EDG. Based on the above, the staff finds that the applicant provided TS considerations for the EDELS. The adequacy of the TS is reviewed in Section 16 of this report.

9.5.7.5 Combined License Information Items

No applicable COL information items were identified in the DCD.

9.5.7.6 Conclusion

The staff finds the APR1400 Emergency Diesel Engine Lubricating Oil System design acceptable and in compliance with regulations as stated in the general design criteria of 10 CFR Part 50, Appendix A. This conclusion is based on the staff’s technical evaluation that determined the DCD meets GDC 2, GDC 4, GDC 5, GDC 17, and 10 CFR 52.47(b)(1) for the EDELS.

9.5.8 Emergency Diesel Engine Combustion Air Intake and Exhaust System

9.5.8.1 Introduction

The emergency diesel engine combustion air intake and exhaust system (EDECAIES) supplies an adequate quantity of combustion air of reliable quality and exhausts combustion products to the atmosphere to allow the EDG to function properly. The APR1400 includes four safety-

related (Class 1E) EDGs. Each EDG has a separate and independent EDECAIES. The following subsections sections contain the staff's review of the design.

9.5.8.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.2, "Emergency Diesel Generator System," describes the principal performance characteristics and safety functions of the EDG s and their supporting equipment, and includes Table 2.6.2-1, Table 2.6.2-2, and Table 2.6.2-3.

DCD Tier 1, Section 2.6.2, Item 14 indicates the air intakes for EDG combustion are separated from the EDG exhaust ducts. Other items in this section state the design requirements for the ASME Section III and seismic Category I portions of all of the EDG support systems.

DCD Tier 2: The DCD Tier 2, Section 9.5.8, "Emergency Diesel Engine Combustion Air Intake and Exhaust System," and Figure 9.5.8-1, "Emergency Diesel Engine Combustion Air Intake and Exhaust System Flow Diagram," provide the EDECAIES system description, which is summarized, in part, as follows:

Each EDG has its own dedicated and independent EDECAIES as described in DCD Tier 2, Section 9.5.6. The EDECAIES consists of silencer, filter, expansion joints, air inlet duct, air exhaust piping, and instrumentation. The exhaust duct and vent stack are protected from external missiles. The combustion air intake opening is located at a level to minimize the intake of dust in the EDG engine. The diesel engine exhaust gases are discharged to the atmosphere through a stack in a direction away from the engine air intake with sufficient separation, thereby minimizing the effects of the engine exhaust being drawn into the combustion air inlet.

ITAAC: DCD Tier 1, Table 2.6.2-3, provides ITAAC requirements for the EDGs. Item 1 of this table requires verification of the functional arrangement of the overall EDG. Although Tables 2.6.2-1 and 2.6.2-2 contains list of components and piping provided with the EDECAIES, and Table 2.6.2-3 also provides specific requirements for the air intake and exhaust (Item 14), there is no functional arrangement provided for the EDECAIES system. The resolution of this item is discussed in Section 9.5.8.4 of his SER. In addition to the above, there are other ITAAC that apply generally to the overall EDG design and are discussed in Section 14.3 of this report.

Technical Specifications: DCD Tier 2, Chapter 16 does not specifically identify the EDG air intake and exhaust systems. However, EDG testing and surveillance requirements under TS 3.8.1 will indirectly measure the effectiveness of air intake and exhaust in that these systems are an integral part of EDG performance and capacity.

9.5.8.3 Regulatory Basis

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are specified in NUREG-0800, Section 9.5.8, "Emergency Diesel Engine Combustion Air Intake and Exhaust System," and are summarized below. Other areas of review (other SRP sections) that include interfaces with this SRP section are identified in NUREG-0800, Section 9.5.8.

1. GDC 2, "Design bases for protection against natural phenomena," as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods without loss of capability to perform their safety functions.

2. GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs that must be protected from, or be capable of withstanding the effects of, externally- and internally-generated missiles, pipe whip, and jet impingement forces associated with pipe breaks.

3. GDC 5, "Sharing of structures, systems, and components," as it relates to the capability of systems and components important to safety shared between units to perform required safety functions.

4. GDC 17, "Electric power systems," as it relates to the capabilities of the EDECAIES to meet independence and redundancy criteria.

5. 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 AEA, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

1. For GDC 2, acceptance is based on the verification that the EDECAIES design meets quality group classification per RG 1.26 and seismic Category per RG 1.29 for safety and non-safety related portions of the system.

2. For GCD 4, acceptance is based on the verification that the EDECAIES design has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

3. For GDC 5, acceptance is based on the verification that sharing of EDECAIES systems and components in multiple-unit plants does not impair the ability to perform their safety functions.

4. For GDC 17, acceptance is based on the verification that the EDECAIES are independent and a single failure of any one EDECAIES will only affect its associated EDG.

5. For 10 CFR 52.47(b)(1), acceptance criteria is based on the verification that the EDECAIES meets corrosion control criteria per RG 1.137 and inspections, tests, analyses, and acceptance criteria in SRP Section 14.3 and 14.3.7.

9.5.8.4 Technical Evaluation

The APR1400 consists of four EDGs and their respective support systems such as fuel oil, lube oil, engine cooling water, starting air, and combustion air intake and exhaust systems. The staff reviewed the APR1400 EDECAIES in accordance with NUREG-0800, Section 9.5.8, Revision 3. The staff's acceptance of the EDECAIES is based on the system design being in compliance with the requirements of the GDCs specified above.

9.5.8.4.1 GDC 2, Design bases for protection against natural phenomena

The staff reviewed the DCD to ensure that the EDECAIES is protected from natural phenomena. As indicated in DCD Section 9.5.8.3, the EDECAIES portions that are required for safety function performance are classified as safety-related, seismic Category I, safety Class 3. The exhaust duct and vent stack are protected from external missiles. In addition, DCD Figure 9.5.8-1 shows a missile-protected roof penetration is included for the exhaust gas line exiting the building to the stack. DCD Tier 2, Table 3.2-1 lists the components of the combustion air intake and exhaust duct work as safety-related (SC-3), Quality Group G, and seismic Category I, which is consistent with Figure 9.5.8-1 of the DCD. As indicated in DCD Tier 2, Section 3.2.2, "System Quality Group Classification," Quality Group G pertains to safety-related fluid systems and components that are designed to codes other than ASME Section III. Figure 9.5.8-1 further designates drains for the exhaust silencer and exhaust stack as Quality Group D, seismic Category II. Although Table 3.2-1 indicates all components of EDECAIES are Quality Class G, Figure 9.5.8-1 does not define seismic and quality group designation for piping located upstream of designation flag/classification on the exhaust gas outlet line. Therefore, the staff issued RAI 127-8010 (ML15227A007), Question 09.05.08-3, requesting the applicant to provide additional description and designation of this piping to ensure it would not degrade the operability of seismic Category I SSCs during a design basis accent event. In its response dated September 14, 2015 (ML15257A409), the applicant stated that the exhaust pipe spool are dependent on the engine model and type. However, the EDECAIES, including the exhaust pipe spool, are designed as Safety Class 3, seismic Category I, and Quality Group G. The staff finds that the proposed safety class, seismic category, and quality group will ensure that the EDECAIES will meet GDC 2. Therefore, the staff finds that the RAI response is adequate and considers this issue resolved.

There are four EDG units for the APR1400 and each EDG provides Class 1E power to one of the four independent Class 1E buses during a LOOP event. Two are located in the auxiliary building and two in the EDGBs. The two EDG units in the auxiliary building are separated so they are on opposite sides of the building in a mirror-like configuration. The seismic Category I EDGB houses the other two EDG units and supporting equipment in two separate compartments. Each EDG compartment is designed to be physically separate to provide protection from fire, aircraft, missiles, and the environment. The EDGBs and auxiliary building are both classified as seismic Category I, allowing them to withstand the effects of natural phenomena including earthquakes, tornadoes, hurricanes, floods, as well as external missiles, as described in DCD Tier 2, Sections 3.3, 3.4, and 3.8.

The exhaust duct and vent stack are protected from external missiles. The combustion air intake opening is located approximately 6.10 m (20 ft) above grade level to minimize the intake of dust in the EDG engine. The diesel engine exhaust gases are discharged to the atmosphere through a stack in a direction away from the engine air intake with sufficient separation, thereby minimizing the effects of the engine exhaust being drawn into the combustion air inlet. For the reasons discussed in the paragraphs above, the staff finds that the EDECAIES is adequately protected from natural phenomena and, therefore, meets the requirements of GDC 2.

9.5.8.4.2 GDC 4, Environmental and dynamic effects design basses

As indicated in DCD Tier 2, Section 9.5.8.1, Design Bases, the EDECAIES is protected from externally- and internally-generated missiles and pipe breaks as discussed in DCD Sections 3.5 and 3.6, respectively. In addition, each EDG train is located in a dedicated room or

compartment in the EDGB or auxiliary building. There are four separate and independent trains of the EDGs so that the consequence of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks upon an EDECAIES do not lead to a loss of more than one EDG. Each EDG has a separate and independent EDECAIES and a failure of any pressure line will only have the potential to impact the function of the SSCs in that division. Therefore, based on the redundancy of EDGs and separation of EDG locations minimizing impact on multiple EDGs, the staff finds that the EDECAIES meets the requirements of GDC 4. Therefore, the staff has determined that the applicant has demonstrated the EDECAIES has adequate separation and redundancy to preclude the loss of multiple EDGs due to environmental and dynamic effects.

9.5.8.4.3 GDC 5, Sharing of structures, systems, and components

DCD Tier 2, Section 9.5.8 describes that each EDG as having a separate and independent EDECAIES so that a single active failure of any component in one EDECAIES cannot result in a complete loss of more than one EDG. The EDECAIES consists of silencer, filter, expansion joints, air inlet duct, air exhaust piping, and instrumentation. Since, the APR1400 has four independent EDGs, each with a separate and independent EDECAIES that is not shared between other diesel generators or other nuclear units, the staff finds that the EDECAIES design meets the requirements of GDC 5.

9.5.8.4.4 GDC 17, Electric power systems

The staff reviewed the DCD to ensure that no single failure of the EDEAICS will affect multiple EDGs. DCD Tier 2, Section 9.5.8 describes the operation of the EDECAIES. Upon initiation of the diesel engine start, the combustion air is directly taken from outside through an intake filter and air duct and enters the EDG through the turbocharger and the supercharging air coolers. The turbocharger, driven by the hot exhaust gases on one side, compresses the combustion air and forces it into the supercharging air cooler. The supercharging air cooler removes heat from the compressed combustion air, decreasing the air temperature to force more air into the individual cylinders, thereby increasing engine horsepower. Low temperature water flows through the tube side and its temperature increases. The exhaust gases are exhausted from the diesel engine to an exhaust silencer and then vented to the atmosphere through the stack. The design of exhaust piping and silencer does not exceed the manufacturer’s recommended backpressure on the diesel engine.

SRP Section 9.5.8 lists the guidelines for the applicant to meet the requirements of GDC 17, which includes incorporating the recommendations of NUREG/CR 0660. The applicant meets these guidelines as follows:

The guidelines of SRP Section 9.5.8 state that the EDECAIES must meet independence and redundancy criteria. Here, each EDG has a dedicated EDECAIES, and can provide combustion air under all operating modes. Additionally, the combustion air intake system must have a means of reducing airborne particulate over the entire time period requiring emergency power assuming the maximum airborne particulate concentration. DCD Tier 2, Section 9.5.8.1 states the combustion air intake system is provided with air intake filters to reduce the maximum airborne particulate concentration over the entire time period requiring emergency power. Pressure indication and a switch are provided on the local panel to determine the pressure drop across individual air intake filters. staff finds that the dedicated EDECAIES for each EDG

provides independence and redundancy and a means of reducing airborne particulate over the entire time period requiring emergency power, and therefore meets the guidelines of SRP 9.5.8.

SRP Section 9.5.8 also states that the EDECAIS must meet the guidelines of NUREG/CR 0660, which preclude any degradation of continuous engine function, the separation of room ventilation and engine combustion air, and exhaust air should not circulate back into the EDG room, fuel storage room, or any part of the power plant. As indicated in DCD Tier 2, Section 9.5.8.2.1, the combustion air intake opening is located approximately 6.10 m (20 ft) above grade level and filtered to preclude any degradation of continuous engine function. The EDG room ventilation air is drawn through a separate duct and exhausted through a separate return duct system as discussed in DCD Section 9.4.5. The diesel exhaust gases are discharged to the atmosphere in a direction away from the outside air inlet with sufficient separation to minimize the effects of exhaust gas drift to the outside air inlet. These design features meet the guidelines of NUREG/CR 0660.

The applicant has stated that provisions are made to allow for periodic inspection of safety-related components and equipment. Since each EDG is separate and independent, a single active failure in an EDECAIES does not lead to a loss of more than one EDG.

Based on the above, the staff finds the EDECAIES design features, including redundancy and independence, meet the requirements of GDC 17.

9.5.8.4.5 Initial Plant Test Program

The staff evaluated Tier 2, Section 9.5.8.4, to determine whether or not it contains adequate detail to inform the initial test program. DCD Tier 2, Section 9.5.8.4, "Inspection and Testing Requirements," states that the EDECAIES is initially tested using the program detailed in DCD Tier 2, Section 14.2, to demonstrate leaktightness, operability, and the capability of the system to function as intended under accident conditions; thereafter, periodic testing and inspection of the complete EDG system are performed in accordance with the TSs, as described in Chapter 16. However, DCD Tier 2, Section 14.2, does not include any details regarding leaktightness or operability testing of the EDECAIES. Therefore, the staff issued RAI 127-8010, Question 09.05.08-2 requesting the applicant to clarify the testing method applied to the EDECAIES. In its response dated March 10, 2016 (ML16070A134), the applicant stated that operability and capability testing of the EDECAIES are performed during the initial operation tests as described in Section 14.2. Since the EDECAIES cannot be tested independently of the EDG, the system operability and capability is verified during EDG endurance and load test at a load equivalent to the short time rating of the EDG for 2 hours. The applicant proposed revisions to the applicable DCD Tier 2 document, including Section 9.5.8.4 and 14.2.12.1.88 accordingly. The staff found the proposed changes acceptable and subsequently confirmed they have been incorporated into Revision 1 of the DCD. A more detailed evaluation of the initial plant test program can be found in Chapter 14 of this report.

In DCD Tier 2, Section 9.5.8.4, the applicant indicates that system components and piping are tested to pressures designated by ASME Section III Class 3. However, DCD Tier 1, Tables 2.6.2-1 and 3.2-1, indicate that ASME Section III Class 3 is not applicable to the EDECAIES. Therefore, the staff issued RAI 127-8010, Question 09.05.08-1, requesting the applicant to clarify the classification applied to the EDECAIES. In its response dated September 14, 2015 (ML15257A409), the applicant clarified that the EDECAIES is designed in

accordance with the Diesel Engine Manufacturers Association (DEMA) code, not ASME Section III. However, in the proposed revision to Section 9.5.8.4, the applicant stated generically that tested pressures are designated by "manufacturer's standard for safety-related items." Consequently, the staff issued a follow-up RAI 468-8574 (ML16113A216), Question 09.05.08-4, to seek confirmation of the specific standard or code used in designing the EDECAIES. In its response dated June 8, 2016 (ML16160A319), the applicant clarified that the EDECAIES is designed in accordance with the requirements of ASME B31.1, "Power Piping." Intake air duct work is Quality Group G and is designed in accordance with ASME AG-1. Also, diesel engine, engine-mounted components, and generator are Quality Group G and designed in accordance with IEEE 387. Quality assurance requirements for procurement, fabrication, and installation of Quality Group G items are in accordance with Quality Class Q, safety-related requirements. In addition, since system components and piping open to the atmosphere need not be tested in accordance with ASME B31.1, the applicant proposed a revision to DCD Tier 2, Subsection 9.5.8.4 accordingly. The staff found the RAI response acceptable and subsequently confirmed the changes have been incorporated into Revision 1 of the DCD. A more detailed review of the initial plant test program can be found in Chapter 14 of this report.

9.5.8.4.6 ITAAC

The staff reviewed the ITAAC in the DCD to verify that it meets SRP Section 14.2 acceptance criteria. DCD Tier 1 does not contain any figures showing the functional arrangement of the EDECAIES. Therefore, the staff issued RAI 152-8006, Question 09.05.04-6, requesting the applicant to provide functional arrangement drawings to allow acceptable closure of the ITAAC design commitment. In its response dated September 14, 2015, the applicant proposed revisions to applicable DCD Tier 1 sections to provide the appropriate design description, drawing, and ITAAC related to the EDECAIES. The proposed documentation revision provides adequate information to allow the staff to verify the as-built configuration of the EDECAIS system. The staff subsequently confirmed the changes have been incorporated into Revision 1 of the DCD. Therefore, the staff finds that the applicant has properly addressed the requirements of 10 CFR 52.47(b)(1).

9.5.8.4.7 Technical Specifications

The staff reviewed the DCD to ensure that any necessary TS were provided for the EDEAICS. DCD Tier 2, Chapter 16, TS 3.8.1 through TS 3.8.3 provide EDG requirements. There are no specific TS requirements for the EDECAIS. However, EDG testing and surveillance requirements under the above TS will indirectly measure the effectiveness of air intake and exhaust in that these systems are an integral part of EDG performance and capacity. The staff finds this in conformance with NUREG-1432, Revision 4.0, "Standard Technical Specifications - Combustion Engineering Plants." The adequacy of TS is reviewed in Section 16 of this report.

9.5.8.5 Combined License Information Items

No applicable COL information items were identified in the DCD.

9.5.8.6 Conclusion

The staff finds the Emergency Diesel Engine Combustion Air Intake and Exhaust System design acceptable and complying with regulations as stated in the general design criteria of 10 CFR Part 50, Appendix A. This conclusion is based on the staff's technical evaluation that the DCD

meets the requirements of GDC 2, GDC 4, GDC 5, GDC 17, and 10 CFR 52.47(b)(1) for the EDECAIES.

9.5.9 Gas Turbine Generator Facility

9.5.9.1 Introduction

The non-class 1E, non-safety related alternate AC gas turbine generator (AAC GTG) should be designed with independence, redundancy, operational flexibility, and enhanced reliability to perform its function during a LOOP or SBO event. The overall ability of the AAC GTG to perform its standby power source function and to handle SBO or LOOP loads is analyzed in Section 8.4, “Station Blackout,” of this report. In this SER section, the staff reviewed the AAC GTG and supporting systems that enable the AAC GTG to perform its function. Following is the staff’s evaluation of the proposed design.

9.5.9.2 Summary of Application

DCD Tier 1: The DCD Tier 1, Section 2.6.6, “Alternate AC Source,” describes the principal performance characteristics and safety functions of the AAC GTG and its supporting equipment, and includes Table 2.6.6-1, “Alternate AC Source ITAAC.” The AAC GTG is independent from the EDGs and offsite power sources, but can be connected manually to the Class 1E train A or train B bus within 10 minutes in the event of an SBO to support safe shutdown. The AAC GTG has sufficient fuel oil storage capacity to supply power to the required SBO loads for 24 hours, which is greater than the coping time of 16 hours identified in DCD Tier 2 Section 8.4.1.2, “Station Blackout Coping Duration.”

DCD Tier 2: The DCD Tier 2, Section 9.5.9, “Gas Turbine Generator Facility,” and Figure 9.5.9-1, “Gas Turbine Generator Facility Flow Diagram,” provide the AAC GTG system description, which is summarized, in part, below.

The AAC GTG is a 100 percent non-Class 1E standby power source and is physically separated and electrically isolated from the Class 1E EDGs. The AAC GTG is designed with sufficient independence, redundancy, operation flexibility, and enhanced reliability to perform its function during a LOOP or SBO event. The AAC GTG major components include a combustion turbine, reduction gearbox, generator and auxiliaries, provided as a packaged unit, mounted on base skid, and enclosed in a metal enclosure. The AAC GTG supporting auxiliary systems include a fuel oil storage and transfer system, starting system, lubrication system, combustion air intake and exhaust system, and GTG enclosure ventilation system.

ITAAC: DCD Tier 1, Table 2.6.6-1, provides ITAAC requirements for the AAC GTG. The design description of the AAC GTG is also provided in DCD Tier 1, Section 2.6.6.1.

Initial Test Program: Initial plant testing for the AAC GTG system is described in DCD Tier 2, Sections 14.2.12.1.89, “Alternate AC Source System Test,” and 14.2.12.1.90, “Alternate AC Source Support Systems Test.”

Technical Specifications: DCD Tier 2, Chapter 16 does not include any TSs regarding the AAC GTG.

9.5.9.3 Regulatory Basis

There is currently no corresponding NUREG-0800 section for staff review of the use of gas turbine generators as non-safety related alternate AC sources in the event of an SBO. Insofar as it is applicable to the capability of the AAC GTG and its supporting systems to perform their functions for SBO coping time, the staff evaluated DCD Tier 1, Section 2.6.6, and DCD Tier 2, Section 9.5.9, using DC/COL-ISG-021, "Interim Staff Guidance on the Review of Nuclear Power Plant Designs Using a Gas Turbine Driven Standby Emergency Alternating Current Power System," dated January 2011 (ML102510164) ("Interim AAC GTG guidance"). While this guidance was developed for the staff review of gas turbine generators used as safety-related emergency onsite power sources, it does provide GTG-specific guidance regarding support systems, operations, controls, and maintenance. In addition, the staff reviewed the relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, as specified in NUREG-0800, Section 8.4, "Station Blackout," as it relates to the AAC GTG support systems performing their function related to SBO coping time.

10 CFR 50.63, as it relates to the capability to withstand and recover from an SBO.

> 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 AEA, and the NRC's regulations.

9.5.9.4 Technical Evaluation

The staff reviewed the AAC GTG design to ensure that it is capable of providing AC power in the case of an SBO for the station coping time as calculated by the applicant and reviewed by the staff in Section 8.4 of this report.

The AAC GTG is provided as a completely packaged, fully assembled, skid-mounted unit. It is a non-safety related, non-Class 1E standby power source provided for coping with SBO in accordance with 10 CFR 50.63 and RG 1.155. The AAC GTG, including its fuel tanks and supporting systems, is housed in its own seismic Category III building, separate from the EDGs. The AAC GTG auxiliary systems include a fuel oil storage and transfer system, starting system, lubrication system, combustion air intake and exhaust system, and GTG enclosure ventilation system. The staff's acceptance of the AAC GTG and supporting systems is based on the system design being in compliance with the requirements of the regulations specified above.

10 CFR 50.63 requires that each light water reactor be able to withstand and recover from an SBO of a specified duration. RG 1.155, dated August 1988, provides guidance acceptable to the staff for meeting the requirements of 10 CFR 50.63. Staff evaluation of RG 1.155 Regulatory Position 1 regarding EDG target reliability levels, reliability programs, and procedures for restoring AC power; Regulatory Position 2 regarding offsite power; and Regulatory Positions 3.1 and 3.2 regarding coping time evaluation and capability, is provided in Section 8.4 of this report.

The applicant chose an AAC power source to satisfy the requirements of 10 CFR 50.63, specifically, the AAC GTG. In DCD Tier 2, Section 9.5.9, the applicant described the AAC GTG as a packaged, fully-assembled, skid-mounted unit contained in a dedicated seismic Category III building appropriately protected against weather-related events. The four EDG units for the

APR 1400 are physically separated from the AAC GTG (two EDG units located in the auxiliary building and the other two located in the EDGB), whereas the AAC GTG and its supporting equipment is housed in a dedicated seismic Category III Building. Since the EDGs and the AAC GTG are housed in separate, appropriately protected buildings, the staff finds that the AAC GTG building location meets the guidance in RG 1.155, Section 3.3.5, Item 2, in that physical separation will minimize the potential for common cause failure between the EDGs and the AAC GTG and is, therefore, acceptable. Electrical separation of the EDGs and AAC GTG is discussed in Section 8.4 of this report.

In DCD Tier 1, Section 2.6.6.1, the applicant stated that the AAC GTG fuel oil system is independent from that of the Class 1E EDGs. In DCD Tier 2, Section 9.5.9.2, "System Description," the applicant states that the fuel oil system consists of two redundant 100 percent capacity fuel oil transfer pumps, one fuel oil storage tank, one fuel oil day tank, and associated valves, piping, and instrumentation. The fuel oil storage system (the fuel oil storage tank and fuel oil day tank) has enough fuel capacity for the GTG to continuously power required shutdown loads for 24 hours. The fuel oil day tank has a capacity equivalent to at least 60 minutes of AAC GTG operation at full load. When a low level alarm in the day tank is activated by a low-level switch, one of two fuel oil transfer pumps automatically starts in order to take suction from the fuel oil storage tank, through a strainer, and transfer fuel oil to the fuel oil day tank. Once the fuel oil day tank high level alarm is reached, the fuel oil transfer pump automatically turns off. Per DCD Tier 2, Figure 9.5.9-1, "Gas Turbine Generator Facility Flow Diagram (2 of 2)," a tank vent is installed for the fuel oil storage tank, as well as a fill connection from the outdoors. Additionally, the fuel oil day tank has an overflow line from the day tank to the fuel oil storage tank in the case of overfilling, as well as a tank vent. As discussed below, an ITAAC is provided to ensure that the fuel oil transfer pump is able to increase day tank level while the AAC GTG is running at rated load. Based on the information provided by the applicant regarding system design and separation from the EDGs, the staff finds that the AAC GTG fuel oil system conforms to guidance in RG 1.155, Section 3.3.5, Item 4, in that it is designed to provide adequate fuel to power the GTG during SBO conditions for the required coping time, and is, therefore, acceptable.

DCD Tier 2, Section 9.5.9.2 states that the AAC GTG combustion air intake and exhaust system is provided to supply clean air to the GTG and to exhaust the GTG exhaust gases. According to DCD Tier 2, Figure 9.5.9-1, "Gas Turbine Generator Facility Flow Diagram (1 of 2)," the AAC GTG exhaust gases are discharged to the atmosphere through an exhaust duct in a direction away from the GTG air intake, thereby minimizing the effects of the GTG exhaust being drawn into the combustion air inlet. The AAC GTG combustion air intake and exhaust system is non-safety related and is separate from that of the EDGs (the EDG combustion air intake and exhaust system is located in separate buildings). An ITAAC is provided to ensure that the AAC GTG air intakes are separated from the exhaust ducts, with an acceptance criteria that the air intake and air exhaust are separated by analyzed distance and orientation. The staff finds the AAC GTG combustion air intake and exhaust system design acceptable since it ensures that the AAC GTG will be available to perform its SBO coping function as required by 10 CFR 50.63.

DCD Tier 2, Section 9.5.9.4, "Inspection and Testing Requirements," states that the AAC GTG fuel oil tank and day tank will receive non-destructive evaluation in accordance with ASME Section VIII requirements, and that fuel oil samples will be tested upon delivery for quality in accordance with ASTM D975. Additionally, AAC GTG system components and piping are pressure tested as required by appropriate codes. Pressure testing of the AAC GTG system and piping would verify leaktightness of the system, and is, therefore, acceptable. Further, DCD

Tier 2, Section 14.2, includes Sections 14.2.12.1.89, and 14.2.12.1.90. Staff review of the testing specified in DCD Tier 2, Section 14.2, is discussed in Section 14.2 of this report. Regarding periodic maintenance and testing to ensure reliability and operability of the AAC GTG, in a November 18, 2015, response (ML15322A404) to RAI 165-8192, Question 08.04-6 (ML15295A490), the licensee committed to update DCD Tier 2, Section 8.4.2.1, to reflect that all AAC power systems, including the AAC GTG support systems, which are provided to mitigate an SBO conform to the requirements in 10 CFR 50.65, “Requirements for monitoring the effectiveness of maintenance at nuclear power plants.”

9.5.9.4.1 Initial Plant Test Program

Applicants for combined licenses must provide plans for pre-operational testing and initial operations in accordance with 10 CFR 52.79(a)(28) requirements. DCD Tier 2, Tier 2, Sections 14.2.12.1.89, “Alternate AC Source System Test,” and 14.2.12.1.90, “Alternate AC Source Support Systems Test,” describe the initial test program for the AAC GTG.

Section 14.2 of this report addresses the staff’s evaluation of the initial test program for APR1400 AAC GTG.

9.5.9.4.2 ITAAC

The staff evaluated the AAC GTG ITAAC against the requirements in 10 CFR 52.47(b)(1). DCD Tier 1, Section 2.6.6, “Alternate AC Source,” does not contain any figures showing (or any textual description) the functional arrangement of the AAC GTG or its supporting systems. Therefore, the staff issued RAI 501-8635 (ML16188A168) Question 09.05.04-16, requesting the applicant to provide functional arrangement descriptions and drawings to allow acceptable closure of the ITAAC design commitment. In its response dated August 10, 2016 (ML16223A57), the licensee stated the AAC GTG supporting systems such as lubrication, cooling, ventilation, and starting are located in the AAC GTG packaged enclosure; therefore, there is no specific functional arrangement information available. For further clarification, the licensee proposed a revision to DCD Tier 1, subsection 2.6.6.1 and DCD Tier 2, subsection 9.5.9 to include additional functional arrangement and design information for the AAC GTG fuel oil supply system to allow for acceptable closure of ITAAC design commitment. The staff reviewed the proposed changes and found it acceptable and subsequently confirmed the changes have been incorporated into Revision 1 of the DCD.

Additionally, the inspections, tests, analyses statement for design commitment 8.a in DCD Tier 1, Table 2.6.6-1, “Alternate AC Source ITAAC,” indicates that “an analysis and test of each fuel oil transfer pump will be performed to determine the maximum demand at gas turbine generator (GTG) continuous rated load while simultaneously increasing day tank level.” The acceptance criteria for the design commitment is as follows: a report exists and concludes that the size and flow rate of each as-built GTG fuel oil transfer pump bounds the analysis. The use of the expression “a report exists” is not sufficient for verification that the “as-built” (as installed) AAC GTG fuel oil pumps meet the design commitment, as the acceptance criteria does not verify the specific design commitment. By extension, performance of the ITAAC as written may not provide reasonable assurance that the AAC GTG would be able to perform its function for the duration of the required SBO coping time, given that the fuel oil day tank contains enough fuel oil for only 60 minutes of continuous operation at GTG rated load. The acceptance criteria use of a “report exists” would provide confirmation that the components and system are properly sized and designed to meet its demand; however, the use of a report would not verify that the

actual installed components and system would perform its SBO function for the coping time determined by the applicant (specifically, that at continuous rated AAC GTG load, the fuel oil day tank level will rise with each fuel oil transfer pump running). Additionally, the ITA for design commitment 8.a does not specify that the testing and analysis are performed on the as-built fuel transfer pumps. Accordingly, the staff issued RAI 501-8635, Question 09.05.04-15 (ML16188A168), requesting that the applicant describe the specific inspections or tests in DCD Tier 1, Table 2.6.6-1 to verify that the "as-built" AAC GTG meets the design and performance commitments following the completion of its installation at its final location at the plant site. In its response dated August 2, 2016 (ML16215A217), the licensee proposed a revision to DCD Tier 1, subsection 2.6.6.1 and Table 2.6.6-1, to specify testing and analysis are performed to ensure the as-built fuel oil transfer pump would be able to perform its function for the duration of the required SBO coping time. The staff found the RAI response acceptable and subsequently confirmed the changes have been incorporated into Revision 1 of the DCD.

A more detailed review of the ITAAC can be found in chapter 14 of this report.

9.5.9.4.3 Technical Specifications

There are no specific TSs associated with the AAC GTG.

9.5.9.5 Combined License Information Items

The following is a list of applicable COL information items.

Combined License Information Items

Item No.	Description	DCD Tier 2 Section
9.5(14)	The COL applicant is to provide a reliable starting method for the AAC GTG.	9.5.9.2
9.5(15)	The COL applicant is to provide the system design information of AAC GTG building HVAC system including flow diagram, if the AAC GTG building requires the HVAC system.	9.5

COL 9.5(14) states that the COL applicant is to provide a reliable starting method for the AAC GTG. In DCD Tier 2, Section 9.5.9.2, the applicant stated that the AAC GTG can be independently started with several diverse starting methods such as compressed air, diesel engine, DC motor, or electro hydraulic starter. The staff finds it is appropriate for the COL applicant to choose the type of AAC GTG starting method given that a number of GTG starting methods exist which are relatively equal in reliability. In COL 9.5(15), the COL applicant is to provide the design of the AAC GTG building HVAC system, if required. The staff finds this COL information item acceptable since the necessity of an AAC GTG building HVAC system would likely be site-specific, given the air-cooled nature of the GTG system.

9.5.9.6 Conclusion

The staff evaluated DCD Tier 1, Section 2.6.6, and DCD Tier 2, Section 9.5.9, using DC/COL-ISG-021, “Interim Staff Guidance on the Review of Nuclear Power Plant Designs Using a Gas Turbine Driven Standby Emergency Alternating Current Power System,” dated January 2011 (ML102510164) (“Interim AAC GTG guidance”). While this guidance was developed for the staff review of gas turbine generators used as safety-related emergency onsite power sources, it does provide GTG-specific guidance regarding support systems, operations, controls, and maintenance. In addition, the staff reviewed the relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, as specified in NUREG-0800, Section 8.4, “Station Blackout,” as it relates to the AAC GTG support systems performing their function related to SBO coping time. The staff finds the APR1400 Gas Turbine Generator Facility design acceptable and in compliance with the above regulations as applicable to the capability of the AAC GTG and its supporting systems to perform their functions for SBO coping time.