

3 DESIGN OF STRUCTURES, SYSTEMS, COMPONENTS, AND EQUIPMENT

Chapter 3, "Design of Structures, Components, Equipment, and Systems," of this safety evaluation report (SER) describes the results of the review by the staff of the U.S. Nuclear Regulatory Commission (NRC or Commission), hereinafter referred to as the staff, of Chapter 3 of Korea Electric Power Corporation (KEPCO) and Korea Hydro & Nuclear Power Co., Ltd (KHNP), hereinafter referred to as the applicant, Design Control Document (DCD), for the design certification (DC) of the Advanced Power Reactor 1400 (APR1400).

There is no information pertaining to the regulatory treatment of non-safety systems or the minimization of contamination in this area of review.

3.1 Conformance with the NRC General Design Criteria

Pursuant to Title 10 of the Code of Federal Regulations (10 CFR), Section 52.47(a), an application for a standard DC, must contain a final safety analysis report (FSAR) that describes the facility, presents the design bases and the limits on its operation, and presents a safety analysis of the structures, systems, and components (SSCs) and of the facility as a whole, and must include the following information.

10 CFR 52.47(a)(3), requires the application to include:

The design of the facility including:

- (i) The principal design criteria for the facility. Appendix A to 10 CFR Part 50, "General Design Criteria (GDC)," establishes minimum requirements for the principal design criteria for water cooled nuclear power plants similar in design and location to plants for which construction permits have previously been issued by the Commission and provides guidance to applicants in establishing principal design criteria for other types of nuclear power units;
- (ii) The design bases and the relation of the design bases to the principal design criteria;
- (iii) Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the design will conform to the design bases with an adequate margin for safety.

The DCD Tier 2, Section 3.1, "Conformance with NRC General Design Criteria," addresses how the APR1400 design conforms to the GDC.

Chapter 3 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, (LWR Edition)," (SRP), begins with Section 3.2.1, "Seismic Classification," in general, conformance to the applicable GDC is discussed in each individual section of this chapter.

3.2 Classification of Structures, Systems, and Components

In Section 3.2, "Classification of Structures, System, and Components," of the DCD, the applicant states that SSCs in the APR1400 are classified by safety function, seismic category, quality group (QG), and codes and standards. As defined in 10 CFR 50.2, "safety-related structures, systems and components," means those SSCs that are relied upon to remain functional during and following design basis events to assure: (1) the integrity of the reactor coolant pressure boundary (RCPB), (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the applicable guideline exposures as set forth in 10 CFR 50.34(a)(1), or 10 CFR 100.11, as applicable. This section presents a review of the methodology used in the categorization of SSCs in the APR1400.

3.2.1 Seismic Classification

3.2.1.1 Introduction

GDC 2, "Design bases for protection against natural phenomena," of 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," in part, requires that SSCs important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. This section documents the staff's review of the seismic classification of SSCs (including foundations and supports) and the interfaces between SSCs of different classifications.

3.2.1.2 Summary of Application

DCD Tier 2, Section 3.2.1 and Table 3.2-1 identify the APR1400 seismic classification criteria and the seismic classification categories for APR1400 SSCs. These SSCs are classified as seismic Category I, seismic Category II, or seismic Category III. Seismic Category I is consistent with the guidance of Regulatory Guide (RG) 1.29, "Seismic Design Classification," Revision 4. Seismic Category II is defined to represent the specific circumstances discussed in Regulatory Position C.2 of RG 1.29, Revision 4, which describes a method that the staff considers acceptable for use in identifying and classifying those features of light-water-reactor (LWR) nuclear power plants that must be designed to withstand the effects of the (SSE). Seismic Category III is defined as all SSCs not covered by seismic Category I or II, Table 3.2-1 identifies the seismic classification of electrical systems in addition to the SSCs within the review scope of SRP, although Chapter 8 of this SER directly addresses the seismic classification of electrical systems. Piping and instrumentation diagrams (P&IDs), in other sections of the APR1400 DCD, indicate locations where the seismic classification changes in fluid systems.

DCD Tier 2, Table 3.2-1 identifies the applicability of the quality assurance (QA) requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to the SSCs. SSCs are given one of the following designations:

- Yes - Compliance with the requirements of 10 CFR Part 50, Appendix B is required;

- A - Augmented QA requirements of Appendix B, to 10 CFR Part 50, applied; and
- N/A - The requirements of 10 CFR Part 50, Appendix B are not required.

The augmented designation is specified for certain nonsafety-related SSCs. These include SSCs in the areas of anticipated transient without scram (ATWS) prevention, station blackout mitigation, and fire protection, as well as seismic Category II SSCs, external injection provision to cope with severe accidents, and risk-significant SSCs determined by the design reliability assurance program.

DCD Tier 2, Section 3.2.1, commits to conformance with RG 1.29 to fulfill the requirements of GDC 2. This section further commits to conformance with RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants"; RG 1.151, "Instrument Sensing Lines"; and RG 1.189, "Fire Protection for Nuclear Power Plants," to provide guidance in the design and classification of radioactive waste management SSCs, instrument sensing lines, and fire protection SSCs, respectively.

3.2.1.3 *Regulatory Basis*

The staff reviewed DCD Tier 2, Section 3.2.1, in accordance with SRP Section 3.2.1, which identifies RG 1.29 as guidance for an acceptable method of identifying and classifying those plant features that should be designed to withstand the effects of the SSE. The staff's acceptance of the design is based on compliance with the regulations discussed below:

- Appendix A to 10 CFR Part 50, GDC 1, "Quality Standards and Records," requires, in part, that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.
- Appendix A to 10 CFR Part 50, GDC 2 requires, in part, that nuclear power plant SSCs important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. This requirement applies to both pressure-retaining and nonpressure-retaining SSCs that are part of the RCPB and other SSCs important to safety. SSCs that are important to safety ensure various safety functions, including the following:
 - Integrity of the RCPB;
 - Capability to shut down the reactor and maintain it in a safe-shutdown condition; and
 - Capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the exposure requirements in 10 CFR 50.34(a)(1), or 10 CFR 100.11.
- Appendix A to 10 CFR Part 50, GDC 60, "Control of Releases of Radioactive Materials to the Environment," requires that the nuclear power unit design include means to suitably control the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid waste produced during normal

reactor operation, including anticipated operational occurrences (AOOs). The release of radioactive materials from external man-induced events and design basis accidents must also be controlled.

- Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” to 10 CFR Part 50, defines the safe-shutdown earthquake (SSE) for which these SSCs important to safety must be designed to withstand. An evaluation of the maximum earthquake potential forms the basis of the SSE; these SSCs important to safety are designed to remain functional through an earthquake that produces the maximum vibratory ground motion.
- RG 1.29, Revision 4, designates those plant features designed to remain functional in the event of an SSE as seismic Category I and addresses five main topics:
 - Regulatory Position C.1 of RG 1.29, states that applicants should apply the pertinent QA requirements of 10 CFR Part 50, Appendix B, to all activities affecting the safety-related functions of seismic Category I SSCs.
 - Position C.2 of RG 1.29, states that those portions of non-seismic Category I SSCs whose continued function is not required, but whose failure could reduce the functioning of any seismic Category I SSC to an unacceptable level or could result in an incapacitating injury to occupants of the control room, should be designed and constructed so that an SSE could not cause such failure.
 - Position C.3 of RG 1.29, provides guidelines for designing interfaces between seismic Category I and non-seismic Category I SSCs.
 - Position C.4 of RG 1.29, states that the pertinent QA requirements of Appendix B, to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” should be applied to all activities affecting the safety-related functions of SSCs discussed in Positions C.2 and C.3.
 - Position C.5 of RG 1.29, refers to RG 1.189, for seismic requirements applicable to the fire protection system (FPS).
- RG 1.143, referenced in RG 1.29, Revision 4, provides guidance for establishing the seismic design requirements of radioactive waste management SSCs to withstand earthquakes, as set forth in GDC 2 and GDC 60. RG 1.143 identifies several radioactive waste SSCs requiring some level of design consideration.
 - RG 1.151, referenced in RG 1.29, Revision 4, provides guidance for establishing requirements for the design and installation of safety-related instrument sensing lines.

3.2.1.4 *Technical Evaluation*

This section discusses the technical evaluation of the seismic classification portion of the application. Certain issues have commonality across multiple SRP sections and are discussed further in other SER sections. For instance, certain classification methodology issues are common to both SRP Section 3.2.1, and SRP Section 3.2.2. Further discussion of these issues is provided in SER Section 3.2.2.

3.2.1.4.1 *Conformance with Regulatory Guides 1.29, 1.151, 1.143, and 1.189*

In DCD Tier 2, Section 3.2.1, the applicant indicates that the seismic classification used in APR1400 complies with the seismic criteria stated in RG 1.29. The applicant further states that radioactive waste management SSCs, instrument sensing lines and their supports, and FPSs are designed in accordance with the seismic design criteria specified in RGs 1.143, 1.151, and 1.189, respectively. Conformance to these RGs is considered an acceptable means of meeting the requirements of GDC 2, GDC 60, Appendix A to 10 CFR Part 100, and Appendix S to 10 CFR Part 50. The applicant initially took exception to RG 1.29, as indicated in Note (N 3) of DCD Tier 2, Revision 0, Table 3.2-1:

Loss of cooling water and/or seal water service to the reactor coolant pumps (RCPs) may require stopping the pumps. However, the continuous operation of the pumps is not required during or following an SSE. The auxiliaries are therefore not necessarily seismic Category I. The provision for cooling water to the pump bearing oil cooler and pump motor air cooler does not conform to the requirements of RG 1.29.

In order to clarify the applicant's rationale for this exception, the staff issued Request for Additional Information (RAI) 29-7926, Question 03.02.01-5 (ML15166A533). In its response to RAI 29-7926, Question 03.02.01-5 (ML15302A556), which was also incorporated into the DCD the applicant clarified the table entry for the RCP, specifying that the safety function of the RCP is to maintain RCPB integrity and that continuous operation of the pump during or following an SSE is not required. Because of this, the RCP auxiliaries previously considered exceptions to RG 1.29, are no longer classified as such, since the safety function of the RCP is still maintained without the pump bearing oil cooler and pump motor air cooler. The table entry for the RCP is further enhanced by specifying that the components of the RCP that make up the RCPB are those that must be categorized as Safety Class 1, analogous to Quality Group A, as defined in 10 CFR 50.55(a).

3.2.1.4.2 *Criteria Development*

The staff reviewed the criteria identified in DCD Tier 2, Section 3.2.1, that the applicant used to provide appropriate seismic classification to SSCs in DCD Tier 2, Table 3.2-1. In addition to the initial exception discussed above, the application differs from RG 1.29, in that it does not specify SSCs as only seismic Category I, or non-seismic Category I. Rather, in DCD Tier 2, the applicant uses the term seismic Category II and seismic Category III in addition to seismic Category I. The methodology used for seismic Category II—non-seismic SSCs whose failure could adversely affect seismic Category I SSCs or result in incapacitating injuries to personnel in the main control room—is consistent with RG 1.29, Regulatory Position C.2. Seismic Category III is used for all SSCs not covered by seismic Category I or II. The criteria identified in the DCD, are equivalent to those outlined in RG 1.29, Revision 4. Therefore, the staff finds

that the classification criteria for seismic Category I, seismic Category II, and seismic Category III are consistent with the guidance of RG 1.29, Revision 4.

3.2.1.4.3 *Application of RG 1.29 to Seismic Category I*

The staff reviewed the applicant's treatment of seismic Category I SSCs to verify conformance with RG 1.29. DCD Tier 2, Revision 0, Section 3.2.1 did not have any discussion regarding the classification of pipe whip restraints. In a public meeting on June 30, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15183A392), during discussion of DCD Tier 2, Section 3.6.2, the applicant committed to update DCD Tier 2, Table 3.2-1 in combination with the other RAI responses described in this section to include the classification of protective features for pipe ruptures. Further discussion of this issue can be found in SER Section 3.6.2.

System Boundaries

In RG 1.29, Regulatory Position C.3, indicates that, concerning the interface between seismic Category I and non-seismic Category I SSCs, the dynamic analysis requirements should be extended to the first anchor point in the non-seismic Category I system. DCD Tier 2, Section 3.2.1, states that seismic Category I requirements extend to the first seismic anchor beyond the interface of the classification change. This is in conformance with RG 1.29, Regulatory Position C.3. The staff reviewed selected P&IDs in order to identify the location of the classification change. While the P&IDs in the DCD did show a sufficient level of detail to indicate the transition between seismic classifications on the component level, they did not include supports, which would not be expected to be depicted on the DCD-level P&IDs. While the applicant did state that supports for piping and components have the same seismic classifications as the piping and components that are supported (consistent with RG 1.29), additional verification was sought on the P&IDs. During an audit of design and procurement specifications, held from August 24 - 27, 2015 (ML15350A057), the staff examined detailed P&IDs to verify system classifications, and also received confirmation from the applicant that supports (to be completed as part of detailed design) have the same seismic classifications as the piping and components that are supported (consistent with RG 1.29). The information in the DCD, combined with the information confirmed in this audit, provides the staff with reasonable assurance that the applicant's treatment of system boundaries, including supports for piping and components, is adequate.

Quality Assurance

In DCD Tier 2, Section 3.2.1, the applicant states that seismic Category I SSCs meet the QA requirements of 10 CFR Part 50, Appendix B. This conforms to the guidance in RG 1.29, Regulatory Position C.1. However, staff identified several SSCs listed in Table 3.2-1 as inconsistent with this statement and raised this to the applicant during a public meeting on April 14-15, 2015. In its letter dated June 1, 2015 (ML15152A248), the applicant submitted a DCD markup that clarified that the pertinent QA requirements of 10 CFR Part 50, Appendix B would be applied to seismic Category I SSCs. This markup was incorporated into the DCD. This is consistent with RG 1.29 and resolves the issue of seismic Category I SSCs not meeting the pertinent QA requirements of 10 CFR Part 50, Appendix B. Based on its review of DCD Tier 2, Table 3.2-1, and the incorporation of the changes discussed above, the staff finds that the

applicant has consistently applied methodology consistent with RG 1.29, Regulatory Position C.1, to seismic Category I SSCs.

Given the above considerations, the staff finds that the guidance of RG 1.29 has been applied to seismic Category I SSCs.

3.2.1.4.4 *Application of RG 1.29 to Seismic Category II*

Regulatory Position C.2 of RG 1.29, states that those portions of non-seismic Category I SSCs of which continued function is not required, but of which failure could reduce the functioning of any seismic Category I SSC to an unacceptable 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.

In RAI 29-7926, Question 03.02.01-3 (ML15166A533), the staff requested the applicant to clarify the definition of seismic Category II on DCD Tier 2, Section 3.2.1, Page 3.2-4 to address consistency with RG 1.29, Regulatory Position C.2. In its response to RAI 29-7926, Question 03.02.01-3 (ML15302A556), the applicant updated DCD Tier 2, Section 3.2.1, in the DCD to state that seismic Category II SSCs are those which do not perform a safety-related function, and whose continued function is not required, but whose structural failure could reduce the functioning of a seismic Category I SSC to an unacceptable safety level or could result in incapacitating injury to occupants of the control room.

The staff finds this approach acceptable because the definition is consistent with Regulatory Position C.2 of RG 1.29.

During review of the chemical and volume control system (CVCS), the staff noted that DCD Tier 2, Table 3.2-1, has Division 1 component cooling water system (CCW) piping for the letdown heat exchanger supply and return identified as seismic Category II, Quality Group D. However, the letdown heat exchanger itself is classified as seismic Category I, Quality Group C. Therefore, the staff issued RAI 29-7926, Question 03.02.01-6 (ML15166A533), requesting the applicant to clarify why the classification was not consistent.

In its response to RAI 29-7926, Question 03.02.01-6 (ML16232A559), the applicant indicated that the letdown heat exchanger was conservatively classified higher in order to support uniform manufacturing requirements for the heat exchanger and provide a higher degree of mechanical integrity. The function of the heat exchanger and the supply and return piping is nonsafety-related, and would thus support a classification of seismic Category II, Quality Group D. The applicant's voluntary upgrade of the heat exchanger's classification is acceptable, as it is more conservative than the associated guidance. Additionally, the applicant has shown the transition between classifications to occur at the flange between the piping and the heat exchanger – an easily identifiable, discrete location that can be clearly located both in the field and on drawings.

3.2.1.4.5 *Inconsistencies in Table 3.2-1*

The staff reviewed DCD Tier 2, Revision 0, Table 3.2-1, and identified several entries needing additional clarification. Some entries had multiple classifications assigned to the SSC, without a clear way to distinguish how the separation would be determined. This prompted the staff to issue RAI 30-7927, Question 03.02.02-1. In response to this RAI, the applicant revised many entries in DCD Tier 2, Table 3.2-1, to better clarify the separation in classifications. Additionally,

the applicant provided explanation for the multiple classifications for the “Non-safety related” entry for nuclear steam supply system (NSSS) process instrumentation. Specifically, the applicant indicated that there are more than 300 instruments included in the NSSS process instrumentation and those nonsafety-related instruments are not required to function during and after a seismic event (thus, they need not be seismic Category I). The nonsafety-related instruments which are located near safety related equipment and could potentially affect its safety function during a seismic event are classified as seismic Category II, and all remaining nonsafety-related instruments are classified as seismic Category III. This explanation is consistent with the applicant’s seismic classification definitions (which conform to RG 1.29), and is therefore acceptable.

The staff also identified inconsistent application of an identifier intended for seismic Category II SSCs within DCD Tier 2, Revision 0, Table 3.2-1. Specifically, “(3)(d),” is noted in the “Remarks,” column of Table 3.2-1, which designates the SSC as a seismic Category II SSC, requiring augmented quality controls. The staff sought clarification in RAI 29-7926, Question 03.02.01-4, which requested verification that seismic Category I and III SSCs with the seismic Category II identifier in the “Remarks,” column were not intended to be seismic Category II SSCs and that seismic Category II SSCs without the identifier were correctly classified as seismic Category II SSCs. The applicant provided a mark-up of Table 3.2-1, which adequately addresses this issue with the response to RAI 72-8020, Question 03.02.02-5, which was incorporated into the DCD.

3.2.1.4.6 *Treatment of Radioactive Waste Management SSCs*

The staff has reviewed the information presented in DCD Tier 2, Section 3.2.1, and Table 3.2-1. The staff’s review of the systems and equipment qualification can be found in Sections 10.4.8, 11.2, 11.3, and 11.4 of this safety evaluation. In the staff’s review of the radioactive waste systems, the staff observed several systems listed as radioactive waste safety class RW-IIa, the most stringent classification provided in RG 1.143. The staff confirmed that the DCD states that the radioactive waste treatment structure will be designed to RW-IIa, as found in footnote 4 of DCD Tier 2, Table 3.2-1. The staff also observed that components for the Steam Generator Blowdown system are housed within the seismic Category I auxiliary building, whose structural requirements exceed those for the classification of RW-IIa.

The staff has reviewed the information present for treatment of radioactive waste management SSCs and finds that the applicant conforms to RG 1.143 and the staff finds appropriate the RW IIa classification provided in DCD Tier 2, Table 3.2-1.

3.2.1.4.7 *Treatment of Instrument Sensing Lines*

In DCD Tier 2, Section 7.2.2.3 and 7.3.2.3, as well as the Safety I&C System Technical Report (APR1400-Z-J-NR-14001), the applicant discusses the treatment of cabling and sensing lines. Discussion of the applicant’s commitment to the guidance of RG 1.151, and the staff’s review of this topic is in SER Section 7.1.

3.2.1.4.8 *Treatment of Fire Protection Structures, System, and Components*

In DCD Tier 2, Section 9.5.1, the applicant discusses the treatment of fire protection SSCs. Specifically, the applicant mentions a seismic Category I water supply system that provides

water to standpipes and hose connections for manual firefighting in areas that contain safety-related systems and components required for safe shutdown in the event of an SSE.

This water system includes two 100 percent capacity seismic fire-protection water tanks and pumps. A check valve isolates the normal fire-protection water supply from the seismic Category I header upon loss of system pressure due to a seismic event. Firehose and standpipe systems located in the containment, EDG, and auxiliary buildings meet seismic Category I requirements.

The staff reviewed the above information against the guidance found in RG 1.189, specifically that water should be supplied to at least two standpipes and hose connections for manual firefighting in areas containing equipment required for safe plant shutdown in the event of an SSE. Additionally, this piping system should be analyzed for SSE loading and should be supported to ensure system pressure integrity. Finally the piping and valves should, at a minimum, satisfy ASME B31.1. The staff reviewed the DCD against these criteria and confirmed that they are met. Therefore, the staff finds that the applicant has submitted a FPS that is seismically categorized in accordance with the guidance of RG 1.189. Additional evaluation of the FPS is provided in SER Section 9.5.1.

3.2.1.5 Combined License Information Items

DCD Tier 2, Section 3.2.1, contains the following combined license (COL) information item pertaining to seismic classification. As indicated, the applicant specifies the identification of seismic classification for site-specific SSCs as a COL action item. The staff considers this acceptable, as site-specific SSCs are unique to the COL applicant and should be addressed at the time of COL application. The staff concludes that the applicant has adequately addressed the need for COL items for this review section.

Table 3.2.1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.2(1)	The COL applicant is to identify the seismic classification of site-specific SSCs that are to be designed to withstand the effects of an SSE.	3.2.1

3.2.1.6 Conclusion

The SSCs (excluding electrical features) that are important to safety and that are required to withstand the effects of an SSE and remain functional have been classified as seismic Category I items and have been identified in an acceptable manner in Table 3.2-1, and on system P&IDs in the DCD. Other SSCs not identified as seismic Category I, but whose failure could reduce the functioning of any seismic Category I to an unacceptable safety level, or injure control room personnel, are identified for analysis to assure the SSE will not cause such failures.

The staff concludes that the SSCs important to safety that are within the scope of this review have been properly classified, are within the scope of the applicant’s QA program, and thus

meet the relevant requirements of GDC 1, GDC 2, GDC 60, 10 CFR Part 50, Appendix B, and 10 CFR Part 50, Appendix S.

This conclusion is based on the following:

- GDC 1, requires in part that a, “quality assurance program shall be established and implemented in order to provide adequate assurance that these SSCs (important to safety) will satisfactorily perform their safety functions.” The applicant met this aspect of GDC 1 by stating in the DCD that seismic Category I SSCs will be designed, constructed and operated under a QA program, in compliance with the requirements of 10 CFR Part 50, Appendix B. This is discussed in the subsection “Quality Assurance” above within Section 3.2.1.4.3.
- The applicant meets the requirements of GDC 2, and 10 CFR Part 50, Appendix S, by having properly classified SSCs important to safety as seismic Category I items in accordance with the positions of RG 1.29, RG 1.151, and RG 1.189. The identified SSCs are those plant features necessary to assure: (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe-shutdown condition, and (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the exposure requirements in 10 CFR Part 100. This conclusion is supported throughout Section 3.2.1.4 above.
- Those SSCs not identified as seismic Category I, but whose failure could reduce the functioning of any seismic Category I feature to an unacceptable safety level or result in incapacitating injury to control room personnel, having been identified for analysis to assure they will not fail during an SSE. The applicant has identified these SSCs as “seismic Category II,” as discussed in the subsection, “Criteria Development,” and applied it to SSCs as within Section 3.2.1.4.4 above.
- Radioactive waste system and fire protection SSCs requiring seismic design considerations having been identified consistent with the positions of RG 1.143 and RG 1.189, as discussed in the applicable subsections above.

3.2.2 System Quality Group Classification

3.2.2.1 Introduction

Nuclear power plant SSCs important to safety should be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. This section reviews the quality group classification of fluid systems important to safety and the identification of applicable construction codes and standards for systems and components based on function and relative importance to safety.

3.2.2.2 Summary of Application

DCD Tier 2, Section 3.2.2 and Table 3.2-1, identify the APR1400 quality group classification criteria and the quality group classification categories for water-, steam-, and radioactive-waste-containing components. These SSCs are classified as Quality Group A, B, C, or D in

accordance with RG 1.26, Revision 4, or as Quality Group E or G, as defined within DCD Tier 2 Section 3.2.2. P&IDs in other sections of the APR1400 DCD identify the quality group classification boundaries of interconnecting piping and valves, as well as the interfaces between safety-related and nonsafety-related portions of each system.

DCD Tier 2, Section 3.2.3, also discusses the classification of fluid system components important to safety in accordance with American National Standard Institute (ANSI) and American Nuclear Society (ANS) Standard ANSI/ANS-51.1-1983. SRP Section 3.2.2 discusses the use of the ANS classification system of Safety Classes as an acceptable alternative if they are cross-referenced to the classification groups in RG 1.26, Revision 4. This classification system uses Safety Class 1, 2, and 3, and non-nuclear safety designations, which are functionally equivalent to the Quality Groups A, B, C, and D discussed in RG 1.26, Revision 4. DCD Tier 2, Table 3.2-2 shows the relationship between quality group, safety class, and seismic classification.

3.2.2.3 *Regulatory Basis*

The staff reviewed DCD Tier 2 Section 3.2.2, in accordance with SRP Section 3.2.2, Revision 2, and the guidance in RG 1.26, Revision 4, "Quality Group Classifications and Standards for Water, Steam, and Radioactive-Waste-Containing Components of Nuclear Power Plants," which is cited in SRP Section 3.2.2. The staff's acceptance of the design is based on compliance with the regulations and guidance presented below.

GDC 1, requires, in part, that the nuclear power plant SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. This requirement is applicable to both pressure-retaining and nonpressure-retaining SSCs that are part of the RCPB and other SSCs important to safety. SSCs that are important to safety ensure various safety functions, including the following safety-related functions:

- Integrity of the RCPB;
- Capability to shut down the reactor and maintain it in a safe-shutdown condition; and
- Capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures, comparable to the exposure requirements in 10 CFR 50.34(a)(1) or 10 CFR 100.11.

The requirements in 10 CFR 50.55a, "Codes and Standards," state, in part, that components that are part of the RCPB must meet the requirements for Class 1, components in Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPV Code). For components that are connected to the RCPB, there are exceptions from ASME BPV Code Class 1 requirements cited in 10 CFR 50.55a(c)(2), for the following cases:

Exceptions to RCPB Standards Requirement

Components that are connected to the reactor coolant system and are part of the RCPB as defined in 10 CFR 50.2 need not meet the requirements of 10 CFR 50.55a(c)(1), provided that:

1. Exceptions: Shutdown and cooling capability In the event of postulated failure of the component during normal reactor operation, the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system; or
2. Exceptions: Isolation capability. The component is or can be isolated from the reactor coolant system by two valves in series (both closed, both open, or one closed and the other open). Each open valve must be capable of automatic actuation and, assuming the other valve is open, its closure time must be such that, in the event of postulated failure of the component during normal reactor operation, each valve remains operable and the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system only.

The Quality Group A standards required for pressure-containing components of the RCPB are consistent with ASME BPV Code, Section III, Class 1. In addition, 10 CFR 50.55a also states that Quality Group Band Quality Group C must meet the requirements for Class 2 and Class 3, respectively, of the ASME BPV Code, Section III. The guidelines in RG 1.26, Revision 4, identifies those fluid systems or portions of systems and system functions classified as Quality Group B, C, and D and their applicable quality standards.

3.2.2.4 *Technical Evaluation*

This section discusses the technical evaluation of the portion of the application concerning quality classification of pressure-retaining components. This section excludes structures; internals of mechanical components (shafts, seals, impellers, packings, gaskets); fuel, electrical, instrumentation systems, electrical valve actuation devices; and pump motors, which are covered in other sections of this SER. Certain issues have commonality across multiple SRP sections—for instance certain classification methodology issues also are addressed in SER Section 3.2.1—but are discussed within this section for the sake of clarity.

3.2.2.4.1 *Criteria for Classification*

In DCD Tier 2, Section 3.2.2, the applicant establishes the classification categories and selection criteria for SSCs. RG 1.26, Revision 4, is indicated as the principal document for identifying those SSCs in Quality Groups A, B, C, and D.

Quality Groups E and G, which are defined within DCD Tier 2, Section 3.2.2, do not create any conflict with RG 1.26, Revision 4, and are therefore acceptable for use. RG 1.26 describes a quality classification system related to specified national standards that may be used to determine quality standards acceptable to the staff of the NRC for satisfying GDC 1. Because Quality Groups A, B, C, and D, are in accordance with RG 1.26, Revision 4, the staff finds that the criteria established for quality group classification of APR1400 are consistent with the requirements in 10 CFR 50.55a(c), (d), and (e), the guidelines in SRP Section 3.2.2 and criteria are appropriate to satisfy GDC 1, and therefore are acceptable.

3.2.2.4.2 *Application of Quality Group A*

Quality Group A components, as discussed in RG 1.26, Revision 4, are defined in 10 CFR 50.55a as components that are part of the RCPB (with exceptions) and must meet

the requirements for ASME BPV Code Section III, Class 1, components. The staff reviewed the criteria established by the applicant and finds that the definition of Quality Group A is consistent with the requirements in 10 CFR 50.55a, which states, in part, that components that are part of the RCPB must meet the requirements for Class 1 components in Section III, ASME BPV Code except in the event of postulated failure of the component during normal reactor operation would not prevent the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system. In Page 3.2-6 of DCD Revision 0, Section 3.2.2, the applicant discusses the “loss of enough reactor coolant to prevent orderly shutdown and cooldown,” but this does not capture the full scope of the regulation. The staff issued RAI 72-8020, Question 03.02.02-3, to address this concern. In RAI 72-8020, Question 03.02.02-3, the staff stated that the definitions of Quality Groups A, B, C, and D do not appear consistent with the guidance of RG 1.26 and the other guidance referenced in the SRP. For instance, the definition of Quality Group A does not clearly comply with the language in 10 CFR 50.55a(c), which states, in part, that components that are part of the RCPB must meet the requirements for Class 1 components in Section III, ASME BPV Code except in the event of postulated failure of the component during normal reactor operation would not prevent the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system. The applicant’s response provided a mark-up to be incorporated in a later revision of the DCD of a revised definition of Quality Group A to conform to the language of RG 1.26. The staff confirmed that this definition was incorporated into the DCD. The staff finds this definition is consistent with RG 1.26, and 10 CFR 50.55a(c) and ensures that the quality standards for the design, fabrication, erection, and testing have been established consistent with GDC 1.

The staff reviewed DCD Tier 2, Table 3.2-1, and the associated P&IDs to assess the application of this quality group classification. Specifically, the staff verified that all appropriate components that are part of the RCPB were classified as Quality Group A, as required in 10 CFR 50.55a. Based on this review, the staff finds that the applicant has consistently applied the classification criteria for Quality Group A to the list of APR1400 SSCs presented in Table 3.2-1, thereby meeting the requirement found in 10 CFR 50.55a. In addition, portions of Quality Group A piping and valves located downstream of flow-restricting devices have been indicated as Quality Group B, consistent with the shutdown and cooling capability exception for RCPB components specified in 10 CFR 50.55a. An audit conducted between May 23, 2016 and July 22, 2016 (ML16298A330), verified the calculation supporting these class breaks downstream of flow-restricting devices.

The staff requested clarification regarding several discrepancies between the table, the P&IDs, and information contained in Tier 1 at a public meeting on July 1, 2015 (ML15183A392), as well as through RAI 72-8020, Question 03.02.02-5. The applicant provided clarification and updates to the DCD to address these discrepancies, which were incorporated into the DCD. Based on staff review and the resolution of the issues discussed above, the staff finds that the applicant has established an acceptable definition for Quality Group A, SSCs and consistently applied it to all appropriate components that are part of the RCPB, in accordance with the requirements of 10 CFR 50.55a. GDC 1 states, in part, that SSCs important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety. Quality Group A, is the highest classification and corresponds to the use of ASME Section III, Class 1 standards for the design, fabrication, erection, and testing of SSCs. Therefore, the classification of the RCPB components as Quality Group A, SSCs is consistent

with the guidelines in SRP Section 3.2.2, conforms to GDC 1, and 10 CFR 50.55a, and is therefore acceptable.

3.2.2.4.3 *Application of Quality Groups B, C, and D*

The definitions of Quality Groups B, C, and D did not initially appear consistent with the guidance of RG 1.26. The applicant has stated that the quality groups are assigned in accordance with RG 1.26, but the text did not initially appear to support that statement, so the staff issued RAI 72-8020, Question 03.02.02-3. The applicant provided revised definitions in their RAI response, which are aligned with those found in RG 1.26. RG 1.26 describes a quality classification system related to specified national standards that may be used to determine quality standards acceptable to the staff for satisfying GDC 1. As the definitions of Quality Groups B, C, and D are consistent with those found in RG 1.26 and have been incorporated into the DCD, the staff finds the proposed definitions are consistent with the requirements of 10 CFR 50.55a(d), (e) and GDC 1.

The staff reviewed the contents of DCD Tier 2, Table 3.2-1, to determine how Quality Group B, C, and D classifications were applied to APR1400 SSCs. The staff also examined P&IDs to assess consistency between the sections. The staff noted that portions of the reactor coolant pressure boundary, typically Quality Group A, were classified as Quality Group B, as these portions were downstream of flow-restricting devices. This is consistent with the shutdown and cooling capability exception specified in 10 CFR 50.55a, as discussed in the section above.

The staff issued RAI 72-8020, Question 03.02.02-6, to clarify the applicant's use of Quality Group classification with regards to ASME BPV Code Section III requirements. Specifically, certain SSCs designated as Quality Group B (such as the Control Element Assembly Drive motor assembly) were not also specified as meeting the requirements of ASME BPV Code, Section III, Subsection NC, in the "Codes and Standards" column. This is required by 10 CFR 50.55a(d)(1), for Quality Group B components. The applicant's response added an explanatory note to certain SSCs, which specified that these SSCs were not pressure boundary components and their safety function was limited to scram ability. As such, the ASME BPV Code is not applicable to these non-pressure boundary components. Because the SSCs are not pressure boundary components, the applicant's designation is acceptable. This response was incorporated into the DCD.

Based on its review, the staff finds that the application of Quality Group B, C, and D classifications to APR1400 SSCs are consistent with the guidelines in SRP Section 3.2.2 and RG 1.26, Revision 4. RG 1.26 describes a quality classification system related to specified national standards that may be used to determine quality standards acceptable to the staff for satisfying GDC 1. Therefore, the staff finds Quality Group B, C, and D classifications to APR1400 SSCs conform to GDC 1 and 10 CFR 50.55a, and are therefore acceptable.

3.2.2.4.4 *Application of Quality Groups E and G*

The staff reviewed the contents of DCD Tier 2, Table 3.2-1 to determine how Quality Group E and G classifications were applied to SSCs. The staff confirmed that the applicant consistently applied Quality Group E classifications to nonsafety-related SSCs designed to codes other than those listed in RG 1.26, Revision 4, such as ASME AG-1-2009, and applied Quality Group G

classifications to safety-related SSCs designed to codes and standards other than those listed for Quality Group A, B, and C, in Table 1 of RG 1.26, as incorporated in the DCD. In reviewing the codes listed for Quality Group G SSCs, it was noted that the Diesel Engine Manufacturer's Association's 1972 standards were listed as the reference for items associated with the emergency diesel generators. These standards are considered obsolete and should be updated to a more current standard. This issue is discussed in Section 9.5.8 of this SER.

3.2.2.4.5 *Multiple Classifications*

Several entries in Table 3.2-1 were given multiple classifications, which can result in unclear and potentially conflicting requirements for these SSCs. The staff issued RAI 30-7927, Question 03.02.02-1 to seek clarification on this issue, specifically how to distinguish between the multiple classifications within the same entry. The applicant's response provided clarification for these multiple classifications through splitting several of the entries into separate rows by classification and clearly describing the transition from one classification to another. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 30-7927, Question 03.02.02-1, is resolved and closed.

3.2.2.4.6 *Safety Class Discussion*

In DCD Tier 2, Section 3.2.3, the applicant describes a safety classification system based on ANSI/ANS-51.1-1983, which establishes four safety classes: 1, 2, 3, and NNS. The applicant states that these four safety classes are equivalent to Quality Groups A, B, C, and D, as described in RG 1.26, Revision 4.

The applicant stated that piping supports and component supports are in the same safety class and have the same QA requirements as the piping and components to which they apply. The staff considers this statement to also apply to the quality group classification of associated supports, as the applicant states that safety class and quality group classifications are equivalent. Since the applicant has aligned safety class with quality groups, it may be inferred that supports have the same quality group classification as their associated SSCs. The staff asked RAI 30-7927, Question 03.02.02-2 to verify this inference. The applicant provided clarification in their RAI response, which stated that supports are designed in accordance with the assigned quality group classification, but are constructed to ASME Code, Section III, Subsection NF requirements for Quality Group A, B, and C supports, as opposed to the code of construction specified for the associated component or piping. This clarification of the treatment of supports is consistent with the guidance provided in SRP Section 3.2.2, specifically Table 3.2.2-1. Based on the review of the DCD, the staff has confirmed incorporation of the clarification; therefore, RAI 30-7927, Question 03.02.02-2, is resolved and closed.

Additionally, Tier 2, Table 3.2-2 shows the relationship between classification systems. The quality group classification column guides the staff's safety findings with respect to SRP Section 3.2.2.

3.2.2.4.7 *Review of Piping and Instrumentation Diagrams*

The staff reviewed selected P&IDs to assess the application of quality group classifications to APR1400 SSCs. The staff confirmed the P&IDs to have sufficient detail to determine classification boundaries for fluid systems important to safety, permitting a verification of

conformance with 10 CFR 50.55a and GDC 1, as discussed in earlier sections of this SER. Changes in quality group classification typically occur at valve locations, with the valve classified as the higher classification. The staff identified a few discrepancies in classification boundaries between the P&IDs and DCD Tier 2, Revision 0, Table 3.2-1, which were communicated to the applicant in a public meeting on July 1, 2015 (ML15183A392), as well as in RAI 72-8020, Question 03.02.02-5. The staff confirmed the correction of these discrepancies in the DCD.

Additional information on the staff's review of system boundaries in detailed P&IDs is found in SER Section 3.2.1.4.3, and also applies to the quality group boundaries described in this section.

The staff finds that the P&IDs are consistent with the classification information found in Table 3.2-1 of the DCD, the guidelines in SRP Section 3.2.2, and RG 1.26, Revision 4 demonstrate an acceptable application of the quality classification system deemed acceptable by the staff for satisfying GDC 1, and 10 CFR 50.55a.

3.2.2.4.8 *Systems Check for Fluid Systems Important To Safety*

Guidance in SRP Section 3.2.2 lists specific fluid systems considered important to safety for pressurized-water reactor (PWR) plants. Appendix A of SRP Section 3.2.2, additionally provides guidance regarding the classification of certain SSCs. The staff screened this list and guidance against the information in Tier 2, Table 3.2-1 to determine if the fluid systems were adequately addressed. The staff finds that the applicant has incorporated the guidance, with the exceptions listed below:

- SRP Section 3.2.2, Table A-1 indicates that combustible gas control systems should be Quality Group B. DCD Tier 2, Table 3.2-1 lists the containment hydrogen control system as Quality Group E (passive autocatalytic recombiners) and N/A (hydrogen ignitors). During discussion at a public meeting on July 1, 2015 (ML15183A392), the applicant indicated that the combustible gas control system is designated Quality Group B in accordance with the guidance, but the passive autocatalytic recombiners are used for severe accidents and are therefore not safety-related. Additionally, the applicant stated that the hydrogen ignitors are not fluid-retaining components, and therefore they are designated N/A. This severe-accident function is described in DCD Tier 2, Section 6.2.5. The staff finds this designation of combustible gas control systems to be consistent with the safety classification and therefore acceptable.
- SRP Section 3.2.2, Table A-1 indicates that emergency diesel systems should be Quality Group C, but DCD Tier 2, Table 3.2-1 lists the starting air compressors, air dryer package, lube oil separator, lube oil/preheating water heat exchanger, high temperature water electric heater, preheating high temperature water pump, prelube oil pump and other nonsafety-related equipment as Quality Group D. This topic was briefly discussed at the public meeting on July 1, 2015, where it was noted that the equipment designated Quality Group D noted above was not required for the emergency diesel generators (EDGs) to perform their safety-related functions. The staff finds this designation of the safety classification consistent with the guidance and is therefore acceptable. Additional discussion on the emergency diesel systems may be found in Section 9.5 of this SER.

- SRP Section 3.2.2, Table A-1 indicates that plant ventilation systems for areas such as the control room and ESF rooms should be Quality Group C, but DCD Tier 2, Table 3.2-1 lists Quality Groups G/E for control room HVAC (ASME AG-1-2009). In the public meeting on July 1, 2015, the applicant noted that control room HVAC system AHU cooling coils are classified as Quality Group C and that other control room HVAC SSCs were not designed to ASME BPV Code Section III and instead were designated Quality Group E or G, depending on whether the SSC served a safety-related function. The staff finds this approach acceptable, because the safety-related functions of the SSCs are considered in assigning the Quality Group classifications.

3.2.2.5 Combined License Information Items

The DCD Tier 2, Section 3.2.2, contains the following COL information items pertaining to quality group classification. As indicated, the applicant specifies the identification of quality group classification for site-specific SSCs as a COL action item. The staff considers this acceptable, as site-specific SSCs are unique to the COL applicant and should be addressed at the time of a COL application. The staff concludes that the applicant has adequately addressed the need for COL items for this review section.

Table 3.2.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.2(2)	The COL applicant is to identify the quality group classification of site-specific systems and components and their applicable codes and standards.	3.2.1

3.2.2.6 Conclusion

The staff concludes that pressure-retaining components of fluid systems important to safety have been properly classified as Quality Group A, B, C, or D and identified in an acceptable manner in Table 3.2-1 and on system P&IDs in the DCD. These SSCs will be constructed to quality standards commensurate with the importance of the safety function to be performed. Therefore, the staff finds that the requirements of GDC 1 and 50.55a have been met. This conclusion is based on:

- RG 1.26, describes a quality classification system related to specified national standards that may be used to determine quality standards acceptable to the staff for satisfying GDC 1. Therefore, the applicant has met the requirements of GDC 1 by having properly classified SSCs important to safety in accordance with the Quality Group classification system described in the APR1400, DCD Section 3.2.2, which is consistent with RG 1.26, as discussed throughout Section 3.2.2.4, above.
- The applicant's having met the requirements of 10 CFR 50.55a by designating components that are part of the RCPB as subject to the requirements for Class 1,

2, and 3 components in Section III of the ASME BPV Code, subject to certain exceptions, as discussed in Sections 3.2.2.4.2, and 3.2.2.4.3 above.

3.3 Wind and Tornado Loading

3.3.1 Wind Loadings

3.3.1.1 Introduction

Safety-related structures need to meet the requirements of GDC 2 in Appendix A, to 10 CFR Part 50. GDC 2, requires safety-related structures to be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without losing the capability to perform their safety functions. This section of the SER documents the findings from the staff's review and evaluation of the information provided by the applicant that describes the basis for selecting the design wind speed for the APR1400 and the methodology used to convert the design wind speed into an equivalent design wind load that can be used in the design of the plant structures.

3.3.1.2 Summary of Application

DCD Tier 1: DCD Tier 1 information associated with this section appears in DCD Tier 1, Section 2.1, "Site Parameters," Table 2.1-1, "Site Parameters," and DCD Tier 1, Section 2.2, "Structural and System Engineering."

DCD Tier 2: In DCD Tier 2, Section 3.3.1, "Wind Loadings," the applicant described the method for determining wind loads on structures. It stated that wind loads are determined from a design basis wind speed, which is the wind speed of a 3 second wind gust located 10 meters (m) (33 feet (ft.)) above the ground. The selected design wind speed is 64.8 m/second (s) (145 miles per hour (mph)) under open terrain conditions. The resulting wind load on the structure is a function of the design wind velocity, building height, topographic factors, wind directionality factor, and importance factor. The importance factor selected for the APR1400 design is 1.15, which is consistent with a recurrence interval of 100 years.

3.3.1.3 Regulatory Basis

The following NRC regulations contain the relevant requirements for this area of review:

- Part 50 of 10 CFR, Appendix A, GDC 2, as it relates to the requirement that SSCs important to safety shall be 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. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.
- Section 52.47(b)(1) of 10 CFR, "Contents of Applications; Technical Information," as it relates to the requirement that a design certification application (DCA) 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 is built and will

operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

The acceptance criteria adequate to meet the above requirements are listed in SRP Section 3.3.1, along with the review interfaces with other SRP sections.

3.3.1.4 *Technical Evaluation*

3.3.1.4.1 *Applicable Wind Design Parameters*

Safety-related structures need to meet GDC 2, which requires that they be designed to withstand the effects of tornadoes and hurricanes, among other natural phenomena hazards, without losing the capability to perform their safety functions. This includes consideration of the most severe of natural phenomena that have been historically reported for a site and appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

The DCD Tier 2, Section 3.3, “Wind and Tornado Loadings,” states that all seismic Category I and II SSCs, except those not exposed to wind, are designed for wind and tornado/hurricane loadings (addressed in Sections 3.8.1 and 3.8.4, of this SER on loads and load combinations for concrete containment and other seismic Category I structures, respectively). DCD Tier 2, Section 3.3.1, states that the wind speed used as a basis for determining the wind design load is the wind speed for a 3 second gust measured at 10 m (33 ft.) above the ground. The design wind speed is 64.8 m/s (145 mph) under open terrain conditions. The staff compared the wind speed with the information presented in Figure 6-1 of the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) standard 7-05, “Minimum Design Loads for Buildings and Other Structures,” and confirmed that the design wind speed specified by the applicant represents the highest wind speed for the United States (U.S.) at the prescribed height and open terrain conditions (Exposure Category C), with the exception of the southern tip of Florida and the eastern tip of Louisiana.

The SRP Section 3.3.1 and Section 3.3.2, “Tornado Loadings,” recommend the use of ASCE/SEI 7-05 to transform wind speed into velocity pressure and the design wind loads; therefore, the applicant’s use of this ASCE/SEI standard is acceptable.

Based on ASCE/SEI 7-05, Table 1-1, “Occupancy Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice,” the applicant categorized the occupancy of seismic Category I SSCs as Occupancy Category IV structures. The annual probability of exceedance of Occupancy Category IV is 0.01 (mean reoccurrence interval of 100 years). Therefore, the application of the importance factor of 1.15 (taken from Table 6-1, “Importance Factor I” (wind loads) of ASCE/SEI 7-05) to adjust the velocity pressure is consistent with the guidance in SRP Section 2.3.1, “Regional Climatology.”

Since the design wind speed represents the highest wind speed over most of the U.S. (with only two exceptions—the southern tip of Florida and the eastern tip of Louisiana), and because the COL applicant will confirm that this design maximum wind speed envelops or meets the maximum design wind speed for its specific site, the staff finds the use of a 64.8 m/s (145 mph) wind speed acceptable.

3.3.1.4.2 *Procedures to Transform Wind Parameters into Equivalent Loads on Structures*

In DCD Tier 2, Section 3.3.1.2, "Determination of Applied Wind Forces," the applicant determined velocity pressure on the surface of the seismic Category I and II SSCs using equation (6-15) of ASCE/SEI 7-05. The use of equation (6-15) is appropriate if the Method 2 analytical procedure of ASCE/SEI 7-05 is used to transform wind speed into an equivalent pressure, and then the design wind load to be applied to structures is developed. The staff reviewed information presented in DCD Tier 2, Revision 0, for the APR1400 standard design and verified that it satisfies the first condition for the applicability of the Method 2 analytical procedure in ASCE/SEI 7-05. The applicant must submit additional information before the staff can determine whether the second condition is satisfied.

In evaluating the second condition, the staff reviewed the information presented in DCD Tier 2, and the general configuration of the plant and concluded that the reactor containment building does not have response characteristics that make it subject to cross-wind loading or instability from galloping or flutter, nor does it have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration. The staff needed additional information to confirm whether vortex shedding was addressed and its influence established or why it was not considered before the use of Method 2. In various calls with the applicant on August 20, 2015, and September 17, 2015, the staff asked the applicant either to describe the applied analytical methodology and related wind parameters used or to justify the basis for precluding the vortex effects in the design and provide the supporting analysis. In the first enclosure to its letter (ML15301A919), under Issue #1, the applicant responded that the vortex shedding was not considered because the slenderness ratio of the structure (diameter to height) is very small, which means the vortex would not affect the structure. The staff finds the response acceptable; therefore, the staff concludes that use of the Method 2 analytical procedure in ASCE/SEI 7-05 is adequate in establishing the design wind load.

Equation (6-15) of ASCE/SEI 7-05 has a number of parameters that are used to calculate the resulting wind pressure load. These parameters are K_z , which is a velocity pressure exposure coefficient that varies with height z ; K_{zt} , which is a function of topography; K_d , which is a wind directionality factor; and I , which is an importance factor for the structure. The applicant used the values recommended in the SRP for all these parameters. Therefore, the staff concludes the acceptance criteria for these parameters in SRP Section 3.3.1, Acceptance Criteria II, No. 3 are met.

The SRP Section 3.3.1, II.3.B states that the coefficients for K_z should be based on exposure Level C, which is applicable for flat open country, grasslands, and all water surfaces in hurricane prone regions. The selection of exposure Level D provides higher K_z coefficients. According to the ASCE/SEI 7-05 standard, exposure Level D includes smooth mud flats, salt flats, and unbroken ice outside of hurricane prone regions. Shorelines along the continental U.S. in exposure Level D include inland waterways; the Great Lakes; and coastal areas of California, Oregon, and Washington. Since the wind pressure load is a function of the velocity squared, and the velocity in exposure Level D regions provided in ASCE/SEI 7-05, Figure 6-1, is lower and, in most cases, significantly lower than the hurricane wind speed selected, the staff finds the use of K_z values for exposure Level C acceptable, as the higher hurricane wind speed more than compensates for the higher K_z value associated with exposure Level D.

The DCD Tier 2 information does not indicate how the applicant will use the velocity pressure from equation (6-15) and develop the design wind loading. Therefore, in various calls with the applicant on August 20, 2015, and September 17, 2015, the staff asked the applicant to clarify the methodology used to determine the wind loads. In the first enclosure to its letter (ML15301A919), under Issue #2, the applicant stated that the general arrangement of the structures for seismic Category I and II is classified as enclosed or partially enclosed structures; therefore, the design wind loads were determined in accordance with equation (6-17) of ASCE/SEI 7-05. The staff finds that the methodology is consistent with the guidance in SRP Section 3.3.1, and finds this acceptable, as it meets the associated acceptance criteria. The staff verified that the changes proposed in the responses dated October 28, 2015, were incorporated into the DCD.

3.3.1.4.3 Tier 1 Information

The DCD Tier 1, information associated with this section appears in DCD Tier 1, Section 2.1, which states that the maximum wind speed, excluding tornado wind, is 64.8 m/s (145 mph). The staff noted that this agrees with the wind speed cited in DCD Tier 2, Section 3.3.1, which the staff finds acceptable, as summarized in its review above. Design descriptions and their associated ITAAC in DCD Tier 1, Section 2.2, identify the design loads for structures. The evaluation for DCD Tier 1, Section 2.2, regarding wind loads is in Section 14.3.2.4.4, "Flood, Wind, Tornado, Rain, and Snow," of this SE.

3.3.1.5 Combined License Information Items

Table 3.3.1 lists COL information item numbers and descriptions related to wind loading from DCD Tier 2, Table 1.8-2, "Combined License Information Items."

Table 3.3.1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.3(1)	The COL applicant is to demonstrate that the site-specific design wind speed is bounded by the design wind speed of 64.8 m/s (145 mph).	3.3.1.1
COL 3.3(2)	The COL applicant is to demonstrate that the site-specific seismic Category II structures adjacent to the seismic Category I structures are designed to meet the provisions described in Subsection 3.3.1.2.	3.3.1.2
COL 3.3(4)	The COL applicant is to provide reasonable assurance that site-specific structures and components not designed for the extreme wind loads do not impact either the function or integrity of adjacent seismic Category I SSCs.	3.3.2.3

The staff finds the above listing of COL information items to be complete. Further, the list adequately describes actions necessary for the COL applicant. DCD Tier 2, Table 1.8-2, does not need to include any additional COL information items for wind loading.

3.3.1.6 Conclusion

The staff concludes that the applicant has provided sufficient information with respect to the development of wind speed and the methodology used to convert the design wind speed into equivalent design wind loads and thus satisfies the applicable NRC regulations.

Based upon its review, the staff has made the following conclusions:

- The applicant has met the acceptance criteria in SRP Section 3.3.1, as it relates to the development of design-basis wind loads on structures, as described above. The design of the facility meets the minimum principal design criterion provided in Criterion 2 of 10 CFR Part 50, Appendix A and 10 CFR 52.47(b)(1), with respect to the capability of the structures to withstand design wind loading. The design reflects appropriate consideration of severe hurricane wind, an appropriate combination of the effects of normal and accident conditions with the design wind load, and the importance of the safety function to be performed by safety-related structures. In Sections 3.8.1 and 3.8.4, of this SER, the staff notes that the applicant has designed the plant structures to prevent structural damage during a natural phenomenon related to wind, such as hurricane and tornado, and has used methods provided in ASCE/SEI 7 05 to transform wind speed into equivalent pressures on structures, which the staff reviewed and found acceptable, as described above. The design of seismic Category I structures includes wind load and the loads resulting from normal and accident conditions.
- The use of these methods provides reasonable assurance that in the event of design basis winds, the structural integrity of the plant structures that are designed to resist the effects of the design wind speed would not be impaired, and the safety-related systems and components located within these structures are adequately protected and would perform their intended safety functions.

3.3.2 Tornado Loadings

3.3.2.1 Introduction

Seismic Category I structures must withstand design basis tornado and hurricane loads and maintain their safety-related functions during and following a tornado or hurricane event. This section documents the findings from the staff's review and evaluation of the description of the APR1400 design parameters applicable to tornadoes and hurricanes, and the procedures used to transform the wind and associated atmospheric pressure drop into equivalent loads on structures. It also provides the evaluation of non-seismic Category I structures that have the potential for interacting with seismic Category I structures. The response of non-seismic Category I structures must not affect the safety-related functions of seismic Category I structures under tornado or hurricane load conditions.

3.3.2.2 Summary of Application

DCD Tier 1: DCD Tier 1, Section 2.1, and Table 2.1-1 provide DCD Tier 1 information on tornado design parameters.

DCD Tier 2: In DCD Tier 2, Section 3.3.2, the applicant described a method for determining tornado loadings on structures. It stated that tornado loads are determined for a design basis tornado, which has a probability of exceedance equal to 1×10^{-7} per year. Tornado loads include loads caused by tornado wind pressure, atmospheric pressure change, and tornado generated missile impact.

As specified in DCD Tier 2, Table 2.0-1, "Site Parameters," the maximum horizontal tornado wind speed is 102.8 m/s (230 mph), translational wind speed is 20.6 m/s (46 mph), tornado rotational speed is 82.2 m/s (184 mph), radius of maximum rotational speed is 45.7 m (150 ft.), maximum pressure differential is 8.274 kilopascals (kPa) (1.2 pounds per square inch (psi)), and rate of pressure drop is 3.447 kPa per second (kPa/s) (0.5 psi/s). The maximum wind speed of the design hurricane is 116 m/s (260 mph), the annual probability of exceedance is 1×10^{-7} , and the wind speed is a nominal 3 second peak gust at a height of 10 m (33 ft.) in flat, open terrain.

DCD Tier 2, Section 3.5, "Missile Protection," describes the wind-generated missile loads and missile protection design criteria. In addition to the description of the tornado wind load applied to seismic Category I and II structures, Section 3.5, addresses tornado wind load on non-seismic Category I structures and the measures used to prevent their interaction with seismic Category I structures.

The ITAAC items for this area of review relate to structures being designed for external events, including tornadoes and tornado-generated missiles. DCD Tier 1, Section 2.2, provides the ITAAC.

3.3.2.3 *Regulatory Basis*

The following NRC regulations contain the relevant requirements for this area of review:

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

SRP Section 3.3.2, lists the acceptance criteria adequate to meet the above requirements, as well as review interfaces with other SRP sections. In addition, the following guidance documents provide the acceptance criteria that confirm the above requirements have been adequately addressed:

- Regulatory Guide (RG) 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," as it relates to the maximum tornado wind speed, rate of pressure drop, and tornado missile characteristics.
- RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," as it relates to design requirements for tornado wind and tornado missiles for radioactive waste structures.

- RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,” as it relates to the maximum hurricane wind speed and hurricane missile characteristics.

3.3.2.4 *Technical Evaluation*

This section of the SER provides the staff’s evaluation of the applicant’s development of tornado and hurricane wind loads to be used in the design of seismic Category I structures. This review ensures compliance with the requirement in 10 CFR Part 50, Appendix A, GDC 2, that SSCs important to safety shall be designed to withstand the effects of a tornado or hurricane without losing the capability to perform their safety functions. The specific loads considered in this section are those associated with design-basis tornado winds and associated atmospheric pressure changes, as well as hurricane winds.

The staff also reviewed the applicant’s submittal for compliance with the requirement for non-seismic Category I structures or components not designed for tornado loads to ensure that they will not affect the capability of safety-related structures or components to perform their necessary safety functions under tornado and hurricane loadings.

The staff also reviewed the selection of missiles generated by tornadoes and extreme winds, addressed in DCD Tier 2, Section 3.5.1.4, “Missiles Generated by Tornadoes and Extreme Winds” (reviewed by the staff in SER Section 3.5.1.4), and protection from tornado generated missiles, addressed in DCD Tier 2, Section 3.5.3, “Barrier Design Procedures” (reviewed by the staff in SER Section 3.5.3).

3.3.2.4.1 *Applicable Design Parameters*

DCD Tier 2, Section 3.3.2, states that tornado wind and related parameters used as a basis for the applicable tornado design load parameters are chosen according to the characteristic design basis tornado for Tornado Region I. This tornado region provides the most severe tornado conditions of the three regions presented in RG 1.76, Table 1, “Design-Basis Tornado Characteristics.” These conditions correspond to a maximum horizontal tornado wind speed of 102.8 m/s (230 mph), translational wind speed of 20.6 m/s (46 mph), tornado rotational speed of 82.2 m/s (184 mph), radius of maximum rotational speed of 45.7 m (150 ft.), maximum pressure differential of 8.274 kPa (1.2 psi), and rate of pressure drop of 3.447 kPa/s (0.5 psi/s). All of the parameters chosen for the design basis tornado are consistent with RG 1.76.

The maximum wind speed for the design basis hurricane is 116 m/s (260 mph), the annual probability of exceedance is 1×10^{-7} , and the wind speed is a nominal 3-second peak gust at a height of 10 m (33 ft.) in flat, open terrain. This represents the highest wind speed for the U.S., with the exception of the southern tip of Florida and the eastern tip of Louisiana. The selected design basis hurricane meets the acceptance criteria specified in RG 1.221.

Since both of these conditions represent the highest wind speed over most of the U.S. (with only two exceptions), and because the COL applicant will need to confirm the tornado and hurricane wind speed for the specific site, the staff finds the use of wind speeds of 102.8 m/s (230 mph) for tornadoes and 116 m/s (260 mph) for hurricanes acceptable.

3.3.2.4.2 *Determination of Forces on Structures*

The applicant used the methods outlined in DCD Tier 2, Section 3.3.1.2, to determine the forces on seismic Category I and II SSCs from the postulated straight extreme winds. The staff concurs with the methodology, as it is consistent with the guidance in SRP Section 3.3.2, and finds this acceptable as it meets the associated acceptance criteria.

In DCD Tier 2, Section 3.3.2.2, “Determination of Forces on Structures,” the applicant stated that the forces on seismic Category I and II SSCs from postulated extreme winds are obtained using methods outlined in DCD Tier 2, Section 3.3.1.2. SER Section 3.3.1.4.2, contains the evaluation for SRP acceptance criterion 3.3.2.II.B.iii, and the staff finds the methodology acceptable.

In DCD Tier 2, Section 3.3.2.2.2, “Hurricane Missile Effects,” the applicant stated that the design missile spectrum is identified in DCD Tier 2, Table 3.5-2, “Design Basis Missiles,” and DCD Tier 2, Section 3.5.3, describes the design of the missile barriers to prevent penetration and perforation and to withstand scabbing effects. The staff documented its evaluation of the missile barrier design in SER Section 3.5.3.

In DCD Tier 2, Section 3.3.2.2.3, “Tornado Pressure Drop,” the applicant addressed the categories of enclosures used to compute the tornado pressure drop effects during the design basis tornado and stated that SSCs have been evaluated based on the enclosure category of the building for seismic Category I and II SSCs, as applicable. Vented, partially enclosed, or enclosed buildings are designed to withstand the pressure drop, while pressure drop effects are not considered in the interior of unvented structures. In DCD Tier 2, Section 3.3.2.2, the applicant stated that the pressure drop effects from the design basis tornado were determined using the guidance provided by Simiu and Scanlan 1996, and DCD Tier 2, Tables 3.8-2, “Seismic Category I Structure Load Combination for the Reactor Containment Building,” 3.8-7A, “Seismic Category I Structures Excluding Containment Structure Reinforced Concrete – Ultimate Strength Design Load Combination Table,” and 3.8-7B, “Seismic Category I Structures Structural Steel – Elastic Design Load Combination Table,” describe the load combinations associated with the postulated extreme wind loadings.

The staff evaluated this information and concluded that the methodology and the load combinations the applicant used are acceptable, as they are consistent with the guidance in SRP Section 3.3.2 and meet Acceptance Criteria 3.3.2.II.C and 3.3.2.II.3.E. However, in DCD Tier 2, Section 3.3.2.2.3, the applicant stated that vented or partially enclosed and enclosed buildings are designed to withstand the pressure drop, while pressure drop effects are not considered in the interior of unvented structures. It was not clear to the staff how the loads for partially enclosed (vented) structures were determined as a result of the atmospheric pressure change during the passage of a tornado. Therefore, in calls with the applicant on August 20, 2015, and September 17, 2015, the staff asked the applicant to clarify whether or not venting was adopted as a way to reduce the atmospheric pressure change effect on the structure. In the first enclosure to its letter (ML15301A919), under Issue #4, the applicant stated that all vented and partially enclosed buildings are designed to withstand pressure drop effects by applying the same method as that for enclosed buildings assuming there is no venting. By assuming that the buildings are enclosed, the applicant used the maximum pressure and is in agreement with the applicable SRP provision for the pressure drop of enclosed structures. Therefore, the staff finds the applicant’s approach acceptable.

3.3.2.4.3 *Effect of Failure of Structures Not Designed for Extreme Wind Loads*

SRP Acceptance Criterion 3.3.2.II.4 indicates that applicants should provide information to demonstrate that failure of any structure or component not designed for tornado loads will not affect the capability of safety-related structures or components to perform their necessary safety functions.

In DCD Tier 2, Section 3.3.2.3, “Effect of Failure of Structures or Components Not Designed for Extreme Wind Loads,” the applicant provided information on the approach to be used in ensuring that the safety function of seismic Category I SSCs will remain unaffected from any interaction with non-seismic SSCs. The COL applicant has the following three options:

1. Design the SSCs with seismic Category II designation and adjacent to seismic Category I SSCs to wind and tornado/hurricane loadings.
2. Investigate the effect of adjacent structural failure on seismic Category I SSCs to provide reasonable assurance that the ability of the seismic Category I SSCs to perform their intended safety functions is not impacted or affected.
3. Design and provide a structural barrier to protect seismic Category I SSCs from adjacent structural failure.

The staff finds that the first option is not clear, and in calls on August 20, 2015, and September 17, 2015, asked the applicant to clarify the option and describe the method(s) that will be used to design seismic Category II structures. Additionally, the staff asked the applicant to describe the methods that will be implemented to ensure protection of the seismic Category I structures. In the first enclosure of its letter (ML15301A919), under Issue #5, the applicant stated that the seismic Category II structures adjacent to seismic Category I structures are designed using the same design wind speed and methodology applied to seismic Category I structures described in DCD Tier 2, Section 3.3. The applicant also revised the description of the first option to make clear that one of the methods to evaluate the nonsafety-related SSCs to design the SSCs adjacent to seismic Category I structures to wind and tornado/hurricane loadings. The staff finds that the methods to evaluate and design the SSCs adjacent to seismic Category I SSCs that are nonsafety related to be acceptable and those SSCs will not affect the ability of safety-related SSCs to perform their intended safety functions. Based on the review of the DCD, the staff has confirmed the changes described above; therefore, this item is resolved and closed.

3.3.2.4.4 *Tier 1 Information*

DCD Tier 1 requires that seismic Category I structures be constructed to withstand design basis loads without loss of structural integrity and safety-related functions. The design basis loads are those associated with normal plant operation, as well as external events; including hurricanes but not tornadoes. Although hurricane wind bounds tornado wind in the APR1400 design, 10 CFR Part 50, Appendix A, GDC 2 specifically includes tornadoes. Accordingly, the staff sent RAI 247-8314, Question 14.03.02-1 (ML15296A015), to the applicant to add tornado as a design basis load. In its response to RAI 247-8314, Question 14.03.02-1 (ML15327A441), the applicant added tornado and tornado-generated missiles as part of the design loads for the

nuclear island structures. Based on the review of the DCD, the staff has confirmed the changes described above; therefore, RAI 247-8314, Question 14.03.02-01, is resolved and closed.

In addition, DCD Tier 1, Table 2.1 1, provides tornado and hurricane design parameters that are in agreement with the design parameters found in SRP Section 3.3.2 and RG 1.76. As such, the staff finds the DCD Tier 1 information acceptable and conforms to the acceptance criteria described above.

Design descriptions and their associated ITAAC in DCD Tier 1, Section 2.2, identify the design loads for structures, including those from tornadoes or hurricane. The evaluation for DCD Tier 1 Section 2.2 regarding to tornado and hurricane loads is in Section 14.3.2.4.4, "Flood, Wind, Tornado, Rain, and Snow," of this SER.

3.3.2.5 Combined License Information Items

Table 3.3.2, lists COL information item numbers and descriptions related to tornado loading from DCD Tier 2, Table 1.8 2.

Table 3.3.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.3(1)	The COL applicant is to demonstrate that the site-specific design wind speed is bounded by the design wind speed of 64.8 m/s (145 mph).	3.3.1.1
COL 3.3(2)	The COL applicant is to demonstrate that the site-specific seismic Category II structures adjacent to the seismic Category I structures are designed to meet the provisions described in Subsection 3.3.1.2.	3.3.1.2
COL 3.3(3)	The COL applicant is to perform an analysis if the site-specific wind and tornado/hurricane characteristics are not bounded by the site parameter postulated for the certified design.	3.3.2.1
COL 3.3(4)	The COL applicant is to provide reasonable assurance that site-specific structures and components not designed for the extreme wind loads do not impact either the function or integrity of adjacent seismic Category I SSCs.	3.3.2.3

After calls with the applicant on August 20, 2015, and September 17, 2015, the staff asked the applicant to address site-specific COL items regarding the responsibilities of the COL applicant for the actions to take if the site-specific wind and tornado/hurricane characteristics are not bounded by the site parameters postulated for the certified design and to demonstrate that the site-specific hurricane and tornado wind speed is bounded by the hurricane or tornado wind speed postulated for the certified design. In the first enclosure to its letter (ML15301A919), under Issue #6, the applicant added COL 3.3(4). COL 3.3(4) contains the COL applicant's responsibilities if the site-specific wind, tornado, or hurricane wind speed is not bounded by design wind speeds postulated for the certified design. Therefore, the staff finds COL 3.3(4) acceptable. The staff verified that the changes proposed in the responses dated October 28, 2015, were incorporated into the DCD.

3.3.2.6 Conclusion

The staff concludes that the applicant has provided sufficient information with respect to the development of tornado and hurricane loads and their application to the structures of the APR1400 design. Based on its review of the information provided in DCD Tier 2, Section 3.3.2, as set forth above, the staff concludes that the requirements of 10 CFR Part 50, Appendix A, GDC 2, as they relate to the design basis tornado and hurricane as well as the development of tornado and hurricane loads on structures, have been met. Specifically, in regard to the design of nonsafety-related structures that are adjacent to safety-related structures, the staff concludes that the application of a Region I tornado load to a nonsafety related structure, combined with a safety margin in its design equivalent to that of a seismic Category I structure, is an acceptable approach for preventing the interaction of a non-seismic Category I structure with a seismic Category I structure during a design basis tornado or hurricane event.

Accordingly, the staff concludes that the applicant has met the requirements of GDC 2 with respect to the capability of structures to withstand design-basis tornado and hurricane wind effects and tornado-generated atmospheric pressure change effects so that their design reflects the following three parameters:

1. appropriate consideration for the postulated most severe tornado with an appropriate margin;
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 function to be performed.

The applicant has designed the plant structures with sufficient margin to prevent structural damage during the postulated most severe tornado or hurricane loadings so that the requirements in Item 1 above are met. In addition, the design of seismic Category I structures, as required in Item 2, includes load combinations reflecting the most severe tornado and hurricane load with loads resulting from normal and tornado/hurricane missile loads.

The use of these methods provides reasonable assurance that in the event of a design basis tornado or hurricane, the structural integrity of the plant structures that have to be designed for tornadoes and hurricanes will not be impaired, and, as a consequence, safety-related systems and components located within these structures will be adequately protected and will be expected to perform their necessary safety functions as credited, thus satisfying the requirement in Item 3 above.

3.4 Water Level (Flood) Design

3.4.1 Internal Flood Protection for Onsite Equipment Failures

3.4.1.1 Introduction

The APR1400 includes measures for protecting safety-related equipment against the effects of flooding that could occur inside the plant from postulated flooding sources. The APR1400 DCD states that all seismic Category I SSCs are designed to withstand the effects of flooding due to natural phenomena or onsite equipment failures without loss of the capability to perform their

safety-related functions. For onsite equipment failures, the DCD provides the facility design and equipment arrangements to mitigate internal flood from both internal (e.g., pipe break, tank failure) and external (e.g., failure of exterior tanks) causes.

The staff's review of the plant internal flood protection capability in this section includes all onsite SSCs whose failure could prevent safe-shutdown of the plant or result in an uncontrolled release of significant radioactivity. The review of external flood protection from natural phenomena (e.g. probable maximum flood, tsunami, etc.) is performed as a separate review in SER Section 2.4.

3.4.1.2 Summary of Application

DCD Tier 1: DCD Tier 1, Section 2.2.5.1.2, "Internal Flooding," states that the inspection, tests, analyses, and associated acceptance criteria for protection against hazards are specified in Item 2 of Table 2.2.5-1, "Protection against Hazards ITAAC."

DCD Tier 2: DCD Tier 2, Section 3.4, "Water Level (Flood) Design," and DCD Tier 2, Section 3.4.1.3, "Flood Protection from Internal Sources," and Section 3.4.1.5, "Evaluation of Internal Flooding," provide information on measures for protecting safety-related equipment against the effects of flooding that could occur inside the plant. DCD Tier 2, Section 3.4.3, "Combined License Information," identifies applicable COL information.

3.4.1.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 3.4.1, "Internal Flood Protection for Onsite Equipment Failures," Revision 3, and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 3.4.1.

- GDC 2, as it relates to SSCs important to safety being designed to withstand the effects of natural phenomena, such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability in order to perform their safety functions. SSC design bases must reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.
- GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs important to safety being 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 (LOCAs). The effects of normal and accident conditions considered could include the effects of flooding from full circumferential failures of seismically designed piping as well as non-seismic, moderate-energy piping, which are not considered in SRP Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping."
- Section 52.47(b)(1) of 10 CFR, "Contents of Applications; Technical Information," as it relates to the requirement that a DCA 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 is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

3.4.1.4 *Technical Evaluation*

Based on the its initial review of the information provided in the DCD Tier 2, Section 3.4.1, the staff found that the description of the internal flood protection was generally incomplete and did not adequately explain what the SSCs subject to flood protection were, how the flood protection analyses were performed, what assumptions were used for the calculation, how the analyses properly incorporated the DCD design features, how the limiting case was determined with sufficient bases, how the non-safety components were used, and how sufficient qualification and functional capability were demonstrated. To supplement the DCD information, the staff audited the applicant's calculations in its electronic reading room during May 22, 2015, through June 11, 2015. See ML15135A365 for the audit plan and ML15208A386 for the audit report.

During the audit, the staff held a teleconference meeting on June 4, 2015. The following subjects were discussed in the meeting:

- Identification of SSCs Subject to Flood Protection,
- Flood Protection of the Component Cooling Water Heat Exchanger Building and Essential Service Water Building (ESWB),
- Watertight Door Seals,
- Clarification of Layout in Containment for Flood Protection,
- Flood Areas and Heights in Containment,
- Limiting Case Determination for Internal Flooding,
- Methodology for Flood Level Calculation,
- Fire Water Flooding,
- Clarifications and Inconsistencies,
- Additional Information on the Configuration,
- ITAAC, and
- Emergency Overflow Lines.

As a result of this meeting, the applicant provided a follow-up DCD markup in its letter (ML15174A408) addressing many items requiring DCD changes. The staff found that the DCD markup significantly improved the clarity of the application. This DCD markup is referred as, "the DCD markup of June 22, 2015," in this section of the SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue, is resolved and closed.

3.4.1.4.1 *Identification of SSCs Subject to Flood Protection*

GDC 2 requires, in part, that structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions. SRP Section 3.4.1, states that GDC 4 is met if SSCs important to safety are designed to accommodate the effects of discharged fluid resulting from high and moderate energy line breaks. The staff reviewed the safety-related SSCs that must be protected against flooding in accordance with SRP Section 3.4.1, Subsection III.1.

The staff found the following information in DCD Tier 2 addressing the identification of SSCs subject to flood protection:

- DCD Tier 2, Section 3.4, states that all seismic Category I SSCs are designed to withstand the effects of flooding due to natural phenomena or onsite equipment failures without loss of the capability to perform their safety-related functions.
- DCD Tier 2, Section 3.4.1.2, "Flood Protection from External Sources," states that Seismic Category I structures identified in Table 3.2-1, "Classification of Structures, Systems, and Components," are designed for flood protection. In the table, it identifies the following seismic Category I structures: containment building, auxiliary building, emergency diesel generator building (EDGB), ESWR, and component cooling water heat exchanger building.
- DCD Tier 2, Section 3.4.1.5, states that the safety-related SSCs that must be protected against an internal flood and flood conditions are described in Section 7.4, "System Required for Safe Shutdown," of the DCD. However, DCD Tier 2, Table 3.4-1, "Reactor Containment Building Components Protected from Internal Flooding," provides a list of SSCs inside the reactor containment building that require flood protection, while DCD Tier 2, Table 3.4-2, "Auxiliary Building Components Protected from Internal Building," provides a list of SSCs in the auxiliary building that require flood protection.

The staff found the above information inadequate in addressing the SSCs being subject to flood protection and requested additional information in RAI 114-8041, Question 03.04.01-1. SRP Section 3.4.1 states that safety-related SSCs should be protected against flooding. DCD Tier 2, Section 3.4.1.5 refers to Section 7.4 for identifying the systems subject to flood protection. DCD Tier 2, Section 7.4, only describes the systems required for safe shutdown but does not include the complete list of safety-related SSCs. However, DCD Tier 2, Table 3.2-1, lists all the safety-related SSCs. Therefore, the applicant was requested to use Table 3.2-1 or justify the use of Section 7.4 to identify the SSCs subject to flood protection.

The applicant responded to the RAI in its letter, (ML15293A483). In its response, the applicant stated that all safety-related SSCs included in DCD Tier 2, Table 3.2-1, are protected against flooding. The applicant stated that DCD Tier 2, Subsection 3.4.1.5, would be revised to specify Table 3.2-1 instead of Section 7.4. The corresponding Table 3.4-1 and Table 3.4-2 would also be revised to identify the SSCs that are protected against internal flooding. DCD markups of these revisions were provided in the RAI.

The staff found the RAI response acceptable because, by referring to DCD Tier 2, Table 3.2-1, all the safety-related SSCs being subject to flood protection are properly identified in accordance with the guidance in SRP Section 3.4.1, Subsection III.1. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-1, is resolved and closed.

DCD Tier 2, Section 3.4.1.5.3, "Emergency Diesel Generator Building," indicates that EDGs are subject to flood protection. DCD Tier 2, Section 3.4.1.3 identifies site-specific ESWB, and essential service water/ component cooling water heat exchanger building (CCWHXB) being subject to flood protection. The COL information item for the ESWB and CCWHXB, COL 3.4(5), states that the COL applicant is to provide flooding analysis with flood protection and mitigation features from internal flooding for the CCWHXB and ESWB.

In addition, the staff verified that the safety-related components in the ESWB and CCWHXB are identified in DCD Tier 2, Table 3.2-1, and are discussed in DCD Tier 2, Sections 9.2.1, "Essential Service Water System," and 9.2.2, "Component Cooling Water System." These safety-related components in the ESWB and CCWHXB identified in Table 3.2-1 are subject to flood protection, and will be under the flooding analysis specified in COL 3.4(5).

DCD Tier 2, Section 3.4.1 states, "the reactor containment building systems to be protected from flooding are the reactor coolant system (RCS), safety injection system (SIS), reactor coolant gas vent system (RCGVS), and main steam system (MSS). The components to be protected from flooding are the valves and electric instrumentation of these systems."

The staff found the above information incomplete regarding the identification of all the systems and related components, e.g., pumps, subject to flood protection, and requested the applicant, in the meeting of June 4, 2015, to clarify the information. In "the DCD markup of June 22, 2015," the applicant added the list of systems being subject to flood protection, to include feedwater system, auxiliary feedwater system, shutdown cooling system, and component cooling water system, to DCD Tier 2, Section 3.4.1.3.

The applicant also explained the reason pumps are not identified as components to be protected is because the APR1400 design does not include any safety-related pump(s) in the containment building. The staff found this clarification acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In addition, the staff issued RAI 114-8041, Question 03.04.01-2 (ML15293A483), requesting the applicant to clarify whether the instrumentation and valves in the in-containment refueling water storage tank (IRWST) are subject to flood protection or are above the flood level in the containment.

In its response to RAI 114-8041, Question 03.04.01-2 (ML15293A483), the applicant clarified that the level, temperature, and pressure instruments for the IRWST are located above the flood level. The staff found the clarification acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-2, is resolved and closed.

DCD Section 3.4, states that the failures of non-seismic and "non-tornado" protected tanks are analyzed for flood protection. The staff requested the applicant to clarify the term "non-tornado"

tanks in the meeting of June 4, 2015. The applicant provided “the DCD markup of June 22, 2015,” to revise the “tornado-protected” tanks to “high-wind (including tornado and hurricane) protected” tanks. The staff found the DCD markup acceptable because it clarifies that the tank failures from both the tornado and hurricane are being considered for flood protection. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In a seismic event, the failure of nonsafety-related onsite tanks such as condensate storage facilities (CSF), main condenser (MC), and circulating water system (CWS) could result in potential flooding. Section 3.4.1.4.9, “External Sources from Pipe or Tank Failures,” of this report provides the staff’s evaluation.

Based on the above, the staff found the applicant has adequately identified all the SSCs that are important to safety and are subject to flood protection.

3.4.1.4.2 *Flood Protection Techniques*

The staff reviewed the proposed flood protection techniques in accordance with SRP Section 3.4.1, Subsection III.2. DCD Tier 2, Section 3.4.1.3 describes the techniques being used for flood protection in APR1400 including the following:

- Physical separation of redundant safety-related SSCs,
- Structural enclosures or barrier walls,
- Drainage systems,
- Emergency sump,
- Internal curbs or ramps,
- Watertight doors, and
- Sealed penetrations.

The APR1400 design minimizes penetrations through enclosures or barrier walls below the flood level. Enclosures and barrier walls below the flood level are sealed to maintain water tightness. No credit is taken for operation of sump pumps to mitigate the flood consequences.

Inspection of Watertight Door and Seal Penetration

SRP Section 3.4.1, Subsection III.2 provides guidance for the staff to evaluate the adequacy of flood protection features including watertight doors. DCD Tier 2, Section 3.4.1.3 states that watertight doors are used for internal flood protection. Watertight doors are specified to withstand the static pressure from the maximum flood elevation as determined in the flooding analysis. Sensor signals to indicate the status of open and closed of the watertight doors are provided to the main control room. Watertight doors are periodically inspected to ensure their functionality. However, the staff found that the periodical inspection is not identified in COL information items. The staff requested the applicant in the meeting of June 4, 2015 to incorporate a COL item. The applicant provided a clarification in “the DCD markup

of June 22, 2015,” to establish a new COL information item, COL 3.4(4), for a periodic inspection of watertight doors and sealed penetrations to ensure their functionality. The staff found the DCD markup acceptable because COL 3.4(4) adequately addressed the periodic inspection of the seal leakage. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Based on the above, the staff found the applicant has adequately addressed the techniques being used for flood protection.

3.4.1.4.3 *Plant Arrangement, Layout Drawings*

In accordance with SRP Section 3.4.1, Subsection III.2, the applicant should provide sufficient information on plant arrangement, layout drawings, configurations, and enclosures to analyzed flood levels in all the floodable areas.

DCD Tier 2, Section 3.4.1.5.1 states that the flood protection in the reactor containment building allows flooding sources to flow to the lowest level of the building through the floor openings and stairwells. Section 3.4.1.5.1 also states that water at EL.136 ft. 6 in., EL.114 ft., and EL.100 ft. flows to the containment annulus area.

During the meeting of June 4, 2015, the staff requested clarification on the water distribution in the lowest containment level because the DCD Tier 2, Revision 0, Section 3.4.1.5.1 is unclear and could read as if all the water in the bottom of the containment is distributed in the annulus. The applicant clarified in, “the DCD markup of June 22, 2015,” that the flood water envelops the entire containment floor area at EL.100 ft., including both the annulus area and the bottom floor of containment area. The staff finds this clarification acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Based on the above, the staff found the applicant has adequately addressed the plant arrangement, layout drawings, and enclosures for the flood analysis.

3.4.1.4.4 *Limiting Case Determination for Containment Internal Flood Analysis*

SRP Section 3.4.1 states that GDC 4 is met if SSCs important to safety are designed to accommodate the effects of discharged fluid resulting from high and moderate energy line breaks of seismically qualified piping that are postulated in SRP Section 3.6.1, “Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment,” and SRP Section 3.6.2. In addition, the staff reviewed the identification of potential flood sources in accordance with SRP Section 3.4.1, Subsection III.3, which indicates that moderate energy piping that is not seismically supported should be considered for full circumferential ruptures, not just cracks.

In DCD Tier 2, Section 3.4.1.5, the applicant states that the flood level in the reactor containment building is determined by dividing the accumulated volume of discharged water from a 50-second loss of coolant accident (LOCA) by the total floodable area at EL.100 ft. The flood level in containment is determined to be 2 ft. The staff requested the applicant to explain its calculation in the meeting of June 4, 2015. Specifically, the staff asked for the justification for the flood water source being, “first 50 seconds of LOCA blowdown,” and using, “break flow,” instead of break water volume to determine the worst case.

The applicant provided clarification in “the DCD markup of June 22, 2015,” under Action Item AI 3-49.9. In the clarification, the applicant stated that, for a postulated LOCA event, most of the water is released into containment within the first 50 seconds. This volume corresponds to a flood level in containment of 2 ft. After 50 seconds, the outflow rate of water is greater than the inflow rate such that the level of 2 ft. is the maximum flood level.

The staff found this clarification insufficient. The outflow was based on a formula from ANSI 56.11-1988 standard. The staff found that ANSI 56.11-1988 was withdrawn by the standard committee. In addition, the staff could not find the necessary configuration data and flow parameters in the DCD or in the calculation reports provided by the applicant in the audit. The DCD did not specify an opening in the design configuration to demonstrate that it can adequately handle the outflow. The nonsafety-related drainage system has not been demonstrated to have the sufficient capability and maintenance requirements to handle the required outflow. As a result of the above review, the staff determined the applicant’s clarification of using 50-second LOCA limit as the flooding source term to be insufficient.

With the above finding as well as additional questions being raised in the meeting of June 4, 2015 regarding the determination of the worst-case flooding, the staff issued RAI 8041, Question 03.04.01-3 (ML16188A448), Question 03.04.01-4 (ML16188A448), and Question 03.04.01-6 (ML15352A267), requesting the applicant to provide information regarding the limiting case determination for further review.

RAI 114-8041, Question 03.04.01-3, noted that DCD Tier 2, Sections 3.4.1.3 and 3.4.1.5, identify the containment flooding sources as coming from a LOCA or from a break in the FPS. The applicant stated that the worst-case flooding event is a LOCA, because it results in the “maximum break” flooding source within the reactor containment building. The staff found that “maximum break,” which meant “maximum break flow,” is inadequate for the determination of the worst case in-containment flooding. Specifically, the applicant was requested to provide following information:

- Provide a comprehensive explanation of the calculation method for using “maximum break,” instead of “maximum flood water volume” to determine the worst case flooding event. In general, flood level is determined by the water volume. Provide design requirements (such as the drain capability) and the basis to support the method being used by APR1400.
- Explain the basis for the determination of the worst case being LOCA with duration of 50 seconds. It should be noted that LOCA has higher peak flow dropping quickly, but lasts much longer than 50 seconds, while other pipe failures such as fire protection water could leak indefinitely without isolation, resulting in larger volume of flood water. If isolation is used, provide the design basis and justifications.
- Explain how the failures of other in-containment water sources (such as main feedwater line, main steam line, auxiliary feedwater system, shutdown cooling system, component cooling system, safety injection tank (SIT), and other water carrying piping) are compared to LOCA for the worst case in-containment flood determination.

In its response to RAI 8041, Question 03.04.01-3, (ML15247A169), the applicant submitted its Revision 1 response (ML16188A448); Revision 2 response (ML16273A575); and Revision 3 response (ML16354A345).

The following are the applicant's responses and staff's review.

- The applicant responded that the containment flood height is calculated by the maximum flood water volume and flood area at the bottom level. The flood height of the containment upper level is determined by comparing inflow and outflow rates through openings and drainage paths. Flood height of the reactor containment building is based on the maximum flood water volume of a LOCA and is further described in the response to Question 03.04.01-4. The applicant stated that DCD Tier 2, Subsection 3.4.1.5.1 would be revised to change the term from "break flow" to "flood water volume." Section 3.4.1.5 would also be revised to describe the basis of determination of flood height in the containment building.

The staff reviewed the response and found it acceptable, because the response addressed the calculation method and appropriately revised the calculation from using "maximum break," to LOCA "maximum flood water volume."

- The applicant responded that even though, for a postulated LOCA, most of the water may be released into containment within the first 50 seconds, for conservatism, the entire released volume during LOCA blowdown phase is taken to calculate the containment flood height at containment floor with no drainage being assumed. The total discharged water volume from a LOCA is assumed to be the volume of the reactor coolant system (RCS) and the four safety injection tanks. The total assumed water volume corresponds to the maximum flood level in containment of 2 ft. Additional water used for safety injection and containment spray during LOCA recirculation phase is taken from the IRWST inside containment which does not increase the maximum level due to the balance of inflow and outflow through floor openings.

Additionally, the applicant stated that although flooding events from large water volumes such as the FPS could leak water at a lower rate but for a substantially longer time, KHNP has determined this case is bounded by the LOCA flooding scenario. Adequate flood protection measures, including operator actions, can be taken to identify and isolate any indefinite flood source. The reactor containment is equipped with safety-related level instruments and provides indication to the control room. Operating procedures will provide guidance based on abnormal indications and alarms to identify the source of the leakage. Actions can then be taken to isolate the leak. DCD Tier 2, Section 3.4.1.5.1, will be revised to describe the isolation of flood sources that could have a larger volume and where credit is taken for operator action.

The staff reviewed the response and found it acceptable because the applicant revised its containment flood height calculation to conservatively assume the entire released volume of the worst case LOCA throughout the accident, instead of previously assumed, "50-second LOCA blowdown." For flooding from FPS, operator actions and isolation of the fire water source are properly addressed. The applicant no longer made its worst case determination simply based on the break flow.

- The applicant stated that flooding sources inside the reactor containment building other than the reactor coolant system include: main feedwater, auxiliary feedwater, component cooling water, fire protection, and the chemical and volume control systems. The LOCA case is the bounding source for the released water in containment compared to these other postulated piping system failures. Water volumes of high and moderate piping systems inside the reactor containment building and assumed water volumes in the analysis are summarized in Table 1 of the RAI response. The flow rates, and isolation provisions are used to limit the duration of the releases to determine the water volumes. Based on the comparative analysis, it is demonstrated that for all of the break events listed in Table 1, the LOCA is the worst case.

The staff reviewed the response and found it acceptable because flooding sources other than the LOCA are properly considered. Based on the comparison in Table 1 of the RAI response and analysis described in the response, the applicant confirmed that the worst case was LOCA. The staff found that the applicant adequately addressed the methodology, assumptions, and configuration parameters in the analysis.

Based on the above, the staff found the responses to RAI 114-8041 Question 03.04.01-3, Revision 3 acceptable, because the applicant revised the flood level calculation from using “maximum break flow,” to “maximum flood water volume,” removed the “50-second limit LOCA,” and properly compared the worst case LOCA with the other water sources. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-3, is resolved and closed.

Flood Level Determination

DCD Tier 2, Section 3.4.1.5, states that the fluid flow rate through a stairwell or a floor opening is calculated using equation 5.2-1, and the flowrate under a door is calculated using equation 5.2-3. Both these equations are in the referenced ANSI 56.11-1988. The staff found that the referenced ANSI 56.11-1988, has not been endorsed or reviewed by NRC, and has been withdrawn by ANS standard committee. The staff issued RAI 114-8041, Question 03.04.01-4 (ML16273A572), requesting the applicant to provide additional information to demonstrate the acceptability and applicability of the above two equations for the containment flood level calculation in an APR1400 configuration.

In its response to RAI 114-8041, Question 03.04.01-4, the applicant provided its Revision 1 response (ML16188A448), and its Revision 2 response (ML16273A574). In Revision 2, to the response to the RAI, the applicant provided the following information.

- Equation 5.2-1 is based on the broad-crested weir flow formula, and is used in limited, but appropriate applications in the flooding analysis. It is applied to calculate the flow rate through an opening such as a stairwell or floor opening. Similarly, Equation 5.2-3 is a formula used to calculate flow rate under a sluice gate.
- The containment flood level was revised using a conservative method based on the total discharged water volume from a LOCA instead of the previously used discharge volume during the initial 50 seconds of the accident. According to the result of the flooding calculation considering the revised maximum released water volume specified in the response to RAI 114-8041, Question 03.04.01-3 (b), the flood height in the reactor

containment building is determined to be less than 2 ft. The volume of the entire RCS water inventory and four safety injection tanks is conservatively taken to flood the containment with no outflow assumed. This is the total water volume released to the containment during LOCA blowdown phase.

- During LOCA recirculation phase, the inflow of water released to the containment consists of ECCS (SI and CS) injection flow (from the IRWST located in containment) with an outflow to the HVT and discharging back into the IRWST. The analysis shows that the flow out from containment into the IRWST will be greater than the flow into containment, and, therefore, the flood level will not be higher than that determined in LOCA blowdown phase (~2 ft.).
- Figures 2 and 4 of the RAI response show the configuration of the containment floor EL-100 ft., the HVT, and the IRWST. The floodable volume and size of the floor openings are described in the response.

The staff reviewed the RAI response and found it acceptable for the following reasons:

- The applicant revised the methodology to assume zero outflow from the containment floor during the LOCA blowdown phase. The containment flood level of 2 ft. was determined by all the water volume released into the containment during the blowdown phase. This is a conservative approach.
- During LOCA recirculation phase, the floor openings can remove sufficient flow resulting from the inflow of containment spray and safety injection. This outflow was calculated by the broad-crest weir flow formula. The broad-crest weir flow formula is a steady-state flow equation. Although to apply this formula for the first 50 second of LOCA in transient without sufficient justification may be questionable, it is reasonable to apply this formula for the LOCA recirculation phase when the steady-state flow is well established. The calculation results in the RAI response, which incorporated the size of the floor opening, showed significant margin in the flow balance and flood level determination.

Based on the above, the staff found the responses to RAI 114-8041, Question 03.04.01-4, Revision 2, acceptable because of the conservative methodology and sufficient margin. Therefore, RAI 114-8041, Question 03.04.1-4 is resolved and closed.

Floor Drains

During the audit review of the calculations, the staff found that the in-containment flood level calculation might have taken credit of outflow from containment bottom floor because no outflow opening is specified. The staff issued RAI 114-8041, Question 03.04.01-6 (ML15208A282), requesting the applicant to provide additional information to clarify the use of non-safety drainage system in the internal flood level calculation, to specify and justify the required functional capability of the drainage system, and to explain how a failure of the drainage system affects the flood level determination.

In its response to RAI 114-8041, Question 03.04.01-6, (ML15352A267), and its revised response (ML16179A429), the applicant clarified that the discharge flow through the floor drains is not credited in the calculation of flood level of the containment building.

The functional capability of the equipment and floor drainage system (EFDS) is to drain the flooded water to the sump located in the lowest elevation of the building. Although the piping of the drainage system is classified as seismic Category II, it is embedded into the concrete of seismic Category I structures, such as the reactor containment building and auxiliary building. Therefore, the integrity of the embedded piping is practically assured, and the intended function of drainage system can be accomplished. Additionally, procedures and administrative controls to prevent clogging of the floor drains are to be established by the COL applicants (COL 3.4(3)).

The potential blockage of drain paths is not an issue in terms of draining the discharged water to the sump due to a high energy line break (HELB) in the reactor containment building because floor drains are conservatively not credited (i.e., assumed to be entirely blocked) in the calculation. The areas where high energy line breaks are postulated in the auxiliary building have large emergency flood relief paths to discharge the flooded water out of the auxiliary building.

Because the discharge flow through the floor drains is not credited in the calculation of flood level in the reactor containment building and drainage system does not have any safety function other than the containment isolation, the staff found that procedures and administrative controls in COL 3.4(3) adequately address the concern of drainage system being nonsafety-related. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-6, is resolved and closed.

Fire Water Sources

SRP Section 3.4.1, Subsection III.3 indicates that the operation of the fire protection should be considered in potential flood source determination. DCD Tier 2, Section 3.4.1.5, addresses the operation of the fire protection for flood protection. DCD Tier 2, Section 3.4.1.5, states that indoor hydrants that could reach the area or zone where a fire occurs are considered as internal flooding sources when a fire occurs. The total discharge flow rate from these indoor hydrants is assumed to be 0.044 m³/s (700 gpm).

The staff issued RAI 114-8041, Question 03.04.01-5 (ML15208A282), requesting the applicant to provide information on why the assumption of a 700 gpm flow rate from two manual hose stations is adequate for flood protection, and how long it is assumed for fire water systems. Further, the staff asked what the flood height in containment would be from the flow of fire protection water, which may last for a long time. The staff also requested that the applicant state in DCD Tier 2, Section 3.4, that the flooding analysis also includes the inadvertent operation of FPSs as required by GDC 3.

In its response to RAI 114-8041, Question 03.04.01-5, (ML15293A483), the applicant stated that the maximum discharge flow rate from two manual fire hose stations (indoor hydrants) for a fire area is conservatively assumed as 700 gpm (350 gpm each) for the flood analysis, although the rated capacity of a hose station is 250 gpm (total 500 gpm) as described in DCD Tier 2, Section 9.5.1.2.2, "Fire Protection Water Supply System." Additionally, the applicant stated that the fire would be extinguished well before discharging the entire water volume of the fire protection water supply tanks, which is 690,000 gallons. Operating personnel or fire fighters would isolate the water source or correct any failures that may occur prior to depletion.

Regarding flooding in containment, the applicant stated that adequate flood protection measures, including operator actions, can be taken to identify and isolate any indefinite flood source. The reactor containment is equipped with safety-related level instruments located at elevation (EL.) 106 ft. 3 in., that can measure levels from 100 ft. 4 in., to 102 ft. 10 in., and which provide indication to the control room. Other indications of internal flooding for the operator include sump pump start indications and alarms and fire pump start indication and alarms. The fluid flow rate due to a through wall crack is calculated to be 184 gpm. The time that it takes to flood containment up to the 0.61 m (2 ft.) height from the 100 ft. elevation is 36.5 hours. For the inadvertent operation of the automatic sprinkler system it would be 11.4 hours. The 0.61 m (2 ft.) height is the flood height calculated for the LOCA case. These times are considered to be more than sufficient for operators to identify and isolate the FPS in a flooding event. As described in DCD Tier 2, Section 9.5.1, sectional isolation valves are located along the fire protection water distribution system to isolate portions of the fire main for maintenance or repair. Valves are also installed to permit isolation of outside hydrants. Water flow to a wet pipe suppression system can be stopped by manually closing the water supply isolation valve.

The applicant provided a markup to DCD Tier 2, Section 3.4, stating that the flood analysis will include the inadvertent operation of FPSs. Based on the above, the staff found the applicant's response to RAI 114-8041, Question 03.04.01-5, acceptable because the applicant has met the requirements of GDC 3, the guidance in SRP Section 3.4.1, and has adequately addressed the staff's concerns. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-5, is resolved and closed.

In its review the staff noted in DCD Tier 2, Section 3.4.1.5 that the applicant states, "[a] malfunction of the FPS is not considered in this area because it has a CO₂ suppression system," while in DCD Tier 2, Section 9.5.1, "Fire Protection Program," the applicant states that there are no CO₂ systems used in the APR1400. The staff issued RAI 114-8041, Question 03.04.01-8 (ML15208A282), requesting the applicant to clarify this issue. In its response to RAI 114-8041, Question 03.04.01-8, (ML15293A483), the applicant stated that CO₂ suppression systems are not used in the APR1400 design and that the statement regarding CO₂ suppression systems will be deleted in DCD Tier 2, Section 3.4.1.5. The staff found the clarification acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-8, is resolved and closed.

Non-Seismic Piping

SRP Section 3.4.1, Subsection III.3 states that moderate energy piping that is not seismically supported should be considered for full circumferential ruptures, not just cracks. In DCD Tier 2, Section 3.4.1.5, the applicant states that, for the flood analysis, the single worst-case piping rupture for non-seismically analyzed piping is assumed for each analyzed area. However, it is not clear how the non-seismic pipe failures are analyzed. The staff found the DCD information incomplete and requested the applicant in the meeting of June 4, 2015 to clarify the DCD information. The applicant provided in, "the DCD markup of June 22, 2015," the following clarification.

All piping inside containment is seismically qualified and, therefore, the containment flooding analysis does not include rupture of a non-seismic pipe.

For worst case flooding inside containment, all possible sources were considered; including those that have the potential to be long lasting, such as the FPS. However, ruptures in systems that have the potential to provide a long lasting supply of water will be isolated by plant operators based on indications that are provided in the control room including: containment sump level indication and alarms, sump pump start indications and alarms, and fire pump start indication and alarms. The volume of water that would flow into containment prior to isolation, accounting for sufficient time for operator identification and isolation, is bounded by the volume of water that results from a LOCA. Therefore, the worst case internal flooding source as been established as a LOCA and not from long lasting sources such as from the FPS. The DCD will be updated to explain why LOCA event is selected as the limiting source.

The above DCD markup clarified that the non-seismic pipe failures would not be worse than a LOCA event due to the isolation provision in the design. The staff found this clarification acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is considered resolved and closed.

Based on the above, the staff found the applicant has adequately addressed the containment internal flood analysis.

3.4.1.4.5 *Internal Flood Analysis for Auxiliary Building*

DCD Tier 2, Section 3.4.1.5.2, "Auxiliary Building," describes the evaluation of internal flood in the auxiliary building, which provides physical separation between the quadrants housing redundant trains. DCD Tier 2, Table 3.4-2 provides a list of SSCs in the auxiliary building that require flood protection. The applicant states that the primary means of flood protection are the divisional or quadrant walls. These walls serve as flood barriers between redundant trains of safe shutdown systems and components. Flood barriers provide separation between the quadrants. The flood drainage systems are separated by quadrants with no common drain lines between the quadrants. Floors are generally sloped to allow for good drainage to the quadrant sumps. On the divisional wall, penetrations are sealed and no doors are provided up to EL.64 ft., which is the potential flood level from the bottom elevation. Watertight doors are provided between the quadrants to prevent potential flooding sources from spreading to adjacent quadrants. The applicant states that the worst case flooding in the auxiliary building is at EL.55 ft., the lowest elevation being analyzed, and the water source is from the IRWST. The maximum water level is 2.74 m (9 ft.) with some margin. The released water volume is contained within the affected quadrant. At higher elevations, the flood water drains to the lower elevation through floor drains, stairwells, and openings. To avoid flooding adjacent quadrants, a curb or ramp is installed at each quadrant intersection. For each floor at different elevation, the applicant has determined the worst-case flooding scenario and the flood level, and demonstrated that the SSCs subject to flood protection are above the flood level.

Following its review, the staff requested the applicant in the meeting of June 4, 2015, to provide clarification to address the height of the divisional walls to demonstrate that walls are sufficiently high to contain the released water within the affected quadrant. The applicant stated in "the DCD markup of June 22, 2015," that the divisional wall heights are 13 ft. and have sufficient margin to contain the released water volume. The staff found the response acceptable because it adequately clarified the height of the divisional wall. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In the audit of the calculations, the staff found that emergency overflow lines (EOLs) are used for flood protection in the Auxiliary Building quadrants A, B, C, and D, at elevation 55'. However, the staff could not find any discussion of EOLs in the DCD. Therefore, in RAI 114-8041, Question 03.04.01-9 (ML15208A282), the staff requested the applicant to provide a description of how the emergency overflow lines are used for flood protection and to specify the functional requirements and seismic classification of these lines.

In its response to RAI 114-8041, Question 03.04.01-9 (ML15293A483), the applicant stated the following information relating to EOLs and provided markups of the revised Section 3.4.1 of the DCD.

- a. The vertical and horizontal Emergency Overflow Lines (EOLs) are used to provide flow paths for the draining of flooded water, in addition to floor drains, as one of the flood mitigation measures.
- b. EOLs are the embedded pipes that connect rooms. Most of those pipe lengths are buried in the concrete walls or slabs. EOLs are seismically designed as Seismic Category II. The sizes of the EOLs are determined based on the combination of available number of floor drains and required flow area needed to support drainage of the flooded water volume.

The staff found the RAI response acceptable because the response has adequately addressed the missing information of the EOL being used for the flood protection measures. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8041, Question 03.04.01-9, is resolved and closed.

Based on the above, the staff found the applicant has adequately addressed the auxiliary building flood analysis.

3.4.1.4.6 *Main Control Room*

DCD Tier 2, Section 3.4.1.5.2, states that the equipment to be protected from flooding at EL. 156 ft. 0 in. includes instrumentation and control (I&C) equipment, cubicle coolers, and the console in main control room. The main control room area is protected from flooding in that no water lines are routed above or through the control room or computer room. Water lines routed to heating, ventilation, and air conditioning (HVAC) air handling units around the control room are contained in rooms with curbs that preclude the potential for water leakage from entering the control room or computer room.

Based on the above, the staff found the applicant has adequately addressed the main control room flood analysis.

3.4.1.4.7 *Emergency Diesel Generator Building*

DCD Tier 2, Section 3.4.1.5.3 states that the EDGs are separated by distance and flood barriers so that an internal flooding event does not affect both EDGs simultaneously.

Based on the above, the staff found the applicant has adequately addressed the EDG building internal flood analysis.

3.4.1.4.8 *In-Leakage Sources*

SRP Section 3.4.1 states that provisions should be provided for protection against possible in-leakage sources, such as non-mechanistic cracks in structures, and exterior openings and penetrations in structures located at a lower elevation than the flood level.

The APR1400 was found to withstand these effects by the following design features:

- Waterstops are used in all horizontal and vertical construction joint in all exterior walls up to flood-level elevation.
- Water seals are provided for all penetrations in exterior walls up to flood-level elevation.
- All below-grade exterior walls and basemats of seismic Category I structures are thickened by more than or equal to 0.6 m (2 ft.) to protect against water seepage, as required in SRP Section 14.3.2, "Structural and systems engineering – Inspection, Tests, Analyses, and Acceptance Criteria."

Based on the above, the staff found the applicant has adequately addressed the protection against possible in-leakage sources for flood analysis.

3.4.1.4.9 *External Sources from Pipe or Tank Failures*

In a seismic event, the failure of nonsafety-related onsite tanks such as CSF, MC, and CWS could result in potential flooding.

Condensate Storage Facilities

In RAI 135-8001, Question 09.02.06-1 (ML15220A036), the staff requested the applicant to provide a discussion of the provisions and design features to ensure adequate protection against the effects of CSF tank failure.

In its response to RAI 135-8001, Question 09.02.06-1 (ML16107A045), the applicant stated that the tanks are located in the tank yard that has adequate distance from safety-related structures, and watertight doors are installed at the exterior entrance located on the ground level of safety-related structures to prevent inflow to safety-related structures. The site-specific design of plant grading and drainage will be provided by the COL applicant. This is reviewed in SER Section 9.2.6.

Main Condenser

DCD Tier 2, Section 10.4.1.3, "Safety Evaluation," states that the failure of the APR1400 MC and any resultant flooding does not prevent safe shutdown of the reactor since the flood water from the turbine building does not enter the safety-related building.

In RAI 99-7836, Question 10.04.01-3 (ML15204A914), the staff requested the applicant to provide additional information in the DCD regarding flood effects due to failure of the MC and its components. Specifically, the staff requested the applicant to specify the flood analysis height compared to the height of the bottom of the non-watertight openings.

In its response to RAI 99-7836, Question 10.04.01-3 (ML15308A583), the applicant stated that the floodwater due to the failure of the MC in the turbine generator building (TBG) is bounded by a postulated circulating water (CW) pump discharge piping break and when six CW pumps are operating with runout conditions. The flood height due to the postulated CW piping failure in the turbine generator (T/G) building is determined to be 4.0 ft. from EL.100 ft. 0 in., of the T/G building. The floodwater is drained to the outside of T/G building through the emergency flood relief opening (flood relief panel) which is installed at EL.100 ft-0 in. of the building. Flooding of the T/G building does not affect the auxiliary building because there is no opening on the auxiliary building wall that connects to the T/G building below the EL.104 ft., 0 in. This response is reviewed in SER Section 10.4.1, "Main Condenser."

In RAI 402-8477, Question 10.04.01-6 (ML16041A092), the staff requested the applicant to specify additional information regarding the drainage away from the structures containing safety-related equipment (e.g., auxiliary building, emergency diesel building, fuel tanks for safety-related diesel generators, etc.)

In its response to RAI 402-8477, Question 10.04.01-6 (ML16107A048), the applicant stated that plant grading, drainage, and watertight doors that are installed at the exterior entrances of the safety-related building as described in DCD Tier 2, Section 3.4.1.4, will mitigate the flooding. The flooding in the turbine building that results from a failure of the MC is bounded by that of a CWS line break in the turbine building. This response is reviewed in SER Section 10.4.1.

Circulating Water System

The failure of nonsafety-related CWS could result in a potential flood source. In RAI 89-8052, Question 10.04.05-1, (ML15201A502) the staff requested the applicant to provide a discussion of the provisions and design features to ensure adequate protection against the effects of CWS failures.

In its response to RAI 89-8052, Question 10.04.05-1 (ML16152B012), the applicant stated that the floodwater due to a CW piping failure in the turbine generator (TG) building is bounded by a postulated CW pump discharge piping break, when six CW pumps are operating with runout conditions. The flood height due to the postulated CW piping failure in the TG building is determined to be 4.0 ft., from EL.100 ft. 0 in., of the TG building. The floodwater is drained to the outside of the TG building through the emergency flood relief opening (flood relief panel), which is installed at EL.100 ft. 0 in., of the building. Flooding of the TG building does not affect the auxiliary building because there is no opening on the auxiliary building wall that connects to the TG building below the EL.104 ft. 0 in. This response is reviewed in SER Section 10.4.5, "Circulating Water System."

Based on above, the staff found the applicant has adequately addressed that the failure of nonsafety-related onsite tanks such CSF, MC, and CWS does not affect the safety-related SSCs.

3.4.1.4.10 Inspections, Tests, Analyses, and Acceptance Criteria

DCD Tier 1, Section 2.2.5.1.2, states that the inspection, tests, analyses, and associated acceptance criteria (ITAAC) for protection against hazards are specified in Item 2 of Table 2.2.5-1. It also states that the inspection of the as-built protective provisions against internal flooding hazard will be conducted. These provisions include divisional flood barriers,

watertight doors, penetrations in the flood barrier, and safety-related electrical I&C equipment in nuclear island located above the internal design flood level.

However, the staff found that the ITAAC include only I&C equipment to be located above the flood level but not all the other safety-related SSCs (such as valves and pumps). The staff also found that in the ITAAC, "Acceptance Criteria," only the nuclear island and emergency diesel generator (EDG) structures are included but not the ESWB or CCWHXB. In RAI 114-8041, Question 03.04.01-7, the staff requested the applicant to verify the scope of this ITAAC as well as its acceptance criteria.

In its response to RAI 114-8041, Question 03.04.01-7 (ML15293A483), the applicant stated that:

DCD Tier 1, Item 2 of Table 2.2.5-1 will be revised to include the ESW/CCW Heat Exchanger Building in the acceptance criteria. The scope of ITAAC will be revised to clearly state that the safety-related equipment and instruments that shall be protected from flooding in the reactor containment, auxiliary, EDG, and ESW/CCW heat exchanger buildings. The auxiliary building basement floor (EL.55 ft) is not required to be protected from flooding due to the installed divisional walls separating each redundant train.

The staff reviewed the RAI response and determined it acceptable because the response has adequately addressed the ITAAC scope and acceptance criteria. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 114-8041, Question 03.04.01-7, is resolved and closed.

The staff finds that the ITAAC are sufficient to provide reasonable assurance that safety related SSCs will be protected from internal flooding and that they satisfy the requirements of 10 CFR 52.47(b)(1). Therefore, the staff concludes that the internal flooding protection provided for APR1400 SSCs is adequate.

A complete list of all APR1400 related ITAAC is provided in SER Section 14.3.

3.4.1.4.11 *Technical Specifications*

SRP Section 16.0, "Technical Specifications," does not specifically reference flood protection. There are no APR1400 Technical Specification sections for internal flood protection. The staff found this aspect of the DCD acceptable.

3.4.1.4.12 *Risk Evaluation*

SRP Section 3.4.1, Subsection III.4 provide guidance on the flooding risk assessment. DCD Tier 2, Section 19.1.5.3, "Internal Flooding Risk Evaluation," describes the applicant's risk assessment. The staff's evaluation of the flooding risk is in SER Chapter 19.

3.4.1.5 *Combined License Information Items*

DCD Tier 2, Section 3.4.3, identified four COL items, which contain three items for external flood protection and one for internal flood protection. The external flood protection is evaluated in SER Section 2.4. The one for internal flood protection is described below:

COL 3.4(5): The COL applicant is to provide flooding analysis with flood protection and mitigation features from internal flooding for the CCW Heat Exchanger Building and ESW Building.

As a result of the staff's review relating to Confirmatory Item 03.04.01-06, Action Item AI 3-49.4, the applicant incorporated a new COL information item below.

COL 3.4(4): The COL applicant is to periodically inspect watertight doors and the penetration seals to ensure their functionality.

As a result of the staff's review relating to confirmatory item RAI 03.04.01-6, the applicant incorporated a new COL information item below.

COL 3.4(3): The COL applicant is to establish procedures and programmatic controls to ensure the availability of the floor drainage.

Table 3.4.1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 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
COL 3.4(4)	The COL applicant is to periodically inspect watertight doors and the penetration seals to ensure their functionality.	3.4.1.3
COL 3.4(5)	The COL applicant is to provide flooding analysis with flood protection and mitigation features from internal flooding for the CCW Heat Exchanger Building and ESW Building.	3.4.1.3

3.4.1.6 Conclusion

The internal flood protection review included all systems and components whose failure could prevent safe shutdown of the plant and maintenance thereof or result in significant uncontrolled release of radioactivity. As discussed above, based on the review of the applicant's proposed design criteria, design bases, and safety classifications for safety-related SSCs necessary for a safe plant shutdown during and following the flood condition from either external or internal causes, the staff concludes that the design of the facility for flood protection conforms to the requirements as set forth in 10 CFR 50, Appendix A, GDC 2 and GDC 4.

As set forth above, the staff found that the ITAAC, Technical Specifications, and COL applicant information Items specified ensure that site-specific information not provided in the DCD is identified and addressed with respect to internal flood protection, and that flood protection features incorporated in the plant design can be properly inspected, tested and operated in accordance with DCD requirements.

3.4.2 Analysis Procedures

3.4.2.1 Introduction

This section reviews the applicant's data on the highest flood and groundwater levels and the analysis procedure used to transform the static and dynamic effects of the waters into effective design loads for use in the design of structures important to safety. In doing so, the staff evaluates the acceptability of the data and processes used to meet the requirements of GDC 2, by which SSC's important to safety must be designed to withstand the effects of the highest probable maximum flood (PMF) and maximum groundwater levels without loss of their capability to perform the safety functions. This section documents the staff's review, evaluation, and findings regarding the procedure for converting the maximum flood water heights to effective applied loads and the analytical procedures to be applied for the evaluation of building components and structures of the APR1400 design that are important to safety from the effects of this natural phenomena in combination with other concurrent loads.

3.4.2.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Section 2.1, Section 2.2.1, "Nuclear Island," Section 2.2.2, "Emergency Diesel Generating Building," and Section 2.2.5, "Protection against Hazards," which cover the design basis flood loads applied to as well as protection measures implemented in Section 2.2.5.1.1, "External Flooding," for the effect of external flooding on safety related buildings and structures.

DCD Tier 2: The applicant has provided a description of analysis procedures for flood design of structures important to safety in Section 3.4.2, "Analysis Procedures," and external flood protection description in Section 3.4.1.4, "Evaluation of External Flooding," summarized here in part, as follows:

- Structures important to safety are designed to be protected from groundwater and external floods as required by GDC 2.

Loading parameters and protective measures are in part provided by the following:

- The Maximum Flood Elevation of the APR1400 standard design is 0.30 m (1 ft) below plant grade in the vicinity of SSCs important to safety.
- The maximum groundwater elevation for the APR1400 generic design is 0.61 m (2 ft) below plant grade in the vicinity of SSCs important to safety.
- The maximum precipitation rate (1 mi²) is 492.7 mm (19.4 in.) per hour and 157 mm (6.2 in.) in 5 minutes.
- 100-year snowpack roof load is 2.873 kPa (60 lbf/ft²).
- Depth of 48-hour probable maximum winter precipitation (PMWP) is 914.4 mm (36 in).
- No openings or underground tunnels penetrate the exterior walls of structures important to safety below grade.

- Exterior wall or floor penetrations of structures important to safety below grade have watertight seals.
- No permanent dewatering systems are necessary to maintain acceptable groundwater levels.
- All below-grade exterior walls and basemats of structures important to safety are thickened by at least 0.6 m (2 ft) to protect against water seepage.
- Structures important to safety can withstand hydrostatic and hydrodynamic loads resulting from PMF, groundwater and other external flooding events.

ITAAC: ITAAC items for this area of review are provided in DCD Tier 1, Table 2.2.5-1, "Protection against Hazards ITAAC," wherein Item No. 1 provides protective measures against external flooding hazards through external walls of buildings important to safety, of below postulated flood/ground water level using: (1) minimum wall thickness; (2) penetrations be water sealed; and (3) water stops be installed at all construction joints. DCD Tier 1, Table 2.2.1-2, "Nuclear Island Structures ITAAC," DCD Tier 1, Table 2.2.2-2, "Emergency Diesel Generator Building ITAAC," provide design basis flood loads applied to the as-built seismic Category I buildings.

COL Information Items: See Section 3.4.2.5 below.

3.4.2.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in SRP Section 3.4.2, and are summarized below:

- Part 50 of 10 CFR, Appendix A, GDC 2, as it relates to the SSCs important to safety being designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena including consideration of the most severe of natural phenomena that have been historically reported for a site and appropriate combinations of the effects of normal, abnormal and accident conditions with the effects of the natural phenomena.
- Section 52.47(b)(1) of 10 CFR, as it relates to the requirement that a 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 DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, as amended, and NRC regulations.

Review interfaces with other SRP sections and acceptance criteria can also be found in SRP Section 3.4.2. The acceptance criteria necessary to meet GDC 2 are as follows:

- The static and dynamic effects induced by the highest flood and ground water levels used in the design shall be the most severe ones that have been historically reported for the site.

- All possible flood induced loads including hydrostatic pressure, uplifting, floating, and buoyancy must be included to calculate lateral and overturning moments of the structure.
- If the flood level is above the proposed plant grade, the dynamic loads of wave action should be considered.

3.4.2.4 *Technical Evaluation*

In this section of the report, the staff reviewed the procedures used by the applicant to transform static and dynamic effects of the highest flood and groundwater levels into effective loads applied to structures important to safety described in APR1400 DCD Tier 2, Revision 0. In addition, the staff reviewed the appropriateness of applied loads used by the applicant to account for the effects of flood and groundwater on these structures.

This review was performed following the review procedures and acceptance criteria of SRP Section 3.4.2 to ensure conformance with GDC 2, in Appendix A to 10 CFR Part 50. The scope of the review covers information provided in APR1400, DCD Tier 2, Sections 2.2, 3.4, and 3.8, based on guidance provided in SRP Sections 2.0, 2.4.3, 2.4.12 and procedures published in referenced codes and standards for determining the effects of flood and groundwater loads on structures. The review focused on following items:

- Validation of input parameters for structural design appropriate to account for flood and groundwater loadings.
- Verification of the analysis procedures used by the applicant to transform static and dynamic effects of the highest flood and groundwater level into effective loads on the structures to be consistent with SRP Section 3.4.2 and industry standards including, ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures."
- Verification of protection measures for safety-related SSCs from external flooding sources.

3.4.2.4.1 *Design Basis Parameters*

The staff reviewed the information provided in DCD Tier 2, Revision 0 and Table 2.0-1, and determined that it needed additional information to complete its review. In RAI 75-8023, Question 03.04.02-1 (ML15196A602), the staff asked the applicant to provide a list of design input from all sources of water heads. In its response to RAI 75-8023, Question 03.04.02-1 (ML15225A569), the applicant provided a complete list of the design-basis parameters used in flood loading input to the APR1400 standard design, including the following flood, groundwater and precipitation parameters as documented in DCD Tier 2, Table 2.0-1:

Table 3.4.21 Water Heads Considered for APR1400 Flood Design Inputs

Parameter Description	Parameter Value
(i) Maximum flood level	0.30 m (1 ft.) below plant grade
(ii) Maximum ground water level	0.61 m (2 ft.) below plant grade

(iii) 48-hour probable maximum winter precipitation (PMWP)	91.44 cm (36 in.)
(iv) Maximum precipitation rate over 1 mi ²	49.27 cm (19.4 in.) in one hour 15.7 cm (6.2 in.) in 5 min.
(v) Probable maximum water level PMP Probable maximum flood (PMF)	Same as Item (i) Same as Item (iv) To be provided by COL applicant

The applicant further provided the bases in the response for setting the values of the design input parameters as shown in the above Table 3.4.21: for both (i) and (ii), the values are set in “EPRI ALWR Utility Requirement,” Volume II, Table 1.2-6; for (iii), the PMWP value is based on Figures 26, 27, 35, 37 and 45 of the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Report No. 53, “Seasonal Variation of 10-Square-Mile PMP Estimates, United States East of the 105th Meridian”; for (iv), the values for maximum precipitation rate over 1 mi² for 1 h and 5 min. are determined by Hydrometeorological Report No. 51, 53, and 52, respectively; for (v), the value of PMF is site-specific hydrologic information to be set by the COL applicant (COL 3.4(8)). The staff reviewed the whole set of the design input parameters in the above table, and found they properly account for all possible flooding sources and are consistent with Section C of the regulatory position 1a, set in RG 1.59, “Design Basis Floods for Nuclear Power Plants,” Revision 2, and Section C of Regulatory Position 1a, in RG 1.102, “Flood Protection for Nuclear Power Plants,” Revision 1, and therefore are acceptable.

However, it should be emphasized as indicated in Item (v) of the above table that the COL applicant is responsible for providing sufficient site-specific flooding information to be bounded by the parameters set in the above table so as to assure the hydrological events will not affect the safety basis for the APR1400 standard design. Otherwise, the COL applicant is to demonstrate that the design satisfy all applicable regulatory requirements. (See COL 3.4(3) and COL 3.4(8)).

3.4.2.4.2 *Procedures of Transforming Water Heads to Design Basis Flood Loads*

The procedures of transforming water head inputs to design in the above table to design basis flood loads are the major review areas specified in SRP Section 3.4.2, Section I.2. During the review of this section, DCD Tier 2, Section 3.4.2, “Analysis Procedures,” the staff found that the applicant did not provide the information on the transforming procedures here in this section (rather refers the procedures to DCD Sec.3.8). This was requested in RAI 75-8023, Question 03.04.02-1 (ML15196A602). In its response to RAI 75-8023, Question 03.04.02-1 (ML15225A569), the applicant provided methods on how to evaluate hydrostatic loading, buoyancy load and hydrodynamic loading including hydrodynamic water pressure due to earthquakes from design basis water heads prescribed in the above table, based on engineering principles on hydrostatics and soil dynamics. The applicant stated that the hydrostatic loading is calculated as linearly distributed pressure on external walls based on the design basis water level according to the basic equation of hydrostatics. The dynamic ground water pressure is calculated based on Matsuo and O’Hara hydro-dynamic formula in the textbook, (DAS, Braja, Principles of Soil Dynamics, PWS Kent Publishing 1993). For hydrodynamic water pressure induced by earthquakes, the formula gives a parabolic distributed pressure. The buoyant force acting in the direction opposite to the gravitational force at the bottom of the basemat for all loading cases is calculated as the weight of the water displaced by

the building. Since the adopted procedures are based on well-established practices in engineering community, the staff concludes that they are in conformance with SRP Section 3.4.2, acceptance criteria 2 and 3, and thus, are acceptable.

The DCD Tier 2, Section 3.8.5.3, and Table 3.8-2, provide the loads and load combinations used for the design of seismic Category I structures. In its response to RAI 75-8023, Question 03.04.02-1 (ML15196A602), the applicant stated that those individual loads involving flood water head include:

- Hydrostatic load (L_h) in the category of “normal load,”
- Flooding load (Y_f) in the category of “abnormal load,”
- Design flood or precipitation load (H) in in the category of “severe environmental load,”
- PMF or PMP (H_s) in in the category of “extreme environmental load,” and
- Hydrodynamic load in seismic excitation (E_s) in the category of “extreme environmental load.”

These loadings are used as design inputs for load combinations in the design of seismic Category I structures. DCD Tier 2, Table 3.8-2 is used for the reactor containment building, whereas Table 3.8-9A, for other seismic Category I, structures. In addition, the buoyant forces in normal and flood conditions are considered in the stability check of overturning, sliding, and flotation as shown in DCD Tier 2, Table 3.8-10. The staff reviewed these loadings and their classifications, and found they comply with American Concrete Institute (ACI) 349 Chapter 9, code specifications, and SRP Section 3.4.2, acceptance criteria 2, thus are acceptable. Therefore, RAI 75-8023, Question 03.04.02-1, is resolved and closed.

3.4.2.4.3 *Protective Measures Implemented for the Effects of Flooding and Groundwater*

DCD Tier 2, Section 3.4.1.4, covers evaluation of external flooding from sources including natural phenomena and failure of onsite tanks or large buried pipes. The applicant stated that maximum water level and flow velocity are used to estimate flood loads and the watertightness of the seismic Category I structures during an external flood event. DCD Tier 1, Section 2.2.5.1.1, and Tier 2, Section 3.4.1.2, provide protective measures implemented for the effect of external flooding on the seismic Category I buildings and structures. Those measures include: (1) No openings or underground tunnels penetrate the exterior walls of the seismic Category I buildings below grade; (2) Watertight seals are provided for exterior wall penetrations below grade; (3) all exterior walls and basemats are thicken by at least 0.6 m (2 ft) to protect against water seepage. The staff reviewed the protective measures implemented for the standard design of the seismic Category I buildings and structures, and found they are adequate to protect the SSCs important to safety against external flooding events as they are in conformance with SRP acceptance criteria Item 8 on flood load in SRP Section 14.3.2, and RG 1.102, “Flood Protection for Nuclear Power Plants,” Regulatory Position 1c, “Incorporated Barriers.”

Since the above protective measures are implemented in the standard design, the COL applicant is responsible for providing the site-specific measures so as to assure the hydrological events will not affect the safe operation for the APR1400 nuclear power plants.

The applicant was asked to provide all possible site-specific protective measures that can be added to the list of COL Information Items in a letter dated October 28, 2015 (ML15301A920). In response, the applicant updated DCD Tier 2, Section 3.4.1.1, Section 3.4.1.4, and Section 3.4.2, adding the following four (4) items for the COL applicant to consider:

1. The site-specific design of grading and drainage;
2. The site-specific flooding hazards from engineered features such as water tank collapsing, water pipe breaking, etc.;
3. Any site-specific flood protection measures pursuant to RG 1.102, such as levees, seawalls, flood walls, revetments or break waters and site bulkheads; and
4. The site-specific dewatering system if the plant is built below the design basis flood level.

As a result, four new COL Information Items are added to the list in DCD Tier 2, Section 3.4.3, "Combined License Information." Based on the review of the DCD, the staff has confirmed incorporation of the changes above; therefore, this issue is resolved and closed. The staff's review is documented in SER Section 3.4.2.5.

3.4.2.4.4 *Tier 1 Information (ITAAC)*

DCD Tier 1, Table 2.2.5-1, "Protection against Hazards ITAAC," Item No. 1 provides protective measures against external flooding hazards at the external walls of the as-built seismic Category I buildings below postulated flood/ground water level. Those measures include: (1) minimum wall thickness; (2) penetrations should be watersealed; and (3) water stops should be installed at all construction joints. The staff's review and findings are documented in SER Section 3.4.2.4.3.

3.4.2.5 *Combined License Information Items*

DCD Tier 2, Section 3.4.2 provides a complete list of flood design related COL information items and descriptions of which the COL information items associated with DCD Tier 2, Section 3.4.2 are listed in the following table.

Table 3.4.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.4(1)	The COL applicant is to provide the site-specific design of plant grading and drainage.	3.4.1.1
COL 3.4(2)	The COL applicant is to provide site-specific information on protection measures for the design basis flood, as required in DCD Tier 2, Subsection 2.4.10.	3.4.1.1
COL 3.4(6)	The COL applicant is to provide the site-specific flooding hazards from engineered features, such as water tank collapsing, water piping breaking, etc.	3.4.1.4
COL 3.4(7)	The COL applicant is to confirm that the potential site-specific external flooding events are bounded by design basis flood values or otherwise demonstrate that the design is acceptable.	3.4.1.4
COL 3.4(8)	The COL applicant is to provide the site-specific dewatering system if the plant is built below the design basis flood level.	3.4.1.4
COL 3.4(9)	The COL applicant is to provide the basis for the PMF to determine the maximum site-specific ground water elevation above the grade that may occur from tsunami or hurricane sources.	3.4.2
COL 3.4(10)	The COL applicant is to identify any site-specific physical models that could be used to predict prototype performance of hydraulic structures and systems.	3.4.2

The staff finds the above listing to be complete, and the list adequately addresses actions necessary for the COL applicant. No additional COL information items are needed to be included in DCD Tier 2.

3.4.2.6 Conclusion

As described above, the design of the APR1400 seismic Category I structures meets the specific acceptance criteria in SRP Section 3.4.2, as it relates to the consideration of flood effects and hydrostatic/hydrodynamic loads on structures. The staff finds that the applicant also meets the requirements of GDC 2, with respect to the ability of the safety-related structures of the certified design to withstand the effects of the flood and groundwater through consideration of the following:

1. Appropriate consideration for the effects of flood and groundwater.
2. Appropriate combination of the effects of normal and accident conditions with the hydrostatic, hydrodynamic and buoyancy effects of flood and groundwater.
3. The importance of the safety functions to be performed.

The use of these procedures provides reasonable assurance that, in the event of floods and high groundwater, the structural integrity of the plant seismic Category I, structures will not be impaired, and, as a result, safety related systems and components contained within these structures will be adequately protected and may be expected to perform necessary safety functions, as required, thus satisfying the requirement of Item 3 listed above.

Based on the foregoing review and evaluations, the staff concludes that sufficient information has been provided by the applicant with respect to analysis procedures for external flood protection and their load application to the structures of the APR1400 standard design. In addition, based on its review of the information provided in DCD Tier 2, Section 3.4.2, as set forth above, the staff also concludes that, in general, the requirements of 10 CFR Part 50, Appendix A, GDC 2, 10 CFR 52.47(b) (1), and the specific acceptance criteria of SRP Section 3.4.2 for the consideration of the effects of flood and groundwater on the design of safety-related structures have been met, and thus is acceptable.

3.5 Missile Protection

3.5.1 Missile Selection and Description

3.5.1.1 Internally Generated Missiles Outside Containment

3.5.1.1.1 Introduction

All SSCs located outside containment are to be protected from internally-generated missiles to ensure compliance with GDC 4 requirements. This includes internally-generated missiles from component overspeed failures, missiles that could originate from high-energy fluid systems failures, and missiles caused by or as a consequence of gravitational effects. An internally generated missile is a dynamic effect of such failures, and its impact on SSCs outside containment that are important to safety must be evaluated. Protecting SSCs located outside containment from the effects of internally generated missiles ensures the capability to shut down and maintain the reactor in a shutdown condition, and the capability to prevent significant uncontrolled release of radioactivity.

3.5.1.1.2 Summary of Application

DCD Tier 1: DCD Tier 1, Section 2.2.5.1.4, “Internally Generated Missiles (Inside and Outside Containment),” provides a description of the protection associated with internally generated missiles and key characteristics for the different methods of missile protection.

DCD Tier 2: DCD Tier 2, Section 3.5.1.1, “Internally Generated Missiles (Outside Containment),” describes the credible and non-credible internally generated sources and missile protection for SSCs located outside containment. The basis for identifying credible and non-credible missiles is presented along with the design measures to limit missile generation and provide protection to SSCs located outside containment.

ITAAC: DCD Tier 1, Table 2.2.5-1, provides the ITAAC requirements for the protection against hazards, including internally generated missile.

3.5.1.1.3 *Regulatory Basis*

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.5.1.1, and are summarized below. Review interfaces with other SRP sections also can be found in SRP Section 3.5.1.1.I.

- GDC 4, as it relates to the design of the SSCs important to safety to protect them against the dynamic effects of internally generated missiles outside containment. GDC 4 requires, in part, that SSCs important to safety shall be appropriately protected against the dynamic effects of internally generated missiles outside containment that may result from equipment failures.
- Section 52.47(b)(1) of 10 CFR, which requires that a DCA 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 constructed and will operate in accordance with the DC, the provisions of the Atomic Energy Act, and NRC regulations.

3.5.1.1.4 *Technical Evaluation*

The staff reviewed the APR1400 design for protecting SSCs important to safety against internally generated missiles (outside containment) in accordance with the guidance of SRP Section 3.5.1.1. The staff reviewed DCD Tier 2, Section 3.5.1.1. The staff also reviewed DCD Tier 1, Section 2.0, "Design Description and ITAAC," and other DCD Tier 2 sections noted below.

Compliance with GDC 4 is based on conforming to the guidance of the following RGs:

- RG 1.115, "Protection Against Low-Trajectory Turbine Missiles," Revision 1, Regulatory Positions C.1 and C.3, as they relate to the protection of the SSCs important to safety from the effects of turbine missiles. Regulatory Position C.1 specifies that essential systems of a nuclear power plant should be protected against low-trajectory turbine missiles due to failure of main turbine generator sets. Consideration may be limited to the SSCs listed in the Appendix A to RG 1.117, "Tornado Design Classification." The effect of physical separation of redundant or alternative systems may also be considered. Each essential system and its location should be identified on dimensioned plan and elevation layout drawings. Regulatory Position C.3 specifies that when protection of essential systems is provided by barriers, dimensioned plan and elevation layout drawings should include information on wall or slab thicknesses and materials of pertinent structures.
- RG 1.117, Revision 1, Appendix A, as to which SSCs should be protected from missile impacts.

DCD Tier 2, Section 3.5, in part, addresses SSCs required to be protected from internally generated missiles inside and outside containment. DCD Tier 2, Table 3.2-1, lists all the SSCs, both safety-related and nonsafety-related, in various locations of the plant (inside and outside the containment) and identifies for each SSC the associated seismic category, quality group, and equipment classifications. DCD Tier 2, Table 3.5-4, "Essential Systems and Components

to Be Protected from Externally Generated Missiles,” lists essential systems and components to be protected from missiles. DCD Tier 2, Section 7.4, “Systems Required for Safe Shutdown,” lists the systems required to achieve and maintain the reactor shutdown. General arrangement drawings defining the building locations are provided in DCD Tier 2, Section 1.2, “General Plant Description.”

- The applicant stated that protection of safety related SSCs against missiles will be provided by one or more of the following methods:
- Minimizing the sources of missiles by equipment design features that prevent missile generation.
- Orienting or physically separating potential missile sources away from safety-related equipment and components.
- Containing the potential missiles through the use of protective shields or barriers near the missile source or safety-related facility and equipment.
- Hardening of safety-related equipment and components to withstand missile impact when such impacts cannot be reasonably avoided by the methods listed above.

In DCD Tier 2, Section 3.5.1.1, the applicant provides a description and methodology for protection from the potential of internally generated missiles that could result from failure of the plant equipment located outside the containment. The applicant stated that internally generated missiles can be generated from rotating components and pressurized components, such as turbine wheels, fans, pumps, valve stems, valve bonnets, bolted connections on pressure vessels, and instrument wells. If the probability of missile generation P_1 is maintained at less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically significant.

Postulated failure of components are selected and evaluated based on the following conditions:

- Rotating components that are operated during normal operating plant conditions are capable of generating missiles.
- The energy of potential missiles generated from rotating components is based on a 120 percent overspeed condition as a minimum.
- Pressurized components in systems with a maximum operating pressure that exceeds 19.3 kg/cm^3 (275 psig).
- Connecting portions installed on piping or components, such as thermowells, pressure gauges, and lines for vents, drains, and testing.
- Non-ASME pressure vessels with an operating pressure greater than 19.3 kg/cm^3 (275 psig).

- Non-ASME valves in piping systems with an operating pressure greater than 19.3 kg/cm³ (275 psig).
- Pressure bottles containing highly pressurized gas.

DCD Tier 2, Section 3.5.1.1, also identifies potential internally-generated missiles outside the containment that are not considered credible. However, the description was lacking sufficient technical justification to consider valves and pressure vessels not credible. In RAI 8061, Question 03.05.01.01-4 (ML15234A004), the staff requested the applicant to provide additional information such as design criteria and applied codes and standards that demonstrate a high level of quality thus assuring structural integrity of the components in order to conclude that the missile sources are not considered credible.

In its response to RAI 117-8061, Question 03.05.01.01-4 (ML15356A714), and its revision (ML16204A047), the applicant stated that DCD Tier 2, Section 3.5.1.1, would be revised to specify the design criteria and applied codes and standards for rotating and pressurized components and to provide the basis for concluding that the missile sources are not considered credible. Specifically, the applicant stated the following are not considered credible missile sources:

- Valves with bolted bonnets constructed to ASME Section III, or ASME B16.34, are unlikely to become missile sources due to the limitation of stresses in the bonnet-to-body bolting material by rules set forth in the ASME Code.
- Pressure seal bonnet type valves constructed to ASME Section III, or ASME B16.34, are prevented from becoming missiles by a retaining ring.
- Threaded valve stems with face hardened backseats are designed to prevent ejection of the stems.
- Nuts, bolts, and the combination of the two are not considered credible missiles because they do not have enough energy to eject a missile.

The staff reviewed the applicant's response to RAI 117-8061, Question 03.05.01.01-4, and found it acceptable because the additional information, such as design criteria and applied codes, demonstrates the structural integrity of the components and minimizes the likelihood of missile generation. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 117-8061, Question 03.05.01.01-4, is resolved and closed.

DCD Tier 2, Section 3.5.1.1.2, "Potential Missiles from Pressurized Components," adds that valves are considered potential pressurized missiles; however, no postulated missiles are generated by valves for one or more of the following reasons:

- All valve stems are provided with a backseat or shoulder larger than the valve bonnet opening.
- Motor-operated and manual valve stems are restrained by stem threads.
- Operators on motor, hydraulic, and pneumatic operated valves prevent stem ejection.

- Pneumatic-operated diaphragms and safety valve stems are restrained by the actuator casing.

Also, in DCD Tier 2, Section 3.5.1.1.2, the applicant determined the following pressurized components to be non-credible missiles:

- Pressurized gas bottles that are designed with overpressure protection and is located in a separate room in order to control the effect of an explosion.
- Connecting portions if it is welded and its design strength is stronger than that of the base metal.
- ASME vessels because of their controlled design and fabrication.

In its response to RAI 117-8061, Question 03.05.01.01-4 (ML15234A004), the applicant stated that the vessels designed, fabricated, examined, and tested in accordance with ASME code are not considered credible of generating missiles, but did not identify the specific ASME code or standard that would demonstrate a high level of quality thus assuring structural integrity of the vessels in order to conclude that the missile sources are not considered credible. In its revised response to RAI 117-8061, Question 03.05.01.01-4 (ML16204A047), the applicant specified that ASME vessels designed, fabricated, examined, and tested in accordance with ASME Section III are not considered missile generation sources. The staff reviewed the revised response and finds it acceptable because designing pressure vessels to ASME Section III, provides a high level of quality thus assuring structural integrity and reduced likelihood of missile generation.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 117-8061, Question 03.05.01.01-4, is resolved and closed. The applicant also evaluated the potential of rotating components to become missiles. DCD Tier 2, Section 3.5.1.1.1, "Potential Missiles from Rotating Component," specifies that pumps and associated motors are not considered credible missiles for the following reasons.

- Pump motors are an induction type that have relatively slow running speeds and are not prone to overspeed. These motors are pretested at full running speed by the motor vendor prior to installation.
- The motor stator serves as a natural container of rotor missiles if any are generated.
- Safety-related pumps have relatively low suction pressures and are not driven to overspeed due to a pipe break in their discharge lines. In addition, the induction motor would act as a brake to prevent pump overspeed.
- Pumps are designed to prevent the penetration of pump casings from impeller pieces under overspeed conditions through vendor demonstration that the supplied pump casing is adequate to retain postulated fragments.

DCD Tier 2, Section 3.5.1.1, states the turbine building does not contain any safety-related systems or components and therefore does not require protection from rotating and pressurized components that become missiles.

Internally-generated missiles resulting from turbine overspeed failure is addressed in SER Section 3.5.1.3, "Turbine Missiles." The applicant also analyzed potential missiles generated from the main feedwater pump and concluded that any potential missiles would not have sufficient energy to perforate the auxiliary building wall. In addition, the orientation of other rotating components near the auxiliary building is such that it provides missile protection for safety-related systems and components inside the auxiliary building.

It is assumed that credible internally generated missiles from sources outside containment are not postulated to occur simultaneously with other plant accidents. However, it was unclear if postulated missile impacts were assumed to occur in conjunction with a single active failure of the SSCs used to attain safe-shutdown of the plant as discussed in RG 1.115. Therefore, in RAI 117-8061, Question 03.05.01.01-2 (ML15234A004), the staff requested the applicant to explain if missile protection of safety-related SSCs also considers a single active failure. In its response to RAI 117-8061, Question 03.05.01.01-2 (ML15356A714), the applicant stated that the DCD would be revised to clarify that a single active failure in conjunction with an internally generated missile is considered. The staff finds that applicant's response to RAI 117-8061, Question 03.05.01.01-2, acceptable because it ensures that single active failures are considered and is consistent with RG 1.115 and RG 1.117, with respect to protection against internally and externally generated missiles. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 117-8061, Question 03.05.01.01-2, is resolved and closed.

The applicant also addresses the potential for gravitational missiles from falling objects. If the drop of non-seismically designed SSCs outside containment could affect safety-related systems, the applicant specifies that they will be designed to seismic Category II in order to protect the safety-related systems from the impact of dropped objects. Heavy-load crane path will be blocked above any systems or components that are necessary to achieve safe shutdown, and COL 3.5(1) is provided for the COL applicant to provide the procedure for heavy-load transfers and the limited transfer route. Section 9.1.5 of this report addresses the staff's evaluation of heavy loads.

Based on its review, the staff finds the applicant's approach to identify potential missiles, determine the statistical significance of potential missiles, and provide measures for SSCs needing protection against the effects of missiles to be acceptable. Therefore, the staff concludes that the applicant's evaluation of potential internally generated missiles outside containment resulting from equipment and component failures shows that the design satisfies GDC 4.

SER Section 3.5.3, addresses the staff's evaluation of the design of structures, shields, and barriers used for missile protection.

The ITAAC items described in DCD Tier 1, Section 2.0, for the nuclear island (NI) structures, emergency diesel generator (EDG) buildings, and emergency service water/component cooling water (ESW/CCW) heat exchanger building, verify that the safety-related SSCs are protected from internally generated missiles and the structures have been constructed in accordance with the design as described in DCD Tier 2. DCD Tier 1, Table 2.2.5-1 item 4 contains the ITAAC for protective provisions for internally generated missiles; however, the acceptance criteria only identifies the NI structures and EDG building. Therefore, the staff issued RAI 8061,

Question 03.05.01.01-3 (ML15234A004), requesting the applicant to include in the ITAAC all structures that house SSCs requiring missile protection.

In its response to RAI 117-8061, Question 03.05.01.01-3, (ML15356A714) and stated that DCD Tier 1, Table 2.2.5-1, item 4 will be revised to include all structures, (e.g., RCB, AB, and ESW/CCW heat exchanger buildings) that house SSCs requiring internal missile protection. The staff finds the applicant's response to RAI 117-8061, Question 03.05.01.01-3, acceptable because the inclusion all structures that house SSCs required to be protected from missiles in the acceptance criteria ensures that the ITAAC are consistent with the design description in DCD Tier 1, Section 2.2.5.1.4, and DCD Tier 2, Sections 3.5.1.1, and 3.5.1.2. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 117-8061, Question 03.05.01.01-3, is resolved and closed.

The staff finds that the ITAAC are sufficient to provide reasonable assurance that safety related SSCs will be protected from internally generated missiles outside containment and that they satisfy the requirements of 10 CFR 52.47(b)(1). Therefore, the staff concludes that the missile protection provided for APR1400 SSCs located outside containment is adequate.

3.5.1.1.5 *Combined License Information Items*

The following table provides a list of internal missile related COL information items and descriptions from DCD Tier 2, Table 1.8-2.

Table 3.5.1-1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 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

The staff finds the above list of COL information items to be complete, and adequately describes the actions necessary from the COL applicant. No additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for protection from internally generated missiles outside the containment.

3.5.1.1.6 *Conclusion*

Based on its review, the staff concludes that the applicant's design bases for SSCs important to safety necessary to maintain a safe plant shutdown, ensure the integrity of the reactor coolant pressure boundary, and prevent a significant uncontrolled release of radioactivity meet the 10 CFR Part 50, Appendix A, GDC 4, requirements for SSCs to be protected from internally-generated missiles (outside containment), because the applicant has conformed with the guidance recommended in: RG 1.115, Positions C.1 and C.3, as to the identification and protection of SSCs important to safety from the effects of turbine missiles, respectively; and RG 1.117 as to which SSCs should be protected from missile impacts.

3.5.1.2 *Internally Generated Missiles Inside Containment*

3.5.1.2.1 *Introduction*

Criterion 4 of Appendix A to 10 CFR Part 50, states in part that SSCs important to safety shall appropriately protected against dynamic effects, including the effects of missiles. The sources for the internally-generated missiles can be component overspeed failures, high-energy fluid system failures, or missiles caused by or as a consequence of gravitational effects. An internally generated missile has a dynamic effect and its impact on SSCs important to safety must be evaluated to ensure that they are protected adequately and will be capable of performing their safety functions. If a missile has a statistically significant probability of causing damage, it is considered credible. Protecting SSCs located inside containment from the effects of internally generated missiles ensures the integrity of the RCPB, the capability to shut down and maintain the reactor in a shutdown condition, and the capability to prevent a significant uncontrolled release of radioactivity.

3.5.1.2.2 *Summary of Application*

DCD Tier 1: DCD Tier 1, Section 2.2.5.1.4, provides a description of protection associated with internally generated missiles and key characteristics for the different methods of missile protection.

DCD Tier 2: DCD Tier 2, Section 3.5.1.2, "Internally Generated Missiles (Inside Containment)," describes the internally generated missile sources and missile protection for SSCs located inside containment. The basis for identifying credible and non-credible missiles is presented along with the design measure to limit missile generation and provide protection to SSCs inside containment.

ITAAC: DCD Tier 1, Table 2.2.5-1, provides the ITAAC requirements for the protection against hazards, including internally generated missile.

3.5.1.2.3 *Regulatory Basis*

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.5.1.2, "Internally-Generated Missiles (Inside Containment)." Review interfaces with other SRP Section 3.5.1.2.I.

- GDC 4, as it relates to the design of the SSCs important to safety to protect them from internally generated missiles inside containment. GDC 4 requires, in part, that SSCs important to safety shall be appropriately protected against the dynamic effects of internally generated missiles inside containment that may result from equipment failures.
- Section 52.47(b)(1) of 10 CFR, which requires that a DCA 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 constructed and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

3.5.1.2.4 *Technical Evaluation*

The staff reviewed the APR1400 design for protecting SSCs important to safety against internally generated missiles inside containment in accordance with the guidance of SRP Section 3.5.1.2. The staff reviewed DCD Tier 2, Section 3.5.1.2. The staff also reviewed DCD Tier 1, Section 2.

DCD Tier 2, Section 3.5, in part, addresses SSCs required to be protected from internally generated missiles inside and outside containment. DCD Tier 2, Table 3.2-1, SSCs, lists all the SSCs, both safety-related and nonsafety-related, in various locations of the plant (inside and outside the containment) and identifies for each SSC the associated seismic category, quality group, and equipment classifications. DCD Tier 2, Table 3.5-4, "Essential Systems and Components to Be Protected from Externally Generated Missiles," lists essential systems and components to be protected from missiles. DCD Tier 2, Section 7.4, lists the systems required to achieve and maintain the reactor shutdown. General arrangement drawings defining the building locations are provided in DCD Tier 2, Section 1.2.

In DCD Tier 2, Section 3.5.1.2, the applicant provides a description and methodology for protection from the potential of internally generated missiles that could result from failure of the plant equipment located inside the containment. The applicant stated that postulated failure of components are selected and evaluated consistent with DCD Tier 2, Section 3.5.1.1. If the probability of missile generation P1 is maintained less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically significant.

The applicant stated that protection of safety related SSCs against missiles will be provided by one or more of the following methods:

- Minimizing the sources of missiles by equipment design features that prevent missile generation.
- Orienting or physically separating potential missile sources away from safety-related equipment and components.
- Containing the potential missiles through the use of protective shields or barriers near the missile source or safety-related facility and equipment.
- Hardening of safety-related equipment and components to withstand missile impact when such impacts cannot be reasonably avoided by the methods listed above.

The primary means of protecting safety-related equipment from potential damage from internally-generated missiles is through the use of shield walls and separation within containment. DCD Tier 2, Section 3.5.1.2, states these structures include the secondary shield wall, refueling pool wall, structural beams, and floor slabs. In addition, a protective shield is installed above the control element drive mechanism (CEDM) to protect the CEDM, the reactor vessel, and SSCs required for safe shutdown from internally-generated missiles and a missile as a result of CEDM ejection.

Section 3.5.3, of this report addresses the staff's evaluation of the design of structures, shields, and barriers used for missile protection.

DCD Tier 2, Section 3.5.1.2.1, "Potential Missiles from Rotating Components," identifies rotating components inside the containment building which have the potential for becoming missiles; these include reactor coolant pumps (RCPs), heating, ventilation and air conditioning (HVAC) equipment, and pump impellers. DCD Tier 2, Table 3.5-1, "Kinetic Energy of Potential Missiles," identifies potential pressurized components capable of becoming missiles and provides the kinetic energy associated with the components. These include:

- Reactor vessel: closure head nut and stud, control rod drive assembly, and heated junction thermocouple assembly.
- Steam generator: studs and nuts from manways and handholds.
- Pressurizer: safety valve flange bolt, lower temperature element, and manway stud and nut.
- RCP and piping: temperature nozzle with resistance temperature detector (RTD) assembly, surge and spray piping thermowells with RTD assembly, and RCP thermowell with RTD.

Internally-generated missiles from sources inside containment are not postulated to occur simultaneously with other plant accidents; however, postulated missile impacts are assumed to occur in conjunction with a single active failure of the SSCs used to attain safe shutdown of the plant. In addition, the applicant considers the same non-credible internally-generated missiles outside containment identified in DCD Tier 2, Section 3.5.1.1, as non-credible internally-generated missiles inside containment. For the staff evaluation of these non-credible missiles, see Section 3.5.1.1 of this SER.

In reviewing DCD Tier 2, Section 3.5.1.2, the staff identified areas in which additional information was necessary to complete its review. Therefore, the staff issued the RAIs discussed below.

During its review the staff noted that the applicant did not identify or evaluate certain rotating SSCs which have the potential to become missiles. Therefore, the staff issued RAI 113-8062, Question 03.05.01.02-2 (ML15234A003), requesting the applicant to address why the RCP flywheel is not considered a postulated missile. In its response to RAI 8062, Question 03.05.01.02-2 (ML15357A008), the applicant stated that rotating parts of the RCP and RCP motor assemblies, including the flywheel, preclude missiles from occurring through quality controls applied through manufacturing and installation, inservice inspections, and continuous monitoring of shaft and bearing vibrations. In addition, the pumps are designed in conformance with RG 1.14, "Reactor Coolant Pump Flywheel Integrity." The staff reviewed the applicant's response to RAI 113-8062, Question 03.05.01.02-2, and finds it acceptable because monitoring and designing the RCP flywheel to RG 1.14, provides reasonable assurance that there will be an extremely low probability of a flywheel-generated missile. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 113-8062, Question 03.05.01.02-2, is resolved and closed.

During its review, the staff noted DCD Tier 2, Section 3.5.1.2, stated that protective features inside containment provide missile protection for the containment liner, isolation system, and main steam system; however, it was unclear to the staff which design features were being referred to. Therefore, the staff issued RAI 113-8062, Question 03.05.01.02-3 (ML15234A003), requesting the applicant to describe in the DCD the specific protective features that provide missile protection for SSCs inside containment. In its response to RAI 113-8062, Question 03.05.01.02-3 (ML15357A008), the applicant stated that the DCD will be revised to clarify that the use of, "protective features inside containment," was in reference to structural concrete walls, structural steel beams, or floor slabs which serve as missile shields. The staff reviewed the applicant's response to RAI 113-8062, Question 03.05.01.02-3, and finds it acceptable because the DCD will be revised to adequately identify design features used as missile barriers for the protection of safety-related SSCs located inside containment. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 113-8062, Question 03.05.01.02-3, is resolved and closed.

DCD Tier 2, Section 3.5.1.2 states,

[e]ngineered safety features, except for some portions of piping for direct vessel injection following a LOCA, are located outside the secondary shield wall to minimize the effects from missile generated by the RCPB.

However, the applicant did not specify how the remaining piping portions for direct vessel injection will be protected from internally-generated missiles. Therefore, the staff issued RAI 113-8062, Question 03.05.01.02-4 (ML15234A003), requesting the applicant to provide a discussion detailing the method of missile protection for those portions of piping not protected from the secondary shield wall. In its response to RAI 113-8062, Question 03.05.01.02-4 (ML15357A008), the applicant stated that the portions of the direct vessel injection lines located inside the secondary shield wall are designed using the BRL formula noted in DCD Tier 2, Section 3.5.3.1.2, such that the integrity of the piping system is maintained assuming a strike from the identified missiles. The staff reviewed the applicant's response to RAI 113-8062, Question 03.05.01.02-4, and finds it acceptable because the design of the direct vessel inject piping inside the secondary shield wall utilizes missile protection method (4) of SRP Section 3.5.1.2, SRP acceptance criteria 2 (i.e. the equipment is designed to withstand the impact of the most damaging missile). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 113-8062, Question 03.05.01.02-4, is resolved and closed.

During its review, the staff noted that DCD Tier 2, Section 3.5.1.2.1.2, states, "[t]he BOP rotating components inside the containment are...pump impellers, and blades of turbine-driven components." It was unclear to the staff what equipment the applicant is referring to in the aforementioned statement. Therefore, in RAI 113-8062, Question 03.05.01.02-5 (ML15234A003), the staff requested the applicant to clarify what BOP pumps and turbine-driven components are located inside containment. In its response to RAI 113-8062, Question 03.05.01.02-5 (ML15357A008), the applicant provided a list of BOP components located inside the reactor containment building. This list includes the in-core instrumentation (ICI) cavity sump pump, containment drain sump and pump, SG enclosure recirculation fan, annulus area recirculation fan, and reactor containment fan cooler. In addition, the applicant clarified that there are no turbine-driven components inside the reactor containment building and the DCD will be revised in order to make the correction. The staff reviewed the applicant's response to

RAI 113-8062, Question 03.05.01.02-5, and finds it acceptable because the applicant appropriately clarified the type and location of potential missiles from BOP pumps and HVAC components located inside the reactor containment building. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 113-8062, Question 03.05.01.02-5, is resolved and closed.

The staff's review finds the applicant's approach to identify potential missiles, determine the statistical significance of potential missiles, and provide measures for SSCs requiring protection against the effects of missiles to be acceptable. Therefore, the staff concludes that the applicant's evaluation of potential internally generated missiles inside the APR1400 containment resulting from equipment and component failures shows that the design satisfies GDC 4.

ITAAC

The ITAAC items described in DCD Tier 1, Section 2.0, for the nuclear island (NI) structures, emergency diesel generator (EDG) buildings, and emergency service water/component cooling water (ESW/CCW) heat exchanger building, Confirmatory Item 3.5.1.1-3, verify that the safety-related SSCs are protected from internally generated missiles and the structures have been constructed in accordance with the design as described in DCD Tier 2. The staff finds that the ITAAC are sufficient to provide reasonable assurance that safety-related SSCs will be protected from internally generated missiles outside containment and that they satisfy the requirements of 10 CFR 52.47(b)(1).

A complete list of all APR1400 related ITAAC is provided in SER Section 14.3.

3.5.1.2.5 Combined License Information Items

The following table provides a list of missile protection related COL information items and descriptions from DCD Tier 2, Table 1.8-2:

Table 3.5.1-2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(2)	The COL applicant is to provide the procedures which ensure that equipment required during maintenance, should be removed from containment prior to operation, moved to a location where it not a potential hazard to SSC important to safety, or seismically restrained.	3.5.1.2

SRP Section 3.5.1.2, states that controls should ensure that unsecured maintenance equipment is prevented from becoming a missile; however, DCD Tier 2, Section 3.5.1.2, was missing this information. Therefore, the staff issued RAI 113-8062, Question 03.05.01.02-1 (ML15234A003), requesting the applicant to address the potential of gravitational missiles from unsecured maintenance equipment and describe the measures provided to prevent the impact of it falling on safety related SSCs. In its response to RAI 113-8062, Question 03.05.01.02-1 (ML15357A008), and stated that during operation there should not be any unsecured maintenance equipment in containment that have the potential to impact safety-related SSCs. In addition, the applicant stated the DCD will be revised to include a COL item requiring the

COL applicant to develop procedures that ensure unsecured maintenance equipment will be removed from containment, moved to a location where it is not a potential hazard to SSCs important to safety, or is seismically restrained. The staff reviewed the applicant's response to RAI 113-8062, Question 03.05.01.02-1, and finds it acceptable because the potential for internal missiles resulting from failures of unsecured maintenance equipment has been minimized, consistent with SRP Section 3.5.1.2. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 113-8062, Question 03.05.01.02-1, is resolved and closed.

The staff finds the above list of COL information items to be complete and adequately describing the actions necessary from the COL applicant. No additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for protection from internally generated missiles inside the containment.

3.5.1.2.6 *Conclusion*

Based on its review, the staff review concludes that the applicant's design bases for SSCs important to safety necessary to maintain a safe plant shutdown, ensure the integrity of the RCPB, and prevent a significant uncontrolled release of radioactivity meet the 10 CFR Part 50, Appendix A, GDC 4 requirements for SSCs to be protected from internally-generated missiles (inside containment).

3.5.1.3 *Turbine Missiles*

3.5.1.3.1 *Introduction*

GDC 4 of 10 CFR Part 50, Appendix A of the NRC's regulations requires that SSCs important to safety shall be appropriately protected against dynamic effects of postulated accidents, 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. One potential source of plant missiles is the rotor of the main turbine. This must be considered in the plant's design, and the adverse effects of postulated turbine missiles must be protected against.

The objective of the staff's review is to determine that potential turbine missiles have been appropriately identified and that SSCs important to safety have been appropriately protected from any adverse effects that may result from these missiles.

3.5.1.3.2 *Summary of Application*

DCD Tier 1: The applicant describes in DCD Tier 1, Section 2.7.1.1.1(1.b), the orientation of the turbine generator as favorable with respect to essential SSCs.

DCD Tier 2: The applicant has provided a DCD Tier 2 system description in Section 3.5.1.3, summarized here in part, as follows:

The NRC's regulations require that SSCs important to safety shall be appropriately protected against the effects of missiles. One method of protecting SSCs important to safety is to orient the rotational axis of the main turbine rotor such that the trajectory of any postulated missiles will not result in impact of the missile on these SSCs. In accordance with the guidance provided in

SRP Section 3.5.1.3, and RG 1.115, the probability of unacceptable damage from turbine missiles should be less than 1×10^{-7} per year.

This section describes any SSCs that could be impacted by a potential turbine missile. The DCD states that using the NRC's guidance contained in RG 1.115, no essential SSCs are in the low-trajectory missile strike zone, and therefore the turbine generator (T/G) is favorably-oriented. Favorable orientation, combined with DCD Section 10.2 criteria in regards to the design and fabrication processes, the redundant and fail-safe turbine control system, the maintenance and inspection programs, and the overspeed protection systems, results in an acceptably small probability of turbine missiles causing damage to essential SSCs. In addition, the COL applicant is to perform an assessment of the orientation of the T/G at a single-unit site, and of other units at multi-unit sites, for the probability of missile generation using the evaluation of DCD Section 3.5.1.3.2, to verify that essential SSCs are outside the low-trajectory turbine missile strike zone, and denoted as COL 3.5(3).

ITAAC: The ITAAC associated with this area of review are specified in DCD Tier 1, Section 2.7.1.1, "Turbine Generator." The specific ITAAC is given in DCD Tier 1, Table 2.7.1.1-1, "Turbine Generator Inspections, Tests, Analyses, and Acceptance Criteria," Design Commitment 1.b., which verifies that an analysis exists that confirms no essential SSCs are located inside the low-trajectory turbine missile strike zone.

Technical Specifications: There are no Technical Specifications for this area of review.

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

Technical Reports: There are no technical reports for this area of review.

3.5.1.3.3 *Regulatory Basis*

The relevant requirements of NRC regulations for this area of review, and the associated acceptance criteria, are given in SRP, Section 3.5.1.3, Revision 3, and are summarized below. Review interfaces with other SRP sections can be found in Section 3.5.1.3 of NUREG-0800.

- GDC 4 requires SSCs important to safety to be appropriately protected against environmental and dynamic effects, including the effects of missiles that may result from equipment failure. Failure of the large steam turbine rotor at a high rotating speed could generate high-energy missiles that have the potential to damage SSCs important to safety.
- Section 52.47(b)(1) of 10 CFR, which requires that a DC 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, a plant that incorporates the DC has been constructed and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

- Per SRP Section 3.5.1.3 Item II.1, consideration of turbine missile protection is relevant for SSCs necessary to ensure the following: (a) the integrity of the reactor coolant pressure boundary; (b) the capability to shut down and maintain the reactor in a safe

condition; and (c) the capability to prevent accidents that could result in potential offsite exposure, which represent a significant fraction of the guideline exposures specified in 10 CFR 50.67(b)(2), or 10 CFR Part 100, "Reactor Site Criteria." Examples of important to safety systems that should be protected are described in the appendix to RG 1.115, Revision 2, issued January 2012, and are denoted as essential SSCs.

- RG 1.115, Revision 2, as it relates to the identification of low trajectory missiles resulting from turbine failure.
- The probability of turbine missile generation, P1, should be less than 1×10^{-4} per reactor-year for favorably-oriented turbines, and be less than 1×10^{-5} per reactor-year for unfavorably-oriented turbines. The P1 calculation is related to maintenance and inspection of turbine rotors and control valves, operating experience of similar equipment, and inspection results.

3.5.1.3.4 *Technical Evaluation*

The failure of a rotor in a large steam turbine may result in the generation of high-energy missiles that could affect essential SSCs. The probability of a strike by a turbine missile should be sufficiently low so that the risk from turbine missiles to essential SSCs is acceptably small. DCD Tier 2, Section 3.5.1.3, provides information that the probability of the favorably-oriented T/G generating a turbine missile is less than 1×10^{-4} per reactor-year. The staff reviewed this information using the guidelines in SRP Section 3.5.1.3.

SRP Section 3.5.1.3 states that with the use of proper turbine rotor design, materials that satisfy the acceptance criteria in SRP Section 10.2.3, "Turbine Rotor Integrity," Revision 2, and acceptable preservice and inservice nondestructive examination methods, P1 must be no greater than 1×10^{-5} per reactor-year for an unfavorably-oriented turbine and no greater than 1×10^{-4} per reactor-year for a favorably-oriented turbine. These probabilities represent the general minimum reliability requirements for loading the turbine and bringing the system on line.

DCD Tier 2, Subsection 3.5.1.3.1, "Geometry," states that its T/G shaft is placed in line with the containment and auxiliary building, and Figure 3.5-1 shows that the T/G is favorably-orientated so that all essential SSCs are outside of the low-trajectory turbine missile strike zone, as defined by RG 1.115. The low-trajectory turbine missile strike zone is concentrated in an area bounded by lines inclined at 25 degrees to the turbine wheel planes and passing through the end wheels of the low-pressure stages. In a letter dated August 4, 2015, the applicant provided a revised Figure 3.5-1 to provide an accurate site plot plan that is consistent with DCD Tier 2, Figure 1.2-1, and denoting the applicable essential SSCs. However, the revised Figure 3.5-1 did not provide an accurate low-trajectory turbine missile strike zone, since the lines of the strike zone are not depicted as 25 degrees to the turbine wheel planes and passing through the end wheels of the low-pressure stages. Therefore, the staff could not verify whether all essential SSCs are outside of the low-trajectory turbine missile strike zone. In RAI 241-8316, Question 03.05.01.03-1 (ML15296A010), the staff requested that the low-trajectory turbine missile strike zone should be drawn such that it depicts the lines of the strike zone from the ends of the low-pressure stages with a 25 degree angle to the turbine rotor plane, as defined in RG 1.115, similar to the previous Figure 3.5-1.

In its response to RAI 8316, Question 03.05.01.03-1 (ML16004A450), the applicant provided a revised Figure 3.5-1 with a low-trajectory turbine missile strike zone meeting the definition of RG 1.115. The staff found the revised figure acceptable since it meets the guidelines of RG 1.115. In addition, the staff verified that no essential SSCs are within the low-trajectory turbine missile strike zone, as represented in Figure 3.5-1.

In a letter dated August 4, 2015, the applicant provided a revised DCD Tier 1, Section 2.7.1.1.1(1.b), that clarified that the T/G has a favorable orientation as defined in RG 1.115, and clarified DCD Tier 1, Table 2.7.1.1-1(1.b), Design Commitment 1.b., to confirm that no essential SSCs are located inside the low-trajectory turbine missile strike zone. The staff finds that the DCD Tier 1 provides sufficient information, including acceptance criteria for the DCD Tier 1, Section 2.7.1.1 ITAAC, for determining that the T/G is favorably-orientated with respect to the reactor building. This is in addition to the COL applicant's responsibility in COL 3.5(3) to assess the orientation of the T/G at a single-unit site, and of other units at multi-unit sites, for the probability of missile generation as specified in RG 1.115. The staff finds this acceptable since there is acceptance criteria for the DCD Tier 1, Section 2.7.1.1 ITAAC for the T/G orientation consistent with the criteria in SRP Section 3.5.1.3.

SER Section 10.2.3, provides additional discussion of the staff's evaluation of meeting P1 less than 1×10^{-5} per reactor-year, in regards to the turbine ISI program and turbine rotor integrity (including the design, and materials used). SER Section 10.2.2, discusses the staff's detailed evaluation of the turbine overspeed protection system of the APR1400 design. On the basis of the above evaluation, the staff concludes that the probability of turbine missile generation and turbine orientation as required in DCD Tier 2, Section 3.5.1.3, are consistent with the acceptance criteria in SRP Section 3.5.1.3 and RG 1.115, Revision 2.

3.5.1.3.5 Combined License Information Items

The following table provides a list of turbine missile-related COL information item numbers and descriptions from DCD Tier 2, Table 1.8-2:

Table 3.5.1-3 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(3)	The COL applicant is to perform an assessment of the orientation of the turbine generator of this and other unit(s) at multi-unit sites for the probability of missile generation using the evaluation of Subsection 3.5.1.3.2 to verify that essential SSCs are outside the low-trajectory turbine missile strike zone.	3.5.1.2

The staff evaluated whether sufficient COL information items were identified in Table 1.8-2 of the APR1400 DCD.

DCD Tier 2, Section 3.5.4, "Combined License Information," and Table 1.8-2, provided COL 3.5(3), which states that the COL applicant is responsible to assess the orientation of the T/G at a single-unit site, and of other units at multi-unit sites, for the probability of missile generation using the evaluation of DCD Tier 2, Subsection 3.5.1.3.2. The staff finds COL 3.5(2)

acceptable as the evaluation of a multi-unit site is by its nature site-specific. Therefore, the staff finds this acceptable since the evaluation of the site specific SSCs will be provided for each COL application using criteria that is consistent with the criteria in SRP Section 3.5.1.3 and with the evaluation method used in the DCD for determining that the T/G is favorably-orientated with respect to the essential SSCs.

SER Section 10.2.3, provides additional discussion of the staff's evaluation of the turbine ISI program. SER Section 10.2.2, discusses the staff's detailed evaluation of the turbine overspeed protection system of the APR1400 design. On the basis of the above evaluation, the staff concludes that the turbine orientation as required in Section 3.5.1.3, of DCD Tier 2, is consistent with the acceptance criteria in SRP Section 3.5.1.3 and RG 1.115.

3.5.1.3.6 *Conclusion*

The staff finds that the T/G is in a favorable orientation with respect to essential SSCs. Therefore, the staff concludes that the risk posed by turbine missiles for the proposed plant design is acceptable and meets the relevant requirements of GDC 4. The staff bases this conclusion on the applicant having sufficiently demonstrated to the staff, in accordance with the guidance of SRP Section 3.5.1.3 and RG 1.115, that the T/G is favorably-orientated.

3.5.1.4 *Missiles Generated by Tornadoes and Extreme Winds*

3.5.1.4.1 *Introduction*

Missiles generated by extreme winds (such as tornado or hurricane) are identified and evaluated in this section. A COL applicant that references the APR1400 DC will assess whether the actual site characteristics fall within the site parameters specified for the APR1400 design. If a site characteristic does not fall within the corresponding site parameter, the COL applicant will evaluate the potential for other missiles generated by natural phenomena and their potential impact on the missile protection design features of the APR1400.

3.5.1.4.2 *Summary of Application*

DCD Tier 1: Design-specific tornado and hurricane site parameters are listed in DCD Tier 1, Table 2.1-1.

DCD Tier 2: The spectrum of missiles generated by extreme winds are described in DCD Tier 2, Section 3.5.1.4, and include: a rigid missile that tests penetration resistance (pipe), a massive high-kinetic-energy missile that deforms on impact (automobile), and a small rigid missile of a size that is sufficient to pass through openings in protective barriers (small steel sphere).

ITAAC: There are no specific DCD Tier 1 ITAAC items for this area of review.

Initial Plant Test Program: DCD Tier 2, Section 14.2, does not provide any preoperational testing requirements associated with this area of review.

3.5.1.4.3 *Regulatory Basis*

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.5.1.4 and are summarized below. Review interfaces with other SRP sections can also be found in SRP Section 3.5.1.4.

- GDC 2, as it requires, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as tornadoes and hurricanes without loss of capability to perform their safety functions.
- GDC 4, as it requires, in part, that SSCs important to safety shall be appropriately protected against the effects of missiles that may result from events and conditions outside the nuclear power unit.
- Section 52.47(b)(1) of 10 CFR, which requires that a DCD 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 constructed and will be operated in accordance with the DC, the provisions of the Atomic Energy Act, and NRC regulations.

3.5.1.4.4 *Technical Evaluation*

The staff reviewed the APR1400 design for protecting SSCs important to safety against missiles generated by extreme winds in accordance with the guidance of SRP Section 3.5.1.4. The staff reviewed DCD Tier 2, Section 3.5.1.4. The staff also reviewed DCD Tier 1, Section 2.0, and other DCD Tier 2 sections noted below.

Compliance with GDC 2 and GDC 4 with respect to missiles generated by extreme winds is based on meeting the guidance of RG 1.76, and RG 1.221.

DCD Tier 2, Section 3.5.1.4 and DCD Tier 2, Table 3.5-2 provide the following description of design-basis tornado and hurricane winds and associated missile spectra for the APR1400 design.

Design-Basis Extreme Wind Parameters

- tornado has a maximum 3-second gust of 103 m/s (230 mph).
- hurricane has a maximum 3-second gust of 116 m/s (260 mph).

Tornado-Generated Missile Spectra

- a rigid missile that tests penetration resistance, such as a 0.168 m (6.625 in.) diameter schedule 40 pipe has a horizontal strike velocity of 41 m/s (135 ft/s).
- a massive high-kinetic-energy missile that deforms on impact, such as a 1,814 kg (4,000 lb) automobile has a horizontal strike velocity of 41 m/s (135 ft/s).

- a small rigid missile of a size that is sufficient to pass through openings in protective barriers, such as a 2.54 cm (1 in.) diameter solid steel sphere has a horizontal strike velocity of 8 m/s (26 ft/s).
- missile velocities in the vertical direction are 67 percent of the horizontal missile velocities.

Hurricane Generated Missile Spectra

- a rigid missile that tests penetration resistance, such as a 0.168 m (6.625 in.) diameter schedule 40 pipe has a horizontal strike velocity of 64.5 m/s (212 ft/s).
- a massive high-kinetic-energy missile that deforms on impact, such as a 1,814 kg (4,000 lb) automobile has a horizontal strike velocity of 80.2 m/s (263 ft/s).
- a small rigid missile of a size that is sufficient to pass through openings in protective barriers, such as a 2.54 cm (1 in.) diameter solid steel sphere has a horizontal strike velocity of 57.3 m/s (188 ft/s).
- the design-basis vertical missile velocity for all missiles is 26 m/s (85.3 ft/s).

The applicant assumes the automobile missiles to impact at all altitudes less than 10.06 m (33 ft) above plant grade within 0.8 km (0.5 mi) radius of safety-related SSCs. However, the applicant did not address the potential of automobile missiles striking above 10.06 m (33 ft) due to elevated (above plant grade) parking lots. Therefore, the staff issued RAI 74-8060, Question 03.05.01.04-1 (ML15196A600), requesting the applicant address the potential of automobile missiles striking above 10.06 m (33 ft). In its response to RAI 74- 8060, Question 03.05.01.04-1 (ML15236A154), the applicant stated that a COL information item will be added to ensure that automobile missiles cannot be generated within a 0.5 mile radius of safety-related SSCs that would lead to an impact higher than 10.06 m (33 ft) above plant grade. The staff finds the applicants response to be acceptable because it addresses the potential for an automobile missile impact higher than 10.06 m (33 ft). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 74-8060, Question 03.05.01.04-1, is resolved and closed.

The guidance of RG 1.76 only applies to the continental U.S., which is divided into three regions: Region I, the central portion of the U.S.; Region II, a large region of the U.S. along the east coast, the northern border, and western Great Plains; and Region III, the western U.S. The tornado parameter values specified in RG 1.76, Table 1, for Region I are most severe and bound all the tornado parameter values specified for Regions II and III. The staff confirmed that the design-basis tornado parameters and tornado-generated missile spectra in the APR1400 DCD are in accordance with the guidance described in RG 1.76, Table 1, for Region I.

RG 1.221 provides contour maps of U.S. coastal areas most susceptible to hurricanes and associated design-basis wind and missile speeds. The staff confirmed that the design-basis hurricane parameters and hurricane-generated missile spectra in the APR1400 DCD are in accordance with the guidance described in RG 1.221 for a hurricane wind speed of 116m/s (260 mph).

Based on its review, the staff confirmed that the applicant conforms to the guidance in RG 1.76 and RG 1.221 for design-basis tornado and hurricane missiles, respectively. Therefore, the staff concludes that the APR1400 design meets the requirements of GDC 2 and GDC 4 with respect to the protection of SSCs important to safety against the effects of natural phenomena such as tornadoes and hurricanes. SER Section 2.3, contains the staff's evaluation of meteorological site parameters. SER Section 3.8, contains the staff's evaluation of the structural performance of the APR1400 with respect to hurricane and tornado missiles.

ITAAC

Although there is no direct ITAAC for this section, DCD Tier 1, Table 2.1-1, provides the parameters for design-basis tornado and hurricane winds and associated missile spectra. In addition, DCD Tier 1, Section 2.1 specifies that these parameters are to be applied to the design of safety-related SSCs.

Based on its review, the staff finds the above cited design description acceptable because it requires a licensee to design safety-related SSCs against the dynamic effects from missiles generated by tornado and hurricane winds. Therefore, the staff concludes that the missile protection provided for APR1400 safety-related SSCs comply with the requirements of 10 CFR 52.47(b)(1).

3.5.1.4.5 Combined License Information Items

The following table provides a list of external missile related COL information items and descriptions from DCD Tier 2, Table 1.8-2.

Table 3.5.1-4 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(4)	The COL applicant is to evaluate site-specific hazards induced by external events that may produce more energetic missiles than tornado or hurricane missiles, and provide reasonable assurance that seismic Category I and II structures are designed to withstand these loads.	3.5.1.4
COL 3.5(5)	The COL applicant is to confirm that automobile missiles cannot be generated within 0.5 mile radius of safety-related SSCs that would lead to impact higher than 10.06 m (33 ft) above plant grade.	3.5.1.4

The staff finds the above list of COL information items to be complete, and adequately describes the actions necessary for the COL applicant. No additional COL information items need to be included in DCD Tier 2, Table 1.8-2, for missiles generated by extreme winds.

3.5.1.4.6 Conclusion

The staff concludes that the applicant's design-basis tornado and hurricane parameters and tornado and hurricane generated missile spectra for the APR1400 design comply with the 10 CFR Part 50, Appendix A, GDC 2 and GDC 4 requirements for SSCs to be protected from

missiles generated by extreme winds, because the DCD conforms with guidance recommended in RG 1.76, and RG 1.221 for design-basis wind borne missiles for nuclear power plants.

3.5.1.5 *Site Proximity Missiles (Except Aircraft)*

3.5.1.5.1 *Introduction*

This section explains that the design is based on tornado missiles as being the most severe general case, although hurricane missiles are considered, and that the COL applicant will establish site specific missile spectra. The potential threat to the plant from site proximity missiles is site specific and cannot be assessed at the DC stage.

3.5.1.5.2 *Summary of Application*

Section 3.5.1.5, of DCD Tier 2, addresses the need for the evaluation of potential for site proximity explosions and missiles, with a statement that the COL applicant that references the APR1400 DCD will provide site-specific information and evaluations as per COL 3.5(7).

3.5.1.5.3 *Regulatory Basis*

The applicable regulatory requirements for identifying evaluation of site proximity missiles include:

- Section 100.20(b) of 10 CFR, which states that the nature and proximity of man-related hazards (e.g., airports, dams, transportation routes, and military or chemical facilities) must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards and whether the risk of other hazards is very low.
- Section 100.20(b) of 10 CFR, as it relates to the requirement that site characteristics be evaluated to determine whether the risk to individuals and society of potential plant accidents is low.
- Section 100.21(c)(2) of 10 CFR, which states that the applications for site approval for commercial power reactors shall demonstrate that the proposed site meets the radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34 (a)(1).
- Section 100.21(e) of 10 CFR, which states that potential hazards associated with nearby transportation routes and industrial and military facilities must be evaluated and site parameters established such that potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed to be located at the site.
- GDC 4, which requires that SSCs important to safety be appropriately protected against the effects of missiles that may result from events and conditions outside the nuclear power units and that the plant meet the relevant requirements of GDC 4.

The acceptance criteria involve reviewing event probability for which the expected rate of occurrence of potential exposure in excess of the 10 CFR Part 100 guidelines is estimated to be less than an order of magnitude of 1×10^{-7} per year.

3.5.1.5.4 *Technical Evaluation*

Since the information regarding site proximity missiles (except aircraft), in the vicinity of the site, is site specific, the applicant stated, in DCD Tier 2:

[t]hat a COL applicant referencing the APR1400 DCD will address the site-specific information pertaining to the evaluation of potential for site proximity explosions and missiles due to train, truck, ship or barge explosions, industrial facilities, pipeline explosions, or military facilities and others, as per COL 3.5(7). If the total probability of explosion is greater than an order of magnitude of 10^{-7} per year, a missile description, including size, shape, weight, energy, material properties, and trajectory will be specified. A description of the missile effects on the SSCs will be developed and addressed, if necessary.

3.5.1.5.5 *Combined License Information Items*

The following table provides a list of site proximity missile-related COL information Item numbers and descriptions from DCD Tier 2, Table 1.8-2:

Table 3.5.1 -5 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(7)	The COL applicant is to evaluate the potential for site proximity explosions and missiles due to train explosions (including rocket effects), truck explosions, ship or barge explosions, industrial facilities, pipeline explosions, or military facilities.	3.5.1.4

3.5.1.5.6 *Conclusion*

As stated above, the applicant has stated in the DCD Tier 2, that the COL applicant would provide the site-specific information under COL 3.5(7). Since this information is site-specific, the applicant's statement provided in the DCD, that the COL applicant is to supply this site-specific information as per COL 3.5(7) in accordance with SRP Section 3.5.1.5, is considered acceptable. For the reasons given above, the staff concludes, as this information is site-specific, it will be addressed by the COL applicant and, therefore would be reviewed at the time of COL stage. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the values of the actual site characteristics specified in a COL application.

3.5.1.6 *Aircraft Hazards*

3.5.1.6.1 *Introduction*

This section assures that the risks from aircraft hazards are sufficiently low. The COL applicant verifies the site parameters with respect to aircraft hazards. Additional analyses may be required as appropriate.

3.5.1.6.2 *Summary of Application*

DCD Tier 2, Section 3.5.1.6, addresses the need for the evaluation of potential aircraft hazards and an aircraft hazard analysis, with a statement that the COL applicant that references the APR1400 DCD will provide site-specific information and evaluations in accordance with the requirements provided in RG 1.206, as per COL 3.5(8).

3.5.1.6.3 *Regulatory Basis*

The applicable regulatory requirements for identifying evaluation of potential aircraft hazards are:

- Section 100.20(b) of 10 CFR, which states that the nature and proximity of man-related hazards (e.g., airports) must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards and whether the risk of other hazards is very low.
- Section 100.20(b) of 10 CFR, as it relates to the requirement that site characteristics be evaluated to determine whether the risk to individuals and society of potential plant accidents is low.
- Section 100.21(c)(2) of 10 CFR, which states that the applications for site approval for commercial power reactors shall demonstrate that the proposed site meets the radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34 (a)(1).
- Section 100.21(e) of 10 CFR, which states that potential hazards associated with nearby transportation routes and industrial and military facilities must be evaluated and site parameters established such that potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed to be located at the site.
- GDC 3, "Fire protection," which requires that SSCs important to safety have appropriate protection against the effects of fires and explosions.
- GDC 4, which requires that SSCs important to safety have appropriate protection against the effects of missiles that may result from events and conditions outside the nuclear power units.

The acceptance criteria involve reviewing event probability for which the expected rate of occurrence of potential exposure in excess of the 10 CFR Part 100 guidelines is estimated to be less than an order of magnitude of 1×10^{-7} per year.

3.5.1.6.4 *Technical Evaluation*

Since the information regarding potential aircraft hazards in the vicinity of the site is site specific, the applicant stated that the COL applicant that references the DCD will demonstrate that the probability of aircraft hazards impacting the APR 1400 standard plant and causing consequences greater than the 10 CFR Part 100.21(c)(2) (which references 10 CFR 50.34(a)(1) exposure guidelines is less than 1×10^{-7} per year based on the COL applicant's use of site-specific information in accordance with RG 1.206 (SRP Section 3.5.1.6) as per COL 3.5(8).

3.5.1.6.5 Combined License Information Items

The following table provides a list of site proximity missile-related COL information items and descriptions from DCD Tier 2, Table 1.8-2.

Table 3.5.1-6 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(8)	The COL applicant is to provide justification for the site-specific aircraft hazard and an aircraft hazard analysis in accordance with the requirements of NRC RG 1.206.	3.5.1.4

3.5.1.6.6 Conclusion

As set forth above, the applicant has stated in the APR1400 DCD Tier 2, that the COL applicant will provide the site-specific information under COL 3.5(8). Since this information is site-specific, the applicant's statement provided in the APR1400 DCD that the COL applicant is to supply this site-specific information as per COL 3.5(8) in accordance with SRP Section 3.5.1.6, is considered acceptable. For the reasons given above, the staff concludes, as this information is site-specific, it will be addressed by the COL applicant and, therefore would be reviewed at the time of COL stage. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the values of the actual site characteristics specified in a COL application.

3.5.2 Structures, Systems, and Components to be Protected from Externally-Generated Missiles

3.5.2.1 Introduction

To satisfy GDC 2 and GDC 4, safety-related SSCs needed to safely shut down the reactor and maintain it in a safe condition shall be protected from externally-generated missiles. This includes all safety-related SSCs supporting the operation of the reactor including essential service water intakes, buried components, and structure access openings and penetrations.

3.5.2.2 Summary of Application

DCD Tier 1: The DCD Tier 1, information associated with this section is found in DCD Tier 1, Sections 2.2.1, 2.2.2, 2.2.8, and 2.2.9, which describes the design of the NI structures, EDG building, ESW building, and CCW heat exchanger building.

DCD Tier 2: The applicant has provided a DCD Tier 2, description in Section 3.5.2, "Structures, Systems, and Components to be Protected from Externally-generated Missiles," which describes the SSCs requiring protection from externally-generated missiles and the structures that provide missile protection. These structures include the reactor containment and auxiliary buildings, EDGB, ESWR, and component cooling water heat exchanger building. Missile protection is provided by the external walls of the structures.

ITAAC: The ITAAC associated with DCD Tier 2, Section 3.5.2 are given in DCD Tier 1, Tables 2.2.1-2, 2.2.2-2, 2.2.8.-1, and 2.2.9-1, and provide ITAAC requirements for the NI structures, EDGB, ESWR, and component cooling water heat exchanger building.

Initial Test Program: DCD Tier 2, Section 14.2, does not have any initial testing requirements associated with this review item.

3.5.2.3 *Regulatory Basis*

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in NUREG-0800, Section 3.5.2, Revision 3, and are summarized below. Review interfaces with other SRP sections also can be found in NUREG-0800, Section 3.5.2.

- GDC 2, as it requires, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as tornadoes and hurricanes without loss of capability to perform their safety functions.
- GDC 4, as it requires, in part, that SSCs important to safety shall be appropriately protected against the effects of missiles that may result from events and conditions outside the nuclear power unit.
- Section 52.47 of 10 CFR, Item (b)(1), which requires that a DCA 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 constructed and will be operated in accordance with the DC, the provisions of the Atomic Energy Act, and NRC regulations.

3.5.2.4 *Technical Evaluation*

The staff reviewed the APR1400 design for protecting essential SSCs against externally-generated missiles in accordance with the guidance of SRP Section 3.5.2, Revision 3. The staff reviewed DCD Tier 2, Section 3.5.2. The staff also reviewed DCD Tier 1, Sections 2.2.1, 2.2.2, 2.2.8 and 2.2.9, and other DCD Tier 2 sections as noted below.

Compliance with GDC 2 and GDC 4 is based on conforming to the guidance of the following RGs:

- RG 1.13, "Spent Fuel Storage Facility Design Basis," Revision 2, March 2007, as it relates to the capacity of the spent fuel pool cooling (SFPC) systems and structures to withstand the effects of externally-generated missiles and to prevent missiles from contacting the stored fuel assemblies.
- RG 1.27, "Ultimate Heat Sink for Nuclear Plants," Revision 2, as it relates to the capability of the ultimate heat sink and connecting conduits to withstand the effects of externally-generated missiles.
- RG 1.115, Revision 2, as it relates to the protection of the SSCs important to safety from the effects of turbine missiles.

- RG 1.117, "Tornado Design Classification," Revision 1, Appendix A, as it to which SSCs important to safety should be protected from missile impacts.

SRP Section 3.5.2, Revision 3, states that the SSCs required for safe shutdown of the reactor should be identified. RG 1.115, Position C.1, and RG 1.117, Appendix A, provide guidance as to which SSCs should be protected from missile impacts. In DCD Tier 2, Section 3.5.2, the applicant states that all safety-related SSCs required to shut the reactor down and maintain it in a safe condition are housed in seismic Category I structures. In addition, DCD Tier 2, Tables 3.2.2-1 and 3.5-4, identify the SSCs that are safety-related and require missile protection, and, in DCD Tier 2, Section 7.4, the applicant identifies the SSCs that are needed for safe shutdown.

When reviewing DCD Tier 2, Table 3.5-4, the staff noted some inconsistencies and missing information. The staff issued RAI 88-8046, Question 03.05.02-3 (ML15201A473), requesting the applicant to verify appropriate systems and structures are included in the table. In its response to RAI 88-8046, Question 03.05.02-3 (ML15240A208), and its revised response to RAI 88-8046, Question 03.05.02-3 (ML16093A036), the applicant stated that the purpose of Table 3.5-4 is to provide the essential SSCs outside of the reactor containment building in accordance with RG 1.117, Appendix A. The applicant added that the auxiliary feedwater system, the EDG building and compound building will be included in DCD Tier 2, Table 3.5-4. In addition, the applicant corrected nomenclature of other SSCs that was not accurate.

The staff reviewed the applicant's response to RAI 88-8046, Question 03.05.02-3, and finds the modifications to DCD Tier 2, Table 3.5-4 acceptable because it confirms that the DCD will appropriately identify all safety-related SSCs outside the reactor containment building required to shut down the reactor and maintain it in a safe-shutdown condition consistent with RG 1.115, Position C.1 and RG 1.117, Appendix A. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 88-8046, Question 03.05.02-3 is resolved and closed.

The APR1400 application was reviewed to determine whether all essential SSCs necessary to support the reactor facilities are appropriately protected from externally-generated missiles. DCD Tier 2, Table 3.5-4 identifies the RCB, auxiliary buildings (AB), EDG building, CCW heat exchanger building, and the ESW building for providing protection for SSCs against externally-generated missiles. In addition, DCD Tier 2, Section 3.5.2, states that openings and penetrations through the exterior walls and roof of seismic Category I, structures, and the location of equipment in the vicinity of such openings, are arranged so that a missile passing through the opening would not prevent the safe shutdown of the plant. However, the staff could not verify if the piping routed through the CCW piping tunnel between the AB and CCW heat exchanger buildings are adequately protected against externally-generated missiles. Therefore, the staff issued RAI 88-8046, Question 03.05.02-4 (ML15201A473), requesting the applicant to clarify how safety-related piping systems routed outside seismic Category I structures are protected from externally-generated missiles.

In its response to RAI 8046, Question 03.05.02-4 (ML15240A208), and supplement (ML18197A295), the applicant stated that the APR1400 has no seismic Category I buried piping and all safety-related SSCs are housed in seismic Category I structures. In its revised response to RAI 256-8321, Question 09.02.02-5, (ML16062A085), the applicant stated that the CCW piping tunnels are designed to be safety class 3, seismic Category I. The staff finds the

applicant's response to RAI 8046, Question 03.05.02-4, acceptable because the CCW piping routed outside the AB is adequately protected against externally-generated missiles consistent with the methods discussed in SRP Section 3.5.2, and RG 1.117. For the complete review associated with RAI 256-8321, Question 09.02.02-5, see Section 9.2.2 of this SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8046, Question 03.05.02-4, is resolved and closed.

Based on the above, the staff determined that SSCs requiring missile protection identified in DCD Tier 2, Section 7.4, Table 3.2.2-1, and Table 3.5-4 are located in seismic Category I structures and openings in the structures will be protected. Therefore, the staff concludes that the APR1400 plant design conforms to the guidance of RG 1.13, RG 1.27, and RG 1.117.

The staff issued RAI 88-8046, Question 03.05.02-5 (ML15201A473), requesting the applicant to discuss whether the APR1400 design accounts for the failure of nonsafety-related SSC's impact on safety-related SSCs. In its response to RAI 88-8046, Question 03.05.02-5 (ML15240A208), the applicant stated that a basic design concept of the APR1400 is that the failure of nonsafety-related SSCs cannot affect the function of safety-related SSCs. The applicant adds that since a COL applicant can add site-specific SSCs, a COL item will be added for the COL applicant to confirm that the failure of nonsafety-related SSCs due to missiles cannot prevent a safety-related SSC from performing its safety function. The staff finds the applicant's response to RAI 88-8046, Question 03.05.02-5, acceptable because the design prevents the potential failure of nonsafety-related SSCs due to missile impact to adversely affect safety-related SSCs from performing their safety function. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 88-8046, Question 03.05.02-5, is resolved and closed.

During its review, the staff noted that the DCD referred to protection against tornado missiles in several areas and omitted hurricane missiles. Therefore, the staff issued RAI 88-8046, Question 03.05.02-2 (ML15201A473), requesting the applicant to address these statements and include hurricane missile protection, which can sometimes be more limiting than tornado missiles. In its response to RAI 88-8046, Question 03.05.02-2 (ML15240A208), the applicant stated that they performed a review of the DCD and provided a markup that revises Section 3.5.2, and Section 14.3.2.7, accordingly to reflect both tornado and hurricane missiles. The staff finds the applicant's response to RAI 88-8046, Question 03.05.02-2, acceptable because the proposed changes demonstrate that the APR1400 design considers the effects of extreme winds, including both tornados and hurricanes. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 88-8046, Question 03.05.02-2, is resolved and closed.

SER Section 3.5.1.3, addresses the staff's evaluation of the protection from low trajectory turbine missiles, including the evaluation of APR1400 structure conformance to the guidance of RG 1.115.

SER Section 3.5.3, addresses the staff's evaluation of the design of seismic Category I, structures, and barriers used for missile protection.

SER Section 3.7, addresses the staff's evaluation of the design of non-seismic SSCs which, if they fail, could potentially create seismic generated missiles that could affect safety related SSCs.

SER Section 3.8, addresses the staff's evaluation of the design of Category I structures of the NI structures, EDG building, CCW heat exchanger building, and ESW building, including the protection of these structures from the effects resulting from the failure of adjacent non-seismic Category I, structures during an extreme wind event.

ITAAC

In DCD Tier 1, Section 2.0, the applicant provides the design descriptions and ITAAC that verify that the following structures are designed and constructed as described in DCD Tier 2 to withstand the design-basis loads, including externally-generated missiles:

Nuclear Island Structures

The NI structures are safety-related structures that consist of the RCB and the AB. The NI structures are designed to withstand the effect of an aircraft impact.

ITAAC Item 3, listed in DCD Tier 1, Table 2.2.1-2, requires an analysis of the NI structures to ensure that the as-built structures can withstand the design-basis loads and have been constructed in accordance with the design as described in APR1400 DCD Tier 2.

Emergency Diesel Generating Buildings

The EDG building is located adjacent to the east side of the NI, is classified as seismic Category I, and is composed of reinforced-concrete basemat, shearwalls, and slabs.

ITAAC Item 2, listed in DCD Tier 1, Table 2.2.2-2, requires an analysis of the EDG building to ensure that the as-built structures can withstand the design-basis loads and have been constructed in accordance with the design as described in APR1400 DCD Tier 2.

Essential Service Water and Component Colling Water Heat Exchanger Buildings

DCD Tier 2, Table 3.5-4 identifies the ESW building and CCW heat exchanger buildings as providing a missile barrier for externally-generated missiles. DCD Tier 1, Table 2.2.1-3 indicates that the ESW and CCW structures are seismic Category 1; however, DCD Tier 1, Section 2.2 did not contain any ITAAC to verify that the ESW and CCW heat exchanger structures have been built and constructed to withstand design-basis loads. Therefore, the staff issued RAI 88-8046, Question 03.05.02-6 (ML15201A473), requesting the applicant to include appropriate ITAAC for the ESW building and CCW heat exchanger building structures in DCD Tier 1 to provide reasonable assurance that the structures are constructed consistent with the DC.

In its response to RAI 88-8046, Question 03.05.02-6 (ML15240A208), the applicant stated ITAAC items to verify the ESW and CCW heat exchanger buildings are built and constructed to withstand the design-basis loads will be added to the DCD. The staff finds the applicant's response to RAI 88-8046, Question 03.05.02-6, acceptable because the proposed ITAAC provide reasonable assurance that the ESW and CCW heat exchanger buildings will be constructed consistent with the DC. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 88-8046, Question 03.05.02-6, is resolved and closed.

The staff finds that the above cited ITAAC Items, which verify that the safety-related SSCs are protected from externally-generated missiles and have been constructed in accordance with the design as described in APR1400 Tier 2, are acceptable and meet the requirements of 10 CFR 52.47(b)(1).

A complete list of all APR1400 related ITAAC is provided in SER Section 14.3.

3.5.2.5 Combined License Information Items

The following table provides a list of externally-generated missile related COL information items and descriptions from DCD Tier 2, Table 1.8-2

Table 3.5.1-6 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.5(4)	The COL applicant is to evaluate site-specific hazards induced by external events that may produce more energetic missiles than tornado or hurricane missiles, and provide reasonable assurance that seismic Category I and II structures are designed to withstand these loads.	3.5.1.4
COL 3.5(9)	The COL applicant is to provide reasonable assurance that site-specific structures and components not designed for missile loads will not prevent safety-related SSCs from performing their safety function.	3.5.2

The staff finds the above listing to be complete. Also, the list adequately describes actions necessary for the COL applicant. No additional COL information items need to be included in DCD Tier 2, Table 1.8-2 for externally-generated missile considerations.

3.5.2.6 Conclusion

Based on the its review, the staff concludes that the SSCs to be protected from externally generated missiles are in conformance with the guidance described in RG 1.13, RG 1.27, RG 1.115, and RG 1.117 and, therefore the design meets, the requirements of GDC 2, and GDC 4. The staff further concludes that adequate protection features have been provided for the APR1400 to protect safety-related SSCs against externally-generated missiles.

3.5.3 Barrier Design Procedures

3.5.3.1 Introduction

This section documents findings from the staff's review and evaluation of the APR1400 procedures used in design of missile barriers to withstand the local and overall effects of missile impact and impulsive loads.

3.5.3.2 *Summary of Application*

DCD Tier 1: There is no direct DCD Tier 1 information related to missile barrier design procedures. However, indirect DCD Tier 1 information associated with missile protection barriers is found in DCD Tier 1, Sections 2.2.1, “Nuclear Island Structures,” and Section 2.2.5.1.4 “Internally Generated Missiles (Inside and Outside Containment).”

DCD Tier 2: In DCD Tier 2, Section 3.5.3, “Barrier Design Procedures,” the applicant has provided a description of missile barrier design as follows.

Seismic Category I structures are designed to provide protection from external missile caused by natural phenomena, and internal missiles caused by equipment and piping failures. In this design, the barrier must have sufficient strength to prevent perforation by the missile and be able to withstand, in combination with other design loads, the overall effects of the missile impact on the structure. Secondary effects from the impact such as back-face scabbing and front face spalling must also be considered, as well as ductility limits on the overall response of the barrier when a nonlinear elastoplastic analysis is used.

ITAAC: There are no ITAAC directly related to missile barrier design procedures. Related ITAAC associated with missile protection barriers are found in DCD Tier 1, Table 2.2.5-1, “Protection against Hazards ITAAC,” (4 of 4), in which the applicant committed the as-built nuclear island structure including EDG building be designed with protective provisions against internally generated missiles including (1) minimizing the sources of missile generation; (2) orientation of physical separation of missile source away from safety-related SSCs; (3) containing the potential missiles through the use of protective barriers; and (4) hardening the safety-related SSCs to withstand missile impact.

Technical Specifications: There are no Technical Specifications for this area of review.

3.5.3.3 *Regulatory Basis*

The relevant requirements of NRC regulations associated with this area of review, and the associated acceptance criteria, are given in the SRP Section 3.5.3, and are summarized below. Review interfaces with other SRP Section 3.5.3.

- GDC 2, as it relates to the SSCs important to safety being designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the severe effects of the natural phenomena that have been historically reported for a site.
- GDC 4, as it relates to the protection of SSCs that are important to safety against dynamic effects of missiles, pipe whip, and discharging fluids that may result from equipment failures and from events and conditions outside the nuclear power unit.
- Section 52.47(b)(1) of 10 CFR requires that a DCA 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 is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

Acceptance criteria adequate to meet the above requirements include:

- RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, issued March 2007, as it relates to the minimum acceptable barrier thickness for tornado missiles.
- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," issued October 2011.
- RG 1.142, "Safety Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," as it relates to the design of safety-related concrete structures for nuclear power plants.
- RG 1.136, "Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments," as it relates to the design limits, loading combinations, materials, construction, and testing of concrete containments.

3.5.3.4 *Technical Evaluation*

In this section of the report, the staff evaluates the procedures used in the design of seismic Category I structures, shields, and barriers to withstand the effects of missile impact. For the prediction of local damage from missiles, the applicant provided information on the procedures used in the design of concrete and steel, excluding composite barriers. For overall damage assessment, the applicant provided information on the elastoplastic analysis methods that are utilized and structural ductility considerations. In DCD Tier 2, Section 3.8, "Design of Category I Structures," the applicant discusses loads and load combinations for seismic Category I structures which include tornado, hurricane missile loads as well as pipe whip and jet impingement loads. DCD Tier 2, Section 3.8 states that the design for these loads conforms to the procedures of DCD Tier 2, Section 3.5. Detailed staff's review and evaluations are documented below.

3.5.3.4.1 *Local Damage Prediction*

Reviews of this portion of the application were performed in accordance with SRP Section 3.5.3, RG 1.76, and RG 1.221.

Concrete Barriers

SRP Section 3.5.3, acceptance criterion 1.A, dictates that sufficient thickness of concrete should be provided to prevent (1) perforation/penetration; (2) spalling or (3) scabbing of the concrete barriers in the event of missile impact. The applicant in DCD Tier 2, Section 3.5.3.1.1 provided several empirical equations including the modified National Defense Research Committee (NDRC) formula which provide missile impact effects on concrete barriers. The SRP Section 3.5.3, acceptance criterion 1.A, identified and recommends the use of these equations for determining required thicknesses of concrete barriers.

As such, the staff finds the use of these formulas which include methods for calculating missile penetration, perforation, and scabbing to be acceptable for missile barrier design.

In DCD Tier 2, Section 3.5.3.1.1, the applicant stated that the design thicknesses are 20 percent greater than the threshold values calculated below. Moreover, the design thicknesses also satisfy the minimum acceptable barrier thickness requirements for local damage prediction against extreme wind-generated missiles provided in Table 3.5-3, "Minimum Acceptable Barrier Thickness Requirements for Local Damage Prediction against Missile Generated by Natural Phenomena." The staff reviewed these values and found they are conservative and meeting the acceptance criteria in SRP Section 3.5.3, RG 1.76, and RG 1.221.

Penetration

In DCD Tier 2, Section 3.5.3.1.1.1, the applicant stated that the depth of missile penetration is calculated using the modified NDRC formulas. The staff reviewed the formula and found the use of this formula to calculate the depth of missile penetration is acceptable as it meets the SRP Section 3.5.3, acceptance criterion 1.A. However, the staff requested a correction on the symbol for missile weight which is also used to represent length in SEB Issue No. 1 (AI 3-80.1). In response, the applicant changed the symbol and provided the markup. Based on the review of the DCD, the staff has confirmed the changes described above; therefore, AI 3-80.1) is resolved and closed.

Perforation

In DCD Tier 2, Section 3.5.3.1.1.2, the applicant stated that the thickness required to prevent perforation calculated by the modified NDRC formulas. The staff reviewed the formula and found the use of this formula to calculate the thickness of the concrete barrier to prevent perforation is acceptable as it meets the SRP Section 3.5.3, acceptance criterion 1.A.

Scabbing

In DCD Tier 2, Section 3.5.3.1.1.3, the applicant stated that the thickness required to preclude scabbing is calculated using the modified NDRC formulas. The staff reviewed the formula and found the use of this formula to calculate the thickness of the concrete barrier to prevent scabbing is acceptable as it meets the SRP Section 3.5.3, acceptance criterion 1.A.

Steel Barriers

In DCD Tier 2, Section 3.5.3.1.2, "Steel Barriers," the applicant stated that both of the Ballistic Research Laboratory (BRL) and Stanford Research Institute (SRI) formulas (discussed below) will be used as the basis for the design and analysis of steel barriers against missile impacts. However, no criteria were given as to what the minimum thickness of the steel barrier will be used. Thus, the staff in a letter dated October 28, 2015 (ML15301A921) to the applicant (Issue No. 2 and No. 3) requested for such a criterion. In response, the applicant stated that (a) the larger value will be used as the perforation thickness by comparing results from the BRL and SRI formulas; and (b) the minimum thickness will be set at 25 percent greater than the value obtained in (a). Those criteria have been inserted in the FSAR markup. The staff reviewed those responses, and found the criteria are acceptable, since the greater thickness from either the BRL or SRI calculation will be used and subsequently increased by 25 percent, thereby increasing the safety margin. Based on the review of the DCD, the staff has confirmed the changes described above; therefore, this issue is resolved and closed.

BRL Formula

In DCD Tier 2, Section 3.5.3.1.2, the applicant stated that the thickness required to prevent perforation will be calculated by the BRL formulas. The staff reviewed the formula and found the use of this formula to calculate the thickness of the steel barrier to prevent perforation is acceptable as it meets the SRP Section 3.5.3, acceptance criterion 1.B.

SRI Formula

In DCD Tier 2, Section 3.5.3.1.2, the applicant stated that the depth of missile penetration is calculated using the SRI formulas. The staff reviewed the formula and found the use of this formula to calculate the depth of missile penetration is acceptable as it meets the RP 3.5.3, acceptance criterion 1.B. However, in Issue No. 4 (AI 3-80.4) the staff requested an additional information on one of the applicable ranges. In response, the applicant added the new item in the list of applicable ranges and provided the markup.

Composite Barriers

The review procedures in SRP Section 3.5.3, Section III.1.C depict that for the prediction of local damage for missile penetration in composite barriers, the applicant needs to use the criteria delineated in SRP Section 3.5.3, Section II, "Acceptance Criteria," Subsection 1.C. However, there is no local damage prediction procedures provided for composite barriers in DCD Tier 2, Section 3.5.3. Thus, the staff in a letter dated October 28, 2015 (ML15301A921) to the applicant (Issue No. 5 (AI 3-80.5)) requested the applicant to provide a technical basis for not including composite barrier protection in the APR1400 standard design. In response, the applicant stated that there are no composite sections designed as a missile barrier in the APR1400, and the containment liner plate (see DCD Section 3.8.1.4.10) is not designed as a missile barrier, nor is it a part of a composite barrier. These two statements have been added to DCD Tier 2, Section 3.5.3, mark-up. The staff reviewed the DCD mark-up, and found they are acceptable based on the fact that there are no composite barriers used in the APR1400 standard design, therefore there is no need to include the prediction methodology of local damage for composite barriers in DCD Tier 2, Section 3.5.3.

3.5.3.4.2 Overall Damage Prediction

SRP Section 3.5.3.II.2 states that after it has been demonstrated that the missile will not penetrate the barrier, an equivalent static load concentrated at the impact area should then be determined from which the global structural response, together with other design loads can be evaluated using conventional design methods. In DCD Tier 2, Section 3.5.1.4, the applicant states that procedures for overall response include assumptions on acceptable ductility ratios where nonlinear, elastoplastic behavior is relied upon and methods for estimation of forces, bending moments and shears induced in the barrier by the missile's impact (equivalent static) force. In DCD Tier 2, Section 3.5.3.2, the applicant reiterated that for the evaluation of overall response of both reinforced concrete and steel barriers under impact or impulsive loads, nonlinear and elasto-plastic methodology is used. The applicant further stated that excessive deformation is limited by the allowable ductility ratios given in Table 3.5-5 which is based on AISC N690 and RG 1.142 (The staff's review on the ductility requirements is discussed in the following section). However, detailed methodology for overall damage predictions is not provided. Hence, the staff issued RAI-215-8231, Question 03.05.03-1 (ML15259A768), requesting the applicant to provide a description of the methodology used to assess the flexural, shear, force and buckling effects on the overall damage predictions for the steel as well as reinforced concrete barriers. In its response to RAI-215-8231, Question 03.05.03-1 (ML15336A989), the applicant provided the methodology for concrete barriers. The global response of the concrete slab and wall is determined using the inelastic single-degree-of-freedom dynamic analysis methodologies based on ASCE Standard 58: (1) Determine missile forcing function including duration and peak force; (2) Determine natural frequency and barrier resistance; (3) Confirm the ductility ratio is within the allowable specified in Table 3.5.5-5 and (4) Determine the failure mode from flexural behavior of the concrete barrier. In case of soft missile, punching shear and reaction shear on edge impact will be evaluated in accordance with shear provisions in ACI 349. Buckling effects for concrete walls and slabs are also checked based on ACI 349 specifications. The staff reviewed the proposed dynamic, nonlinear elastic plastic methodology for the overall damage prediction for concrete barriers, and found it is acceptable since general engineering principles are followed that meet the requirements depicted by ASCE 58 and ACI 349 code provisions.

With regards to the requested methodology on overall damage prediction for steel barriers subjected to missile impact, the applicant stated in its response to RAI 215-8231, Question 03.05.03-1 (ML15336A989), that there are no steel barriers used in the APR1400 standard design. As a result, the DCD is revised to delete the requirements for steel barriers from DCD Sections 3.5.3.1.2, 3.5.3.2, and Table 3.5-5. A DCD markup was provided as part of the response. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 215-8231, Question 03.05.03-1, is resolved and closed.

3.5.3.4.3 Ductility Requirements for Missile Barriers

For overall damage prediction, SRP Section 3.5.3, acceptance criterion II.2, states that maximum allowable ductility ratios used for steel and reinforced concrete barriers in the evaluation as given in AISC N690 with supplement 2 and in RG 1.142 should be acceptable. In DCD Tier 2, Section 3.5.3, the applicant presents the allowable ductility ratios in Table 3.5-5. The staff reviewed those ductility ratios in each loading case for both steel and reinforced concrete barriers present in the table, and found they meet RG 1.142 and the code

specifications in AISC N690, thus meeting the SRP Section 3.5.3, acceptance criterion II.2, and therefore acceptable.

3.5.3.4.4 *Protective measures*

In DCD Tier 1, ITAAC Table 2.2.5-1 the applicant committed to implementing the following key protective measures for the as-built nuclear island structure including EDG building against internally generated missiles:

- Design features for preventing missile generation.
- Physical separation from potential missile source away from safety-related SSCs.
- Use of protective shields near the missile source.
- Hardening of safety-related SSCs to withstand missile impact.

In addition, DCD Tier 2, Sections 3.5.1.2 and 3.5.2, provide additional measures such as enclosures, missile-resistant doors and covers, and other physical features are designed to resist missiles generated from internal as well as external sources, respectively.

The staff reviewed this ITAAC on “Protection against Hazards,” DCD Tier 2, Section 3.5.1.2, and DCD Tier 2, Section 3.5.2, and determined that these protective measures when use with the design methods described in DCD Tier 2, Section 3.5.3, provide adequate missile protection for seismic Category I structures.

3.5.3.5 *Combined License Information Items*

The staff determined that no COL information items need to be included in DCD Tier 2, Table 1.8-2, “APR1400 Combined License Information Items,” for barrier design procedures consideration.

3.5.3.6 *Conclusion*

Based on its evaluation above, the staff concludes that sufficient information has been provided by the applicant with respect to the design of missile barriers and their capacity to protect the SSCs of the APR1400 standard design from both internal and external missiles and from other types of impact loads.

As discussed above, the staff finds that, the applicant used acceptable methods in barrier design. The staff also finds that the barrier design methods meet the SRP Section 3.5.3, acceptance criteria guidelines, with respect to the capabilities of the structures, shields, and barriers to provide sufficient protection to the safety-related SSCs. The use of these methods provides reasonable assurance that if a design-basis missile should strike a seismic Category I, structure or other missile shields and barriers, the structural integrity of these structures, shields, and barriers will not be compromised to the extent that will result in a loss of required protection and that structures, missile shields or barriers designed with these methods, meet the requirements of 10 CFR Part 50, Appendix A, GDC 2 and GDC 4. Seismic Category I, SSCs are, therefore, adequately protected against the effects of missiles and other impact objects and will perform their intended safety functions. The staff finds that conformance with these

methods is an acceptable basis for satisfying the requirements of GDC 2, and GDC 4, as they relate to providing missile and impact protection for safety-related structures, systems and components.

3.6 Protection Against Dynamic Effects Associated with Postulated Rupture of Piping

3.6.1 Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside of Containment

3.6.1.1 Introduction

This section evaluates the APR1400 design bases and criteria relied upon to demonstrate that essential systems and components are protected against postulated piping failures outside of containment. High- and moderate-energy systems representing potential sources of dynamic effects associated with pipe rupture are identified, and the criteria for separation and the evaluation of adverse consequences are defined.

3.6.1.2 Summary of Application

DCD Tier 1: Information related to protection against pipe rupture effects is discussed in DCD Tier 1, Section 2.3, "Piping Systems and Components." Table 2.3-3 identifies the high- and moderate-energy lines that must be evaluated for pipe break analysis.

DCD Tier 2: The methodology used in designing the protection of essential systems and components from the consequences of postulated piping failures outside containment is described in DCD Tier 2, Section 3.6.1. Such methodology includes: (1) identification of essential systems and components located near high- or moderate-energy pipe systems that need to be protected; (2) identification of the failures for which protection is being provided and assumptions used; and (3) identification of protection considerations in the design. Separation and redundancy of essential systems, methods of analyzing piping failures, and habitability of the main control room are also addressed.

ITAAC: Tier 1, Table 2.3-3, "High and Moderate Energy Piping Systems," identifies all the piping systems that must be evaluated in the pipe rupture hazard analysis report. The Tier 1 Section of each of these system includes an ITAAC related to the pipe rupture hazard analysis.

3.6.1.3 Regulatory Basis

The relevant regulatory requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.6.1, Revision 3, and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 3.6.1.I.

- GDC 2, as it relates to the protection of SSCs important to safety to withstand the effects of natural phenomena, such as earthquakes.
- GDC 4, "Environmental and dynamic effects design bases," as it relates to SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with postulated pipe rupture.

- Section 52.47(b)(1) of 10 CFR, as it relates to the requirement that a 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 DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and NRC regulations.

3.6.1.4 *Technical Evaluation*

In DCD Tier 2, Section 3.6.1, the applicant describes the methodology used in designing the APR1400 to protect essential systems and components from the consequences of postulated piping failures outside containment. The steps include identification of the essential systems and components that are located near high- or moderate-energy piping systems, identification of the failures for which protection is being provided, and identification of protection considerations that are utilized in the design to safeguard essential SSCs.

The fluid systems that contain high- and moderate-energy piping are identified in DCD Tier 2, Table 3.6-1, "High- and Moderate-Energy Fluid Systems."

DCD Tier 2, Section 3.6.1, defines high-energy system as fluid systems or portions of fluid systems that, during normal plant conditions, are either in operation or maintained pressurized under conditions where either or both of the following are met:

- Maximum operating temperature exceeds 93.3 °C (200 °F).
- Maximum operating pressure exceeds 19.3 kg/cm² (275 psig).

A moderate-energy system is defined as a high-energy system that only operates at those conditions for short periods of time (less than 2 percent of the total time the system operates), or fluid systems or portions of fluid systems that, during normal plant conditions, are either in operation or maintained pressurized (above atmospheric pressure) under conditions where both of the following are met:

- Maximum operating temperature is 93.3 °C (200 °F) or less.
- Maximum operating pressure is 19.3 kg/cm² (275 psig) or less.

The reviews of nuclear power plant designs have indicated that the functional or structural integrity of systems and components required for safe shutdown of the reactor and maintenance of cold shutdown conditions could be endangered by fluid system piping failures at locations outside containment. The staff has evolved an acceptable approach for the design, including the arrangement, of fluid systems located outside of containment to ensure that the plant can be safely shut down in the event of piping failures outside containment. This approach is set forth in Branch Technical Position (BTP) 3-3, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," and in the companion BTP 3-4, "Postulated Rupture Locations In Fluid System Piping Inside And Outside Containment."

The staff evaluated these system definitions of high and moderate energy systems and found them to be consistent with the definitions provided in BTP 3-3, which delineates the staff's guidelines for protection against postulated piping ruptures in fluid systems outside the containment. The staff finds the system definitions above acceptable.

GDC 2, Design Bases for Protection Against Natural Phenomena

The requirements of 10 CFR Part 50, Appendix A, GDC 2 states that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes. During a seismic event, it is postulated that non-seismic SSCs could fail. This section evaluates the impact of full-circumferential ruptures of non-seismic moderate-energy piping in areas close to SSCs important to safety, where the effects of a failure are not already bounded by failures of high-energy piping. Acceptance criteria are based on conformance to BTP 3-3.

DCD Tier 2, Section 3.6.1.1, "Design Basis," states that the protection of essential equipment is achieved primarily by separation. Most of the systems and components outside the containment required for safe plant shutdown are located inside the auxiliary building, and separated by structural walls that are credited to act as barriers between redundant trains. Essential systems are identified in DCD Tier 2, Table 3.2-1. Non-essential high-energy piping systems located in the auxiliary building are routed in designated pipe tunnels in order to provide separation from essential SSCs. To the extent possible, non-seismic piping is separated from essential system and, when this is not practical, the non-seismic pipe is designed to seismic Category II criteria.

In DCD Tier 2, Section 3.6.1.2.2, "Specific Protection Consideration," the applicant states that there is no high-energy piping routed in the vicinity of the control room; therefore, there are no effects on the control room habitability.

In DCD Tier 2, Section 3.6.2.1.4.1.1, "Break Locations for High-Energy Fluid System Piping in Areas Other than Containment Penetration," the applicant states that breaks are postulated in non-seismically analyzed piping at terminal ends of the pressurized portions of the network, and at each intermediate location of potential high stress or fatigue, such as pipe fittings, valves, flanges, and welded-on attachments.

The staff finds that crediting separation of essential equipment trains by structural walls provides protection against postulated pipe breaks. Where separation is not practical, the applicant classified the piping segments as seismic Category II piping, therefore the staff determined that the above system description acceptable in reference to the requirements of GDC 2.

GDC 4, Environmental and Dynamic Effects Design Bases

The plant design for protection against postulated piping failure in fluid systems outside containment must meet the requirements of GDC 4, as it relates to accommodating the dynamic effects of postulated pipe ruptures, including the effects of pipe whipping and discharging fluids.

SRP Section 3.6.1 references BTP 3-3 as an acceptable approach to demonstrate compliance with GDC 4.

BTP 3-3.B.1 describes an acceptable protection methodology for the essential SSCs. The BTP states that protection of essential SSCs from postulated pipe ruptures shall be provided by:

- Providing separation between fluid system piping and essential systems and components,

- If separation is not practical, fluid systems should be enclosed within structures or compartments designed to protect nearby essential systems and components, and
- If provisions a and b are not satisfied, redundant design features that are separated or otherwise protected from postulated piping failures, or additional protection, should be provided so that the effects of postulated piping failures are shown by the analyses and guidelines of Section B.3 to be acceptable. Additional protection may be provided by designing or testing essential systems and components to withstand the environmental effects associated with postulated piping failures.

DCD Tier 2, Section 3.6.1, states that the protection of the essential SSCs from the effect of postulated break is basically achieved by separation, physical barriers, or piping restraint protection.

DCD Tier 2, Section 3.6.1.1.1, discusses the criteria and analysis methodology for evaluating the effects of postulated pipe breaks in high-energy fluid systems. High-energy systems are analyzed for their dynamic and environmental effects. Dynamic effects include jet impingement and pipe whip, while the environmental effects include flooding, spray wetting, and increased temperature, pressure, and humidity inside the rooms affected by the postulated failure.

DCD Tier 2, Section 3.6.1, states that the applicant's while evaluating the postulated pipe failure and its mitigation, the applicant has also considered the direct consequence of the failure on the availability of systems and components that could be credited in the event mitigation (these consequences include, but not limited to, reactor trip, loss of offsite power, and/or single active component failures). Therefore, the staff finds that criteria (1) and (2), in BTP 3-3, Section B.3.b, are met with respect to these assumptions.

DCD Tier 2, Section 3.6.2.1.4.1.3.1, "High-Energy Piping," states that an assumed non-mechanistic longitudinal pipe break of one square foot cross-sectional area is postulated for the main steam and feedwater lines, as recommended in BTP 3-3. The staff finds this conforms to the criterion (1), contained in BTP 3-3, Section B.1.a, for these systems, and is therefore acceptable. As discussed above for GDC 2, the main steam and feedwater lines are not routed near the vicinity of the control room; therefore, the staff finds that the design meets criterion (2), contained in BTP 3-3, Section B.1.a.

DCD Tier 1, Table 2.3-3, lists high-energy and moderate-energy piping systems that are evaluated for the dynamic and environmental effects of piping failures. DCD Tier 2, Table 3.6.1-1, "High- and Moderate-Energy Fluid Systems," provides a list of systems that contain piping segments that meet the definition of high- or moderate-energy systems. In RAI 78-8021, Question 14.03.03-2 (ML15196A608), the staff identified an inconsistency in the naming of systems between DCD Tier 1, Table 2.3-3, and the systems identified in DCD Tier 1.

In its response to RAI 78-8021, Question 14.03.03-2 (ML15238B430), the applicant proposed changes to DCD Tier 1, Table 2.3-3, and the corresponding DCD Tier 1 and Tier 2 sections. The applicant's response propose to create 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. However, the staff identified that additional information was required, since two systems from DCD Tier 1, Table 2.3-3, that did not have a corresponding ITAAC requiring the reconciliation of the pipe rupture hazards analyses report. In RAI 372-8461, Question

03.06.01-1 (ML16022A218), the staff requested the applicant to create an ITAAC verifying the pipe rupture hazards analyses for the Auxiliary Steam System and the Compress Air System.

In its response to RAI 372-8461, Question 03.06.01-1 (ML16107A007), the applicant proposed to revise Tier 1, Sections 2.7.1.9 and 2.7.5.1, and to create Tables 2.7.1.9-1, and 2.7.5.1-1. The staff evaluated the proposed DCD markups and found them acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, the staff considers RAI 372-8461, Question 03.06.01-1, resolved and closed.

DCD Tier 2, Section 3.6.1, also discusses pipe leakage crack events involving high- and moderate-energy fluid systems for flooding. The evaluation of flooding effects is addressed in DCD Tier 2, Section 3.4, and the staff's evaluation of the flooding event is located in SER Section 3.4.

As stated in DCD Tier 2, pipe failures are evaluated based on circumferential or longitudinal pipe breaks, through-wall cracks, or leakage cracks. Breaks in high-energy lines are either circumferential breaks, where a through-wall crack extends around the entire circumference of the pipe, or longitudinal breaks (splits), where a through-wall crack runs parallel to the longitudinal axis of the pipe. Breaks in high-energy lines need an evaluation of jet discharge forces (thrust), evaluation of jet impingement, evaluation of the development of pipe whip hinges, and evaluation for the location of pipe whip restraints. These considerations, as well as the postulated break, through-wall crack, and leakage crack locations are described in DCD Tier 2, Section 3.6.2.

For postulated longitudinal or circumferential breaks in high-energy lines, pressurization loads on components and structures are also evaluated. The staff's evaluation of pressurization loading on structures is described in Section 3.8 of this report.

The staff reviewed the assumptions used in pipe failure evaluations, as described in DCD Tier 2, Section 3.6.1, and determined that the assumptions conform to the criteria contained in either BTP 3-3 or SRP Section 3.6.1; therefore, the staff finds the above criteria acceptable.

DCD Tier 2, Section 3.6.1, states that a combination of redundancy, separation, and piping restraint will be utilized such that the reactor can be safely shut down after a postulated piping failure. The staff also evaluated the methodology described in DCD Tier 2, Sections 3.6.1, and 3.6.2, as to how to conduct a pipe hazards analysis. The applicant has completed preliminary evaluation of the piping within the reactor containment building and the main steam valve house according to the graded approach of APR1400 piping design for the DC application (as described in DCD Tier 2 Section 14.3.3).

The staff conducted an audit of APR1400-E-N-NR-14004, "Summary Report of High-Energy Piping Rupture Analysis." As previously stated, the PRHA summary report is limited to piping within the reactor containment building and the main steam valve house. Therefore, the staff reviewed that summary report and several of the piping diagrams to assess how the applicant implements the methodologies for the protection of essential components inside containment. Based on this, the staff can conclude, with high level of confidence, that the applicant is able to apply this methodology to the protection of essential SSCs outside containment. Based on the information provided by the applicant, the staff did not identify any issues with the

implementation of the relevant approved methodology as described in DCD Tier 2, Section 3.6.1.

ITAAC

DCD Tier 1, Section 2.3, discusses piping systems and components, including the protection against the dynamic effects of piping rupture. However, the applicant did not include an ITAAC in this section to confirm the pipe rupture hazards analyses; instead, the applicant opted to create system-specific ITAACs to address the pipe rupture hazards analysis. In DCD Tier 1, Table 2.3-3, the applicant identified all the systems that contain portions of piping that meet the high- or moderate-energy definition.

The staff evaluated the proposed ITAAC to confirm the pipe rupture hazards analyses for the systems identified in DCD Tier 1, Table 2.3-3, and found them acceptable and that they meet the requirements of 10 CFR 52.47(b)(1). The staff also determined that no additional ITAAC is needed. A complete list of all APR1400 related ITAAC is provided in SER Section 14.3.

3.6.1.5 Combined License Information Items

The following table provides a list of the COL information items and descriptions (obtained from DCD Tier 2, Table 1.8-2), that are related to pipe break hazard analysis for site-specific high- and moderate-energy piping systems.

Table 3.6.1-1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.6(1)	The COL applicant is to identify the site-specific SSCs that are safety-related or required for safe shutdown that are located near high- and moderate-energy piping systems and that are susceptible to the consequences of piping failures.	3.6.1.3
COL 3.6(2)	The COL applicant is to provide a list of site-specific high- and moderate-energy piping systems including layout drawings and protection features and the failure modes and effects analysis for safe shutdown due to postulated high-energy line breaks.	3.6.1.3

The staff finds that no additional COL information item is needed to be included in DCD Tier 2, Table 1.8-2, in relation to pipe break hazard analysis.

3.6.1.6 Conclusion

Based on the discussion above, the staff concludes that the APR1400 design, as it relates to the protection of safety-related SSCs from the effects of piping failures outside containment, meets the guidelines of SRP Section 3.6.1 and, therefore, satisfies the requirements of GDC 2, and GDC 4, with respect to accommodating the effects of postulated pipe failure.

3.6.2 Determination of Pipe Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping

3.6.2.1 Introduction

The requirements in GDC 4 of Appendix A to 10 CFR Part 50, requires, in part, that structures, systems, and components (SSCs) important to safety be designed to accommodate the effects of postulated accidents, including protection against the dynamic effects of postulated pipe ruptures. Dynamic effects of postulated pipe ruptures include pipe whip and the jet impingement loads on proximate SSCs important to safety. Pipe whip is caused by the reactive thrust loads produced by the fluid jet exiting the break location. The objective of the staff's review of this section is to verify and to ensure that adequate protection has been provided such that the effects of the postulated pipe breaks do not adversely affect the functionality of SSCs relied upon for safe reactor shutdown and that the consequences of the postulated pipe rupture have been mitigated.

3.6.2.2 Summary of Application

To address compliance with GDC 4, requirements, the applicant describes the criteria and methods of analysis used in the APR1400 design to ensure the adequate protection against the effects of postulated pipe ruptures in the following sections of its DCD.

DCD Tier 1, Section 2.3, Table 2.3-2, "High and Moderate Energy Piping Systems," identifies the high and moderate energy piping systems which are evaluated for pipe rupture hazards analysis (PRHA). In addition, in its response to RAI 546-8782, Question 14.03.03-5 (ML17235B275), the applicant proposed a non-system-based PRHA ITAAC to DCD Tier 1, Table 2.3-3, "Pipe Rupture Hazard Protection ITAAC," to confirm the pertinent design commitment is met to ensure the protection against postulated pipe rupture effects. This PRHA ITAAC table including its associated staff's evaluation is addressed in SER Section 14.3.3.4.5.

DCD Tier 2, Section 3.6.2.1, "Criteria Used to Define Rupture Locations and Configurations," describes the criteria used to determine the locations of the postulated pipe breaks and cracks in high-energy and moderate-energy piping systems designed using either ASME BPV Code Class 1, 2, or 3, criteria, or ASME B31.1, "Power Piping," criteria. The discussion addresses the criteria used for the fluid system piping in containment penetration areas and in areas other than the containment penetrations for which leak-before-break (LBB), as described in SER Section 3.6.3, is not applicable. Furthermore, it describes the assumptions used in defining the postulated breaks and crack configurations including circumferential break, longitudinal break, and leakage crack. Moreover, it describes the information to be included in the pipe rupture analysis report (also referred as pipe break hazards analysis report).

DCD Tier 2, Section 3.6.2.2, "Guard Pipe Assembly Design Criteria," states that guard pipes are not used in all containment penetrations of high-energy piping. DCD Tier 2, Section 3.6.2.3, "Analytical Methods to Define Forcing Functions and Response Models," describes the applicant's analytical methods to define jet forcing functions and response models for piping systems for which LBB is not applicable. DCD Tier 2, Section 3.6.2.4, "Dynamic Analysis Methods to Verify Integrity and Operability," describes the design of pipe whip restraints and jet impingement on essential piping and components. DCD Tier 2, Section 3.6.2.5, "Implementation of Criteria Dealing with Special Features," refers to pipe whip restraint design

as described in DCD Tier 2, Section 3.6.2.4, and augmented volumetric inservice examination as described in DCD Tier 2, Section 3.6.2.1.4.1.3.1, "High Energy Piping," item (f).

DCD Tier 2, Section 3.6.4, "Combined License Information," specifies COL 3.6(1), and COL 3.6(2), related to performing pipe rupture analysis for the site-specific piping systems.

3.6.2.3 *Regulatory Basis*

The relevant requirements for the protection of SSCs against the effects of postulated pipe ruptures include the following:

- Compliance with GDC 4 requires that nuclear power plant 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. These SSCs are to be protected against the effects of pipe whip and discharging fluids resulting from pipe breaks.

Acceptance criteria adequate to meet the above regulatory requirements include:

- SRP Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," Revision 2, March 2007, which describes the acceptance criteria and procedures for the staff's review of protection against the effects of postulated pipe ruptures. SRP Section 3.6.2, also identifies review interfaces with other SRP sections including SRP Section 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment" and SRP Section 3.6.3, "Leak-Before-Break Evaluation Procedures."
- Branch Technical Position (BTP) 3-3, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," Revision 3, March 2007, which delineates the staff's guidance for protection against postulated piping ruptures in fluid systems outside the containment.
- BTP 3-4, "Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment," Revision 2, March 2007, which contains the staff's guidelines for defining postulated rupture locations in fluid system piping inside and outside the containment.

3.6.2.4 *Technical Evaluation*

The staff reviewed the applicant's proposed criteria and methodology used for the protection against the effects of postulated pipe ruptures in the APR1400 design for consistency with the NRC regulations and guidance specified under SER Section 3.6.2.3. The staff's review is discussed in the following sections.

3.6.2.4.1 *Criteria Used to Define Pipe Break and Crack Locations and Configurations*

In DCD Tier 2, Section 3.6.2.1, the applicant provides the criteria for defining the location and configuration of postulated breaks and leakage cracks for high-energy and moderate-energy fluid system piping system in containment penetration areas and in areas other than containment penetration as described below.

Postulated Rupture Locations for Fluid System Piping in Containment Penetration Areas

DCD Tier 2, Sections 3.6.1.1.1 and 3.6.1.1.2, “Moderate-Energy Piping Systems,” provide the respective definitions for high-energy piping systems and moderate-energy piping systems. DCD Tier 2, Section 3.6.1.1.2, states that fluid piping systems that qualify as, “high energy,” for only short operational periods are considered moderate-energy systems if the fraction of the time that the system operates within the pressure-temperature conditions specified for high-energy fluid systems is less than two percent of the total time the system operates. This determination is consistent with the staff’s guidance on defining the short operational period as described in BTP 3-4. A list of high- and moderate-energy fluid systems is provided in DCD Tier 2, Table 3.6-1. In its response to RAI 78 8021, Question 14.03.03-2 (ML15238B430), the applicant provided proposed changes to DCD Tier 2, Table 3.6-1, consistent with Tier 1 changes. The staff’s evaluation of the applicant’s criteria for defining high- and moderate-energy fluid systems as well as the associated list included in DCD Tier 2, Table 3.6-1, is within the scope of SRP Section 3.6.1, and is described in SER Section 3.6.1.4.

DCD Tier 2, Section 3.6.2.1.4.1.3, “Fluid System piping in Containment Penetration Areas” provides criteria for postulated pipe break and crack locations for high-energy and moderate-energy piping in containment penetration areas. DCD Tier 2, Section 3.6.2.1.4.1.3.1, “High-Energy Piping,” provides criteria for the postulated pipe break and crack locations for high-energy piping in containment penetration areas (known as the break exclusion area). DCD Tier 2, Section 3.6.2.1.4.1.3.2, “Moderate-Energy Piping,” provides criteria for the postulated pipe crack locations for moderate-energy piping in containment penetration areas.

For high-energy piping, the applicant indicates that there is no ASME BPV Code Class 1, piping in containment penetration areas. The applicant further indicates that breaks and cracks are not postulated between the containment penetration wall and auxiliary building anchor wall beyond the isolation valves in ASME BPV Code Class 2, piping. In this region, the applicant follows the six additional design criteria given in DCD Tier 2, Section 3.6.2.1.4.1.3.1, paragraphs (a) through (f), related to design stress limits, criteria for welded attachments, piping welds, and augmented volumetric inservice examinations of welds. For moderate-energy piping, the applicant states that through-wall cracks are not postulated in those portions of piping from the containment wall to and including the inboard or outboard isolation valves provided that they meet the requirements of ASME BPV Code Section III, paragraph NE-1120, and the stresses calculated by the sum of Equations (9) and (10) of the ASME BPV Code Section III, paragraph NC-3653, do not exceed 0.4 times the sum of the stress limits given in ASME BPV Code, Section III, paragraph NC-3653.

Based on its review of the applicant’s criteria as described in DCD Tier 2, Sections 3.6.2.1.4.1.3.1, and 3.6.2.1.4.1.3.2, the staff determined that with the following exceptions, the applicant’s criteria for postulating pipe rupture locations for fluid system piping in containment penetration areas are consistent with the pertinent Staff guidelines as delineated in BTP 3-4, Part B, Item A(ii).

DCD Tier 2, Section 3.6.2.1.4.1.3.2, states that cracks are not postulated in moderate-energy ASME BPV Code Class 2, piping from the containment wall to and including the inboard or outboard isolation valves. This statement is consistent with the staff’s guidance as described in BTP 3-4 Part B, Subsection A(ii). However, the break exclusion area for high-energy ASME BPV Code Class 2, piping described in DCD Tier 2, Section 3.6.2.1.4.3.1, is between the

containment penetration wall and auxiliary building anchor wall beyond isolation valves. The descriptions of the break and crack exclusion area for which pipe ruptures are not postulated are inconsistent between these two DCD Tier 2 sections. Furthermore, the staff found that the design requirements for the high-energy piping in the break exclusion area as described in DCD Tier 2, Subsection 3.6.2.1.4.1.3.1, paragraphs (a) through (f), are consistent with the additional design provisions delineated in BTP 3-4, Part B, Item A(ii)(1) through Item A(ii)(7). Initially, however, this list did not address whether the design of the high-energy piping in the break exclusion areas meets the requirements of the ASME BPV Code Section III, paragraph NE-1120. The staff noted that in DCD Tier 2, section 3.6.2.1.4.1.3.2, the applicant states that the design of the portion of moderate-energy piping in containment penetration areas meets the requirements of the ASME BPV Code Section III, paragraph NE-1120, which is consistent with the staff's guidance as described in BTP 3-4 Part B, Item A(ii).

At a public meeting on June 30, 2015, the staff requested the applicant clarify the above inconsistencies in the criteria used for determining the break and crack exclusion area for high-energy and moderate-energy piping and to justify the departure, if any, from the staff's guidance as described in BTP 3-4, Part B, Item A(ii). In addition, the staff requested the applicant to clarify whether the design of the high-energy piping in the break exclusion areas meets the requirements of the ASME BPV Code Section III, paragraph NE-1120. If not, the applicant should justify the departure from the staff's guidance as described in BTP 3-4, Part B, Item A(ii).

In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to these two issues including a markup of DCD Tier 2, Section 3.6.2.1.4.1.3.1. The DCD markup also provides a list of portions of system piping for which the break exclusion area expands to the auxiliary building anchor wall beyond the isolation valve. Subsequently, the staff has verified that DCD Revision, has incorporated these changes.

Based on its review of the information provided by the applicant, the staff determined that the high-energy piping in the break exclusion areas is designed to meet the requirements of the ASME BPV Code Section III, paragraph NE-1120, and the applicant's design requirements for system piping within the break exclusion area as described in the DCD Tier 2, Section 3.6.2.1.4.1.3.1, are consistent with the staff's guidance as described in BTP 3-4, Part B, Item A(ii).

However, the staff also determined that the DCD Tier 2, Section 3.6.2.1.4.1.3.1, primarily addresses the applicant's design requirements for system piping within the break exclusion area. It should be noted that the staff's guidance as delineated in BTP 3-4 is intended to present a means of compliance with the requirements of GDC 4 for the design of nuclear power plant SSCs. This approach uses available piping design information to postulate pipe ruptures at locations having relatively higher potential for failure, such that an adequate level of protection may be achieved. For the fluid system piping in containment penetration areas, the staff's guidance as described in BTP 3-4, Part B, Item A(ii), provides certain design provisions to ensure an extremely low probability of pipe failure in these areas and allows breaks and cracks to be excluded from the design basis for those portions of piping.

To support the staff's safety determination on the acceptability of expanding the break exclusion area to the auxiliary building anchor wall beyond the isolation valve, the staff needed additional information from the applicant to justify the departure from the staff's guidance as described in BTP 3-4, Part B, Subsection A(ii), particularly how the DCD break exclusion area design

provisions are considered and applied to the results of the design of these listed portions of system piping. Therefore, the staff issued RAI 166-8198, Question 03.06.02-3 (ML15006A042), requesting the applicant to provide the following information related to the additional design provisions for the break exclusion area in BTP 3-4:

- A summary of pressure and temperature conditions during normal plant conditions (either in operation or maintained pressurized) including their respective operational period, supporting the applicant's categorization of these portions of system piping as high or moderate energy.
- A figure for the general geometric configuration including the approximate length and any bends in the piping for those portions of system piping in the break exclusion area. The figure should include the inboard isolation valve, outboard isolation valve, and Main Steam Valve House anchor wall and the respective system piping for which breaks are not to be postulated.
- Based on the figure presented in item (2) above, a discussion of how piping bends, circumferential and longitudinal welds, and overall length were minimized to reduce piping stress and the size of the break exclusion area.
- A description of access provisions made to permit inservice volumetric examination (as delineated in item f of DCD Tier 2, Section 3.6.2.1.4.1.3.1) of welds described in item (3), above.
- A discussion on whether the break exclusion only applies to the pertinent main piping (i.e., breaks are postulated for its associated branch piping, if any). If branch piping is included in the break exclusion area, then items (1) through (4), above should be addressed for these piping segments as well.
- A description of essential systems within the break exclusion area. DCD Tier 2, Section 3.6.2.1.4.1.3.1, states that essential equipment is not "concentrated" in the break exclusion zone. This statement is not clear and should be clarified.

In its response to RAI 166-8198, Question 03.06.02-3 (ML15364A586), the applicant provided additional information pertaining to the break exclusion criteria. In its revised response to RAI 166-8198, Question 03.06.02-3 (ML17271A450), the applicant provided its response related to its break exclusion criteria and the application of these criteria to the APR1400 plant design. In the revised RAI response, the applicant described the piping conditions for the portions of piping in the break exclusion area and their associated isometric figures. The applicant stated that when routing the piping, piping bends, circumferential welds and overall length are minimized to reduce piping stress and the size of the break exclusion area to the extent possible. In addition, the applicant stated that longitudinal welds are not used for any piping in the break exclusion area. Moreover, the applicant provided a tabulated, quantitative summary of the calculated maximum stress ranges as calculated by the sum of Equations (9) and (10) in paragraph NC-3653 with a comparison with $0.8(1.8 S_h + S_a)$ for each of piping segments analyzed in the graded approach for which the break exclusion criteria are applied. The applicant also stated that as part of the generic design effort, the applicant ensures that there is sufficient accessibility to perform the volumetric inservice examination of the pipe weld. Furthermore, the applicant stated that essential systems important to safety in the break

exclusion area are main steam, feedwater, and steam generator blowdown piping. A limited number of essential components are in the break exclusion zone that include the isolation valves in the piping systems, the main steam atmospheric dump valves and MSSVs. Other safety related equipment is installed outside the MSVH to avoid the concentration of components important to safety within the break exclusion area.

Based on the information provided by the applicant, the staff found that the applicant has provided sufficient information to explain how the DCD break exclusion area design provisions are considered and applied to the design of these listed portions of system piping in the break exclusion area. For the piping segments analyzed in the graded approach for which the break exclusion criteria are applied, the results of the tabulated, quantitative summary of the calculated maximum stress ranges are low compared to the relevant BTP 3-4, stress limit for postulating break locations. Accordingly, the staff determined that the applicant's response is acceptable because the applicant has adequately demonstrated its design provisions and specifying a 100 percent volumetric inservice examination meet the applicable BTP 3-4, break exclusion criteria in the NRC's guidelines and has appropriately justified the acceptability of expanding the break exclusion area to the auxiliary building anchor wall beyond the isolation valve. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 166-8198, Question 03.06.02-3, is resolved and closed.

Postulated Pipe Rupture Locations for Fluid System Piping in Areas Other Than Containment Penetration Areas

DCD Tier 2, Section 3.6.2.1.4.1.1, "Break Locations for High-Energy Fluid System Piping in Areas Other than Containment Penetration," provides the applicant's criteria for the postulated pipe break locations in high-energy piping systems in areas other than containment penetration areas. DCD Tier 2, Section 3.6.2.1.4.1.2, "Crack Locations," provides criteria for the postulated pipe crack locations for high-energy and moderate-energy piping systems in areas other than containment penetration areas. The containment penetration areas are addressed as described above in DCD Tier 2 Section 3.6.2.4.1, paragraph (1).

Based on its review of the applicant's criteria as described in DCD Tier 2, Sections 3.6.2.1.4.1.1, and 3.6.2.1.4.1.2, the staff determined that issues noted in the following paragraphs of this section needed to be resolved to support the staff's safety determination that the applicant's criteria for postulating pipe rupture locations for fluid system piping in areas other than containment penetration areas are consistent with the pertinent Staff guidelines as delineated in BTP 3-4, Part B, Item A(iii).

DCD Tier 2, Section 3.6.2.1.4.1.1, originally stated that a terminal end is defined as an extremity of a piping run that connects to structures, components, or pipe anchor that acts as a rigid constraint to piping motion and thermal expansion for Class 1 piping. However, it was not initially clear whether other piping geometric configurations (e.g., a branch connection to a main piping run) as identified in Footnote 3 of BTP 3-4 are also applicable to the APR1400 design and, therefore, should be considered as terminal ends for postulating pipe ruptures. In addition, it was not initially clear whether the same "terminal end" definition is also applicable to the piping systems (e.g., Class 2 piping) identified in other subsections throughout DCD Tier 2, Section 3.6.2.

At a public meeting on June 30, 2015, the staff discussed the above concerns with the applicant. In a letter dated July 17, 2015 (ML15198A561), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Section 3.6.2.1.4.1.1. The DCD markup clarifies that branch connections to main piping runs are considered as terminal ends, which conforms to the BTP 3-4, guideline. In addition, the DCD markup clarifies that the definition of "terminal end" is applicable to all Class 1, 2, and 3, APR1400 piping systems.

Based on its review of the information provided by the applicant, the staff determined that the DCD Tier 2, Section 3.6.2.1.4.1.1, markup related to the terminal ends for postulating pipe ruptures conforms to the guidance of Footnote 3 of BTP 3-4, and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

For non-seismically analyzed ASME B31.1, piping attached to seismic piping, the applicant states that the attached non-seismic piping up to the analyzed/unanalyzed boundary is designed not to cause a failure of the seismic piping during a seismic event. It should be noted that RG 1.29, Section C.3, provides the staff's guideline for the interface between seismic Category I, and non-seismic Category I, SSCs. Specifically, it states that at the interface between seismic Category I, and non-seismic Category I SSCs, the seismic Category I, dynamic analysis requirements should be extended to either the first anchor point in the non-seismic system or a sufficient distance into the non-seismic Category I, system so that the seismic Category I, analysis remains valid.

At a public meeting on June 30, 2015, the staff requested the applicant describe how, "the analyzed/unanalyzed boundary," is determined for the APR1400 piping design. In a letter dated August 4, 2015 (ML15216A451), the applicant stated that the seismically analyzed/unanalyzed boundary is defined as the interface between the safety and non-safety piping and is usually designed with an anchor at that location. However, in instances where installation of an anchor is not feasible at that interface, then the seismic Category I, design is extended to the first anchor point. For example, the Main Steam Valve House wall is designed as an anchor wall and is the analyzed/unanalyzed boundary. The applicant also provided a markup of DCD Tier 2, Section 3.6.2.1.4.1.1, stating that for non-seismic piping attached to seismic piping, the attached non-seismic piping up to the analyzed/unanalyzed boundary is designed not to cause a failure of the seismic piping during a seismic event as described in DCD Tier 2, Section 3.12.3.7, "Non-Seismic/Seismic Interaction." It should be noted that DCD Tier 2, Section 3.12.3.7, provides the applicant's design criteria for protecting seismic Category I, piping systems from adverse interactions with a non-seismic Category I, piping system. Further discussion of this issue can be found in SER Section 3.12.

Based on its review of the information provided by the applicant, the staff determined that the interface between seismic Category I and non-seismic Category I piping as defined in the markup of DCD Tier 2, Section 3.6.2.1.4.1.1, is consistent with the staff's guidance provided in RG 1.29, Section C.3, and therefore provides reasonable assurance that the attached non-seismic piping up to the analysis boundary is designed to preclude causing failure of the seismic piping during a seismic event. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

BTP 3-4, Part B, Item A(iii)(4), states that if a structure separates a high-energy line from an essential component, the separating structure should be designed to withstand the

consequences of the pipe break in the high-energy line that produces the greatest effect at the structure, irrespective of the fact that the criteria identified in BTP 3-4, Part B, Items A (iii) (1), (2), and (3), might not lead to postulating a break at this location. However, APR1400 DCD did not initially discuss the structural design criteria for the separating structure of concern. At a public meeting on June 30, 2015, the staff discussed the above structural design issue for the separating structure with the applicant. Specifically, the applicant was requested to clarify whether the APR1400 design criteria for structures that separate high-energy lines from essential components are consistent with the staff's guideline described in BTP 3-4, Part B, Item A(iii)(4).

In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above structural design criteria issue for the structures that separate high-energy lines from essential components, including a markup of DCD Tier 2, Section 3.6.1.2.1.2. In its response, the applicant indicates that its design of the separating structure is in accordance with BTP 3-4, while the DCD markup states that structures separating a high-energy line from an essential component are designed to withstand the consequences of a pipe break including associated pipe whip, jet impingement, and sub-compartment pressurization.

Based on its review of the applicant's response and the DCD Tier 2, Section 3.6.1.2.1.2, markup, the staff determined that the applicant did not adequately address the above staff's concern related to the design criteria for structures that separate high-energy lines from essential components. Specifically, the DCD markup regarding the location of "a postulated break," was not clear and should be clarified. Therefore, the staff issued RAI 224-8267, Question 03.06.02-5 (ML15296A000), requesting that the applicant clarify whether its design criteria for the separation structure are consistent with the staff's guideline as delineated in BTP 3-4, Part B, Item A(iii)(4), such that the separating structure is designed to withstand the consequences of the pipe break in the high-energy line that produces the greatest effect at the structure, irrespective of the fact that the criteria identified in DCD Tier 2, Section 3.6.2.1.4.1.1, might not need such a break location to be postulated.

In its response to RAI 224-8267, Question 03.06.02-5 (ML15336B006), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Section 3.6.1.2.1.2, stating that structures separating a high-energy line from an essential component are designed to withstand the consequences of pipe break in high-energy line that produces the greatest effect at the structure. The applicant also stated that the DCD markup is to be consistent with staff's guideline as delineated in BTP 3-4, Part B, Item A(iii)(4).

Based on its review of the applicant's response and the DCD Tier 2, Section 3.6.1.2.1.2, markup, the staff determined that the proposed DCD change is consistent with the pertinent staff guidance as delineated in BTP 3-4, Part B, Item A(iii)(4), such that the separating structure is designed to withstand the consequences of the pipe break in the high-energy line that produces the greatest effect at the structure, irrespective of the fact that the criteria identified in DCD Tier 2, Section 3.6.2.1.4.1.1, might not need such a break location to be postulated. The applicant's response to RAI 224-8267, Question 03.06.02-5, is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 224-8267, Question 03.06.02-5, is resolved and closed.

BTP 3-4, Part B, Item A(iii)(5), states that safety-related equipment should be environmentally qualified in accordance with SRP Section 3.11. It further states that appropriate pipe breaks

and leakage cracks (whichever results in the most severe environment) are to be included in the design bases for environmental qualification of the safety-related electrical and mechanical equipment both inside and outside containment. At a public meeting on June 30, 2015, the applicant was requested to clarify whether its design basis criteria for environmental qualification of safety-related electrical and mechanical equipment both inside and outside containment are consistent with the staff's guidance as delineated in BTP 3-4, Part B, Item A(iii)(5). If not, justification for the departure should be provided.

In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above concern including a markup of DCD Tier 2, Section 3.6.2.1.4.2, stating that pipe breaks and cracks that result in the most severe environmental consequences are analyzed to determine the design conditions for environmental qualification of mechanical and electrical equipment as described in DCD Tier 2, Table 3.11-2.

Based on its review of the information provided by the applicant, the staff determined that the DCD Tier 2, Section 3.6.2.1.4.2, markup is consistent with the pertinent staff guidance delineated in BTP 3-4, Part B, Item A(iii)(5), and thereby provides reasonable assurance that appropriate pipe breaks and leakage cracks (whichever results in the most severe environment) are to be included in the design bases for environmental qualification of safety-related electrical and mechanical equipment both inside and outside containment and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

BTP 3-4, Part B, Item A(iv), states that in complex systems such as those containing arrangements of headers and parallel piping running between headers, the designer should identify and include all such piping within a designated run for the purposes of break postulation. At a public meeting on June 30, 2015, the staff discussed this issue with the applicant. The applicant was requested to clarify whether its criteria used for break postulation in complex systems is consistent with the above staff guidelines.

In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above staff's concern including a markup of DCD Tier 2, Section 3.6.2.1.4.1.1, stating that for the selection of break locations in complex piping systems, the postulated pipe break locations are selected in accordance with BTP 3-4, Part B, Item A(iv), such that all pipes are identified and considered for the selection of break locations. Based on its review of the information provided by the applicant, the staff determined that the DCD Tier 2, Section 3.6.2.1.4.1.1, markup is consistent with the pertinent staff guidance delineated in BTP 3-4, Part B, Item A(iv), and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

BTP 3-4, Part B, Item A(v)(1), and Item B (iii)(1)(b), provide staff guidelines for postulating leakage cracks in ASME BPV Code Section III, Class 1, high-energy and moderate-energy piping. Item (a) of DCD Tier 2, Section 3.6.2.1.4.1.2, provides the criterion used for determining the crack locations for ASME BPV Code Section III, Class 1, high-energy and moderate-energy piping. It stated that through-wall leakage cracks are not postulated at locations where, for ASME BPV Code Section III, Class 1, piping, the calculated value of "S," is less than 0.4 times the stress or usage limits. However, this DCD section did not initially define the value of "S." Furthermore, the statement of "0.4 times the stress or usage limits," was not initially clear. At a public meeting on June 30, 2015, the staff discussed the above through-wall leakage cracks

criteria issues with the applicant. In a letter dated July 17, 2015 (ML15198A561), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Section 3.6.2.1.4.1.2, stating that for all high-energy and moderate-energy Class 1, piping with a nominal diameter (D) greater than 2.54 cm (1 inch), through-wall cracks are not postulated at locations where calculated value of stress range by Equation (10) in ASME BPV Code Section III, Division 1, paragraph NB-3653, is less than 1.2 S (m).

Based on its review of the applicant's response and the DCD Tier 2, Section 3.6.2.1.4.1.2, markup, the staff determined that the markup is consistent with the pertinent Staff guidance for postulating leakage cracks in ASME BPV Code Section III, Class 1, high-energy and moderate-energy pipes as delineated in in BTP 3-4, Part B, Item A(v)(1), and Item B(iii)(1)(b), and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

BTP 3-4, Part B, Item A(v)(2), and Item B (iii)(1)(c), provide staff guidance for postulating leakage cracks in ASME BPV Code Section III, Class 2, and 3, high-energy and moderate-energy piping or seismically analyzed nonsafety-related high-energy and moderate-energy piping (referred to as ASME B31.1, piping because of its design standard). Item (b) of DCD Tier 2, Section 3.6.2.1.4.1.2, provides the criterion used for determining the crack locations in these piping systems. It stated that through-wall leakage cracks are not postulated at locations where, for ASME BPV Code Section III, Class 2, and 3, high-energy and moderate-energy piping or seismically analyzed ASME B31.1, high-energy and moderate-energy piping, the calculated value of S is less than 0.4 times the stress or usage limits. However, this DCD section did not initially define the value of "S." In addition, the statement of "0.4 times the stress or usage limits," was not initially clear. Furthermore, the applicant did not initially address the criteria used for determining the crack locations for non-seismically analyzed ASME B31.1, piping.

At a public meeting on June 30, 2015, the staff discussed the above issues with the applicant. In a letter dated July 17, 2015 (ML15198A561), the applicant provided its responses to the above concerns, including a markup of DCD Tier 2, Section 3.6.2.1.4.1.2, stating that for all ASME BPV Code Section III, Class 2 and 3 or seismically analyzed ASME B31.1, high-energy and moderate-energy piping with a nominal diameter greater than 2.54 cm (1 inch), through-wall cracks are not postulated at locations where calculated stress by the sum of Equations (9) and (10) in paragraphs NC-3653 or ND-3653 of the ASME BPV Code, Section III (as applicable), is less than 0.4 times the sum of the stress limits given in these paragraphs.

Based on its review of the applicant's response and the DCD Tier 2, Section 3.6.2.1.4.1.2, markup, the staff determined that the DCD Tier 2, Section 3.6.2.1.4.1.2, markup is consistent with the pertinent staff guideline for postulating leakage cracks in ASME Class 2, and 3, or seismically analyzed ASME B31.1, high-energy and moderate-energy pipes as delineated in in BTP 3-4, Part B, Item A(v)(2) and Item B(iii)(1)(c), and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In responding to the other aspect of the staff's concern regarding the criteria used for determining the crack locations for non-seismically analyzed ASME B31.1, piping, the applicant stated in the July 17, 2015, letter referenced above that through-wall cracks for non-seismically designed ASME B31.1 piping are assumed at the locations that result in severe environmental

conditions. The statement of “severe environmental conditions,” was not clear and needed to be clarified. The applicant did not provide any DCD markup associated with this statement. Nevertheless, the staff noted that as a part of the applicant’s response in the same letter to a staff concern related to postulated leakage cracks configurations, the applicant provided a markup of DCD Tier 2, Section 3.6.2.1.4.2, stating that for high energy and moderate-energy piping, through-wall cracks are postulated to be in those axial and circumferential locations that result in the most severe environmental consequences. Therefore, the staff issued RAI 224-8267, Question 03.06.02-4 (ML15296A000), requesting that the applicant clarify whether “the most severe environmental consequences,” also applies to non-seismically designed ASME B31.1 piping. In its response to RAI 224-8267, Question 03.06.02-4 (ML15336B006), the applicant clarified that this design commitment regarding, “the most severe environmental consequences,” also applies to non-seismically designed ASME B31.1 piping.

Based on its review of the applicant’s responses and the DCD markups, the staff determined that the planned DCD Tier 2, Section 3.6.2.1.4.2(b), markup is consistent with the pertinent staff guidance for postulating leakage cracks in high- and moderate-energy fluid system piping including non-seismically analyzed ASME B31.1, piping in areas other than containment penetration areas as delineated in BTP 3-4 Part B, Item A(v)(3) and Item B (iii)(2). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 224-8267, Question 03.06.02-4, is resolved and closed.

Furthermore, it should be noted that according to BTP 3-4, Part B, Item B(iii)(3), leakage cracks should be postulated in moderate-energy fluid system piping designed to non-seismic standards as necessary to satisfy Item B.3.d of BTP 3-3. This item states that the functional capability of essential systems and components should be maintained after a failure of piping not designed to seismic Category I standards, assuming a concurrent single active failure. The staff’s evaluation of the applicant’s criteria for postulating a failure of non-seismic moderate-energy piping with a concurrent single active failure is within the scope of SRP Section 3.6.1, and BTP 3-3, and is described in SER Section 3.6.1.4.

Postulated Breaks and Leakage Cracks Configurations

DCD Tier 2, Section 3.6.2.1.4.2, “Postulated Rupture Configurations,” provides criteria for postulated break and leakage crack configurations. It refers to DCD Tier 2, Section 3.6.2.1.4.1.1, for the criteria to define break types (i.e., circumferential breaks and longitudinal breaks) in high-energy fluid system piping. It also refers to DCD Tier 2, Section 3.6.2.1.4.1.2, for the criteria to define crack types in high- and moderate-energy fluid system piping. Furthermore, it describes the respective criteria for determining the postulated rupture configurations and sizes for circumferential breaks, longitudinal breaks, through-wall cracks, and leakage cracks. DCD Tier 2, Section 3.6.2.1.2, describes that a through-wall crack is assumed to be a circular orifice through the pipe wall of cross-sectional flow area equal to the product of half of the inside pipe diameter and half of the pipe wall thickness. It also describes that a “leakage crack,” as defined for APR1400, is assumed to be a crack through the pipe wall where the size of the crack and corresponding flow rate are determined by analysis and a leak detection system, as described in DCD Tier 2, Section 3.6.3. The staff noted that the leakage crack configuration described in DCD Tier 2, Section 3.6.2.1.2, is the same as that described in BTP 3-4, Part B, Item C(iii)(3).

Based on its review, the staff determined that with an exception described below, the criteria included in DCD Tier 2, Section 3.6.2.1.4.2, are consistent with the staff's guidelines as described in BTP 3-4, Part B, Items C(i), (ii), and (iii), related to types and configurations of breaks and leakage cracks in fluid system piping.

DCD Tier 2, Section 3.6.2.1.4.2(b), "Crack Configuration," originally stated that through-wall cracks are postulated at those axial locations specified in DCD Tier 2, Section 3.6.2.1.4.1.2. It further states that for high-energy piping, through-wall cracks are postulated in those circumferential locations that result in the most severe environmental consequences. However, it should be noted that, according to the staff's guidance as described in BTP 3-4, Part B, Item B(iii)(2), for moderate-energy fluid system piping, leakage cracks should be postulated at axial and circumferential locations that result in the most severe environmental consequences.

At a public meeting on June 30, 2015, the staff discussed the above issue with the applicant. In a letter dated July 17, 2015 (ML15198A561), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Section 3.6.2.1.4.2(b), stating that for high- and moderate-energy piping, through-wall cracks are postulated to be in those axial and circumferential locations that result in the most severe environmental consequences.

Based on its review of the applicant's response and the planned DCD markup, the staff determined that the planned DCD Tier 2, Section 3.6.2.1.4.2(b), markup is consistent with the pertinent staff guidance for postulating leakage cracks in moderate-energy fluid system piping in areas other than containment penetration areas as described in BTP 3-4, Part B, Item B (iii)(2), and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

3.6.2.4.2 Analysis Methods to Define Blowdown Forcing Functions and Response Models

DCD Tier 2, Subsection 3.6.2.3, "Analytical Methods to Define Forcing Functions and Response Models," provides the criteria for determining the dynamic force of the fluid jet discharge and the jet impingement effects. DCD Tier 2, Section 3.6.2.3.2.1.1, refers to the simplified methods described in American National Standards Institute/American Nuclear Society, (ANSI/ANS)-58.2-1988 (also referred to as ANS 58.2), "Design Bases for Protection of Light Water Nuclear Power Plant Against Effects of Postulated Pipe Rupture," for determining the dynamic force of the fluid jet discharge. DCD Tier 2, Section 3.6.2.3.2.1.2, describes the evaluation of jet impingement effects. It states that in determining jet impingement loads, it is assumed that the pipe blowdown force remains constant with distance and that the jet is expanded with a uniform half angle of 10 degrees. Based on its evaluation of the above information in light of issues raised with the potential non-conservatism of ANS 58.2 in SRP Section 3.6.2, the staff determined that the applicant's analytical method for determining the dynamic jet blowdown thrust force and the jet impingement effects was not initially acceptable. The details of the staff's evaluation of the applicant's subsequently revised methodology for the evaluation of dynamic effects resulting from postulated high-energy pipe rupture are addressed below.

DCD Tier 2, Section 3.6.1.2.1.2, "Barriers and Shields," states that where adequate protection does not exist due to separation, additional barriers, deflectors, or shields are provided as necessary to protect nearby essential SSCs. It further states that where barriers and structures are required to provide necessary protection, they are designed to withstand the effects of the

postulated pipe failure concurrent with an earthquake event. Moreover, DCD Tier 2, Section 3.6.2.3.2.2, “Method of Dynamic Analysis of Unrestricted Pipes” describes the applicant’s method of dynamic analysis of unrestricted pipes. It states that the impact energy of an unrestrained pipe into a barrier (e.g., a divisional wall) is governed by the vector component of its velocity at impact that is perpendicular to the barrier. The applicant’s analysis of the impact of small piping into building structures conservatively assumes that all of the impact energy is imparted to the barrier with no dissipation due to local crushing deformation of the pipe.

The staff determined that with the exceptions described below, the applicant’s design criteria for protective features (barriers, shields, and pipe whip restraints) are consistent with the staff’s guidance as delineated in SRP Section 3.6.2.III.2, related to the analyses of pipe motion caused by the dynamic effects of postulated pipe breaks and the analysis of the dynamic response of the piping and restraint system resulting from a postulated pipe rupture.

With respect to the method of dynamic analysis of unrestricted pipes, DCD Tier 2, Section 3.6.2.3.2.2, discusses the assessment of the impact of an unrestrained pipe on a barrier (e.g., a division wall). However, it does not address the impact of an unrestrained pipe on an adjacent pipe.

At a public meeting on June 30, 2015, the staff discussed the above issue with the applicant. In a letter dated July 17, 2015 (ML15198A561), the applicant provided its responses to the above concern including a markup of DCD Tier 2, Section 3.6.2.3.2.2. Specifically, the planned DCD markup provides additional information on the various assumptions made by the applicant if a detailed analysis is not performed to evaluate the response of an impacted pipe. If the impacted pipe is of smaller size than the whipping pipe, the impacted pipe is assumed to be failed at the point of initial contact. If the impacted pipe is of larger or equal size but with thinner wall thickness, the impacted pipe is assumed to develop a through-wall crack. If the impacted pipe has both nominal size and wall thickness larger than or equal to that of the whipping pipe, the pressure boundary integrity of the impacted pipe is assumed to be undamaged.

Based on its review of the applicant’s response and the planned DCD markup, the staff determined that the planned DCD Tier 2, Section 3.6.2.3.2.2, markup is consistent with the pertinent staff guideline for evaluating the effects of an unrestrained pipe on an adjacent pipe as described in SRP Section 3.6.2.III.2 and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

DCD Tier 2, Subsection 3.6.1.2.1.2, “Barriers and Shields,” states that where adequate protection does not exist due to separation, additional barriers, deflectors, or shields are provided as necessary to protect the nearby essential SSCs. It further states that where barriers and structures are required to provide necessary protection, they are designed to withstand the effects of the postulated pipe failure concurrent with an earthquake event. Moreover, DCD Tier 2, Section 3.6.1.1, states that protection of essential equipment is achieved primarily by separation of redundant safe shutdown systems and by separation of high-energy piping from safe shutdown systems. It further discusses the importance of protective features such as pipe whip restraints in providing reasonable assurance of safe shutdown capability following a postulated high-energy line break when protection of essential equipment cannot be achieved by redundancy and separation. However, the staff noted that the relevant DCD Tier 2

subsections including Section 3.2.1, do not clearly address the seismic classification, design code, and allowable stress associated with these protective features.

At a public meeting on June 30, 2015, the staff requested the applicant to provide information regarding the seismic classification, design code, and allowable stress for the protective devices (e.g., barriers, shields, and pipe whip restraints) used in the APR1400 design for protection against postulated pipe failures. In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Table 3.2-1. The applicant stated that the information regarding the seismic classification and design code for protective devices (barriers, shields, and pipe whip restraints) are described in the revised DCD Tier 2, Table 3.2-1. The concrete structures that function as barriers or shields are designed with the same design code and seismic category of the building in which they are located. Table 3.2-1, shows the code classification of those structures. The staff noted that pipe whip restraints are designated as seismic Category I, structures and are designed to the allowable stress specified in ANSI/American Institute of Steel Construction (AISC) N690-1994, as described in the markup of DCD Tier 2, Table 3.2 1.

Based on its review of the applicant's response and the planned DCD markup, the staff determined that the planned DCD Tier 2, Table 3.2-1 markup related to seismic classification, design code, and allowable stress associated with the barriers, shields, and pipe whip restraints conforms with the pertinent staff guidance as delineated in SRP Section 3.2.1, 3.8.4, and 3.8.3, and is therefore, acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

SRP Section 3.6.2.III.2.A, states that the loading condition (internal pressure, temperature, and inertial effects) of a pipe run or branch, prior to the postulated rupture, should be used in the evaluation for postulated breaks. For piping pressurized during operation at power, the initial condition should be the greater of the contained energy at hot standby or at 102 percent power. The staff noted that DCD did not initially provide the above information.

At a public meeting on June 30, 2015, the staff discussed the above issue with the applicant and requested the applicant to clarify whether its criteria for determining the initial condition of a piping system that is pressurized during operation at power is consistent with the staff's guidance as delineated in SRP Section 3.6.2.III.2.A. In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above concerns including a markup of DCD Tier 2, Section 3.6.2.3.2.1.1, stating that the initial conditions of piping pressurized during operation at power are the greater of the contained energy at 102 percent power or hot standby, which conforms to SRP Section 3.6.2.III.2.A. Based on its review of the applicant's response and the planned DCD markup, the staff determined that the markup of DCD Tier 2, Section 3.6.2.3.2.1.1, is consistent with the pertinent Staff guidance for determining the loading condition of a pipe, prior to the postulated pipe rupture and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Pipe Whip Restraints

DCD Tier 2, Subsection 3.6.2.4.1, "Pipe Whip Restraints," provides the information related to design configuration, material, method of dynamic analysis, design loads, and allowable stress for the pipe whip restraints. DCD Tier 2, Figure 3.6-1, shows a typical pipe whip restraint which

consists of energy-absorbing members, non-energy-absorbing members, structural attachments, and support structures. A clearance between a pipe whip restraint and pipe is usually provided for thermal expansion during normal operation. The applicant states that the design of pipe whip restraints is governed not only by the pipe break blowdown thrust, but also by functional requirements, deformation limitations, properties of whipping pipe, and the capacity of the support structure. If a break occurs, the pipe restraints or anchors nearest the postulated break location prevent unlimited movement of the pipe at the point of break. In the absence of analytical justification, a dynamic load factor of 2.0, is applied to account for dynamic nature of the piping thrust load.

The applicant further described the three methods originally used in analyzing the interaction effects between a whipping pipe and a pipe whip restraint including the energy balance method, lumped parameter method, and equivalent static method. The energy balance method is based on the principle of conservation of energy. The kinetic energy of the whipping pipe generated during the first quarter-cycle of movement is assumed to be converted into equivalent strain energy. For the lumped-parameter method, the lumped mass points are interconnected by springs to take into account inertia and stiffness properties of the system. For the equivalent static analysis model, a dynamic load factor of 2.0, and an amplification factor of 1.1, to account for the potential occurrence of pipe rebound upon impact on the restraint are considered in determining the design load of the pipe whip restraints.

Moreover, the applicant indicates that the strain of energy-absorbing members is limited to 50 percent of the minimum elongation specified by ASTM International (formerly the American Society for Testing and Materials). A 10-percent increase in yield strength is used to account for strain rate effect. The allowable stresses for non-energy-absorbing members, structure attachment, and support steel structure are specified in ANSI/AISC N690.

Based on its review of the information provided in DCD Tier 2, Section 3.6.2.4.1, the staff determined that with the exceptions described below, the applicant's design criteria for pipe whip restraints are consistent with the pertinent Staff guidance as delineated in SRP Section 3.6.2.III.2.A, and 3.6.2.III.2.B.

SRP Section 3.6.2.III.2.A, provides the staff's guidance for determining the allowable capacity of crushable material, such as honeycomb, used in pipe whip restraint systems. It states that the allowable capacity of crushable material should be limited to 80 percent of its rated energy dissipating capacity as determined by dynamic testing, at loading rate within 50 percent of the specified design loading rate. The staff noted that DCD did not initially provide information related to crushable materials.

At a public meeting on June 30, 2015, the staff requested the applicant to clarify whether the above staff guidance is applicable to the APR1400 pipe whip restraint system design. In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above question including a markup of DCD Tier 2, Section 3.6.2.4.1.1, stating that crushable honeycomb material is not used in pipe whip restraint systems. Based on its review of the applicant's response and the planned DCD markup, the staff determined that the markup of DCD Tier 2, Section 3.6.2.4.1.1, adequately clarifies that the above staff guidance is not applicable as crushable honeycomb material is not used in pipe whip restraint systems for APR1400 design and is therefore acceptable. Based on the review of the DCD, the staff has

confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

SRP Section 3.6.2.III.2.B(i) and (ii), provide the staff guidance for the dynamic analysis of postulated ruptured pipes and pipe whip restraint systems. For both the energy balance analysis model and the lumped parameter analysis model, the staff's guidance states that the maximum possible initial gap between the pipe whip restraint and the pipe should be used to account for the most adverse dynamic effects of pipe whip. The staff noted that DCD Tier 2, Section 3.6.2.4.1, "Pipe Whip Restraints," states that the pipe whip restraint is designed for the impact force induced by the maximum possible initial gap between the pipe whip restraint and the pipe. However, it was not initially clear whether this pipe whip design criterion was applicable for both the energy balance method and the lumped parameter method described in DCD Tier 2, Section 3.6.2.4.1.2, "Methods for the Dynamic Analysis of Pipe Whip."

At a public meeting on June 30, 2015, the staff discussed the above issue with the applicant. In its response (ML15216A451), the applicant provided a markup of DCD Tier 2, Section 3.6.2.4.1.2. In its response, the applicant stated that a clearance between a pipe whip restraint and pipe is provided for thermal movement of pipe during normal operation. This maximum possible initial gap is used in the pipe whip restraint dynamic analysis using the energy balance method. The applicant further stated that the lumped parameter method is no longer used in the dynamic analysis of pipe whip restraint systems for the APR1400 design. The staff noted that the planned DCD Tier 2, Section 3.6.2.4.1.2, markup was revised accordingly. Based on its review of the applicant's response, the staff determined that the applicant's criteria as described in the markup of DCD Tier 2, Section 3.6.2.4.1.2, are consistent with the pertinent staff's guidance delineated in SRP Section 3.6.2.III.2.B(i) and (ii), related to the dynamic analysis of pipe whip restraint system and are therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Dynamic Blast Wave and Jet Impingement Effects

In DCD Tier 2, Section 3.6.2.4.2, "Jet Impingement on Essential Piping and Components," the applicant refers to the ANS 58.2 methodology for evaluating jet impingement resulting from postulated high-energy piping. Prior to 2008, the ANS 58.2 methodology for jet modeling was commonly used by the nuclear industry for estimating jet plume geometries and impingement loads based on the fluid conditions internal and external to the piping. However, following interactions with the Advisory Committee on Reactor Safeguards (ACRS) on the jet models described in ANS 58.2, the staff determined that there were potential non-conservatisms in these models with respect to the assessment of dynamic blast wave and jet impingement effects. These potential non-conservatisms include the assessments of the jet plume expansion and zone of influence, distribution of the pressure within the jet plume, and jet dynamic loading including potential feedback amplification and resonance effects. In addition, initial blast waves are unaccounted for in the standard.

SRP Section 3.6.2, provides a high-level discussion of this issue and states that the staff will review analyses of the jet impingement forces on a case by case basis. Details of the potential non-conservatisms are further discussed in Appendix A to the mPower Design Specific Review Standard (DSRS), Section 3.6.2 (ML12230A013), which was recently updated and re-issued in a draft revision to SRP Section 3.6.2 (ML14230A035).

To address the potential non-conservatism in ANS 58.2, the applicant initially submitted a technical report, APR1400-E-N-NR-14003, "Evaluation Methodology of Jet Impingement Loads on SSCs," on October 6, 2015. Subsequently, in a letter dated November 1, 2017 (ML17305B346), the applicant submitted a technical report, APR1400-E-N-NR-17001, Revision 1, "APR1400 High Energy Line Break Jet Impingement," with alternative approaches to address the staff's concerns regarding the potential non-conservatism in ANS 58.2. The three open items related to RAI 359-8448, Questions 03.06.02-6, 03.06.02-7, and 03.06.02-8 (ML16011A246), identified in the earlier versions of SER Section 3.6.2, are related to the superseded APR1400-E-N-NR-14003, and have been closed. These questions are not applicable to APR1400-E-N-NR-17001, Revision 1, and are therefore, not addressed further in SER Section 3.6.2.

In APR1400-E-N-NR-17001, Revision 1, the applicant developed a design-specific approach to addressing jet impingement loads. In its revised response to RAI 41-7957, Question 03.06.02-2 (ML17296A493), the applicant provided its markup of DCD Tier 2, Sections 3.6.2.4.2 and 3.6.2.4.3, which provides a nonproprietary summary of the technical report. The staff's evaluations of the technical report and the DCD markup are described below.

Jet Impingement Loads

The applicant addressed the jet impingement loads in Section 3, of the technical report. The applicant's assessment considers jet impingement effects in the APR1400 for three possible HELB fluid conditions including a HELB yielding a single phase steam, a HELB yielding a two phase stem/water jet, and a HELB yielding a single phase liquid jet. The jet impingement effects for these three different fluid conditions are addressed through different methodologies that consider jet range, shape, and direction such that zone of influence (ZOI), jet blowdown pressure distribution within the jet plume and jet impingement force, including thrust coefficient.

For the single-phase liquid jets, the cross-sections of their ZOIs are the same as those of the postulated breaks themselves. The penetration distance for a liquid jet is assumed to extend infinitely until it impinges on a target. Because the distances from potential HELBs to nearby surfaces are relatively short, gravitational effects are not considered. A thrust coefficient of 2.0, is applied. The staff found the applicant's methodology as described acceptable because it is consistent with the applicable staff's guidance within SRP Section 3.6.2, for assessing the single phase liquid jet.

For two-phase jets, the jet expansion and penetration distance are analyzed according to the methodology in NUREG/CR-2913. The jet expansion is determined according to the numerical analyses documented in Chapter 2 and Appendix A of NUREG/CR-2913. The effects of the two-phase jets are analyzed up to the penetration distance specified of 10 L/D, which is supported by the experimental foundation of NUREG/CR-2913. The staff found the applicant's methodology as described acceptable because the NUREG/CR-2913 methodology is appropriate to be used for analyzing the two phase jets for the APR1400 plant design. The staff also noted that NUREG/CR-2913 methodology has been accepted by the staff for analyzing the two-phase jets in previous DCD applications.

For steam jets, the applicant performed axisymmetric computational fluid dynamics (CFD) analyses using the ANSYS CFX Version 17.0 code to determine the characteristics of free jets for three scenarios that are representative of the range of steam conditions and pipe diameters

in the APR1400. The CFD simulations represent the steady-state conditions, assuming the upstream source pressure and temperature remain constant/fixed. The resulting pressure distribution contours display a characteristic Mach disk, within which the pressure is essentially constant at the stagnation pressure at the postulated break exit plane. Outside of the Mach disk, the steam jet pressure drops off rapidly with distance beyond the Mach disk.

The applicant stated that the CFD analyses were used to determine a conservatively large ZOI that bounds any of the thermodynamic conditions for steam jets in the APR1400. Moreover, the initial spreading angle of the ZOI is broader than that in ANSI/ANS-58.2-1988 (i.e., the Modified Moody Model). The CFD simulation results for the three representative scenarios show that although the jet persists beyond a distance of 25 pipe diameters, the pressures farther out are localized and fairly low. In light of the limited distances between the postulated break locations and nearby potential targets inside the APR1400 plant, a penetration limit of 25 pipe diameters is considered to bound the range of impingement effects and is also consistent with the pertinent SRP Section 3.6.2, guideline for the consideration of steam jet penetration.

Furthermore, the applicant stated that the CFD analyses which bounds the thermodynamic conditions found in the APR1400 were used to determine a conservative static loading methodology to apply to targets inside the ZOI of the postulated breaks. The applicant stated that although steam jet pressure drops off rapidly with distance beyond the Mach disk, no credit is taken for this decrease as the jet expands and pressure decreases. Accordingly, the applicant conservatively assumes that any point within this Modified Moody steam jet zone is exposed to the jet impact pressure value of the jet stagnation pressure at the exit plane of the postulated break location. The applicant also noted that from conservation of energy, the applied impingement force is maximum at the break exit plane. In addition, for targets smaller than the jet ZOI, the force exerted on the target will be limited due to the smaller area of intersection between the target and the jet. Furthermore, the applicant stated that a thrust coefficient of 1.26, is applied for steam jets, which the staff concludes is consistent with guidance in the SRP Section 3.6.2.

Based on its review of the information described above, the staff determined that the applicant's methodology for determining jet pressure loading for the single phase steam jet is acceptable because the applicant's assumptions were reasonable and consistent with the pertinent guidance in the SRP Section 3.6.2. The staff also found that it is conservative for not taking credit of the jet pressure decrease as the jet expands within the ZOI such that any point within this Modified Moody steam jet zone is exposed to the jet impact pressure value of the jet stagnation pressure at the exit plane of the postulated break location.

Dynamic Jet Loads Amplification and Resonance

Appendix A of SRP Section 3.6.2, identifies a concern about a potential for jet load amplification associated with formation of unsteadiness in free jets, especially supersonic jets, which propagate in the shear layer to induce time-varying oscillatory loads on obstacles in the flow path. The concern is that synchronization of transient waves with the shear layer vortices emanating from the jet break can lead to significant amplification of the jet pressures and forces (a form of resonance). Should the dynamic response of the neighboring structure also synchronize with the jet loading time scales, further amplification of the loading can occur as the result of formation of a feedback loop. When the impingement surface is within 10 diameters of

the jet opening, and when resonance within the jet occurs, significant amplification of impingement loads might result.

The applicant addressed the effects of dynamic jet load amplification and resonance in Section 4, of the technical report. In its evaluation of potential occurrence of dynamic amplification and resonance in HELB jets for the APR1400 plant design, the applicant stated that the dynamic amplification and resonance phenomenon occurs in experiments where engineered nozzles discharge a single phase, high speed gas jet. The applicant also stated that for the effects to occur, the jet flow field must be susceptible to resonance such that the flow field must be capable of supporting a feedback loop between the impingement target to the jet exit. Also, a phase-lock must be established at the discharge shear layer between the outgoing and returning waves. In addition, the frequency of the jet must coincide with the natural frequency of and be capable of exciting the impinged target. Moreover, the applicant made a comparison of the behavior of high speed gas jets and the behavior HELB jets. The applicant discussed a number of ways that a HELB differs from the scenarios in which resonance have been reported in single phase gas jet experiments. In particular, the applicant referred to results of experiments documented in open literature by several researchers to discuss the thermodynamics of the jet fluid issuing from a HELB. The applicant explained how the process of expansion and condensation, resulting in phase changes, redistribute energy and showed that the HELB jet conditions are not consistent with those needed for dynamic amplification.

Furthermore, the applicant discussed multiple physical characteristics of APR1400 HELBs which prevent occurrence of a resonance. These include self-damping effects of a two-phase jet (which is not relevant to single-phase jets, where resonance has been seen), lack of perpendicular flat surfaces of sufficient size to establish a feedback loop, variation in jet discharge angle and distance that prevent establishing a stable feedback loop, and irregularities in the contours of the broken pipe end and the impingement target that distort the outgoing jet and spread out reflected acoustic energy. The applicant also described how the absence of HELB resonant effects described above was substantiated through a survey of experimental results. Accordingly, the applicant concluded that potential dynamic amplification and resonant induced pressure loading is not a concern for jet impingement upon SSCs of the APR1400.

Based on its review of the above information, the staff determined that the applicant's approach and the conclusion are technically justified and therefore are acceptable. Specifically, the applicant has demonstrated that the conditions needed to establish resonance and dynamic amplification, as identified in the open literature, will not be present for HELB's in the APR1400 and the potential dynamic amplification and resonance induced pressure loading is not a concern for jet impingement upon SSCs of the APR1400. Therefore, the staff found the applicant's evaluation and approach to address potential dynamic jet amplification and resonance acceptable because the applicant has demonstrated reasonable assurance that this phenomenon will not exist for HELB's at the APR1400 plant.

Blast Wave Effects

Appendix A of SRP Section 3.6.2, identifies a concern about the potential blast wave effects resulting from postulated HELB in nuclear power plant. It states that the first significant fluid load on surrounding SSCs due to a HELB would be induced by a blast wave. Although a spherically-expanding blast wave is reasonably approximated to be a short-duration transient

and analyzed independently of any subsequent jet formation, reflections and amplifications in enclosed areas of the plant may need to be evaluated.

The applicant addressed the blast wave (also referred as shock wave) effects in Section 5, "Blast Effects," of the technical report. In that section, the applicant discussed shock wave behavior, pressure imposed by shock waves and how they are conservatively modeled by the correlation methodology. The applicant also discussed their CFD modeling and the results that justified their methodology. In assessing the shock wave effects, the applicant surveyed numerous related open literature on the shock wave forming phenomena. However, the formation of a blast wave and its propagation are complex, interactive phenomena with limited data available to characterize the shock loads due to a HELB. The applicant stated that formation of a blast wave in a HELB is limited to locations that are initially superheated or saturated and not in portions of systems with subcooled liquids form.

The staff determined that the applicant's assertion is consistent with the March 31, 2010, letter (ML100570364) from J. Rowley, US NRC, to A. Nowinowski, Westinghouse Electric Company, "Nuclear Regulatory Commission Conclusions Regarding Pressurized Water Reactor Owners Group Response to Request for Additional Information dated January 25, 2010, Regarding Licensee Debris Generation Assumptions For GSI-191," which concluded that a blast wave would be insignificant for a sub-cooled liquid and was accepted by the staff. For the APR1400 HELB, the applicant performed CFD modeling for some of the most limiting steam line break locations which simulated various scenarios of APR1400 HELBs. To assess the general applicability of the CFD results and sensitivity to model inputs, the pipe dimensions, boundary conditions and initial conditions, and the computational domain representing the ambient were varied.

For those postulated steam line breaks, the CFD results showed a moderate pressure blast wave formed rapidly, propagated away from the postulated HELB location, and was subject to reflections that resulted in higher localized pressures at certain points on SSC surfaces. For each of the cases studied, the applicant considered the effects of plant-specific geometry on the peak reflected pressure on the target surface. The applicant stated that for a postulated HELB, the amount of energy that can participate in forming the shock wave is limited by the fluid that can be discharged before the shock initiates. In all cases studied, the shock wave pressure positive impulse was brief (a few milliseconds), which limits the impact upon SSCs in its path.

In Section 5.2, of the technical report, the applicant also described the specific steps to how the results from the APR1400-specific CFD analysis were used to develop a simplified methodology that can be applied to other HELB locations that have not been analyzed by CFD. The simplified methodology applies an experimentally-determined pressure versus distance relationship found in the referenced literature. The initial energy available to form the shock wave is conservatively determined. The methodology then applied geometric correction factors as discussed in Section 5.2.2, of the technical report to account for effects of plant geometry on the blast wave loading on the impacted SSCs. The geometric correction considers the effects of the specific geometry of the impacted SSCs as well as the effects of the proximity and shape of nearby reflecting surfaces on reflection and dissipation of the blast wave pressure to determine a conservative estimate of the surface pressure at a point on the surface of an SSC. The specific steps to implement the simplified methodology is summarized in Section 5.5, "Determining Shock Wave Loading of SCCs," of the technical report. In Section 5.6, "Conservatism in the Blast Effects Methodology," of the technical report, the applicant also

discussed the conservatisms of the assumptions (e.g., assuming constant exit pressure at the break location that adds considerable extra mass and energy to the domain, thereby, over-predicting the magnitude of the blast wave) used in its CFD modeling for determining the blast wave effects. In Section 5.7, “CFD Validation and Verification (V&V),” of the technical report, the applicant discussed the V&V activities that have been completed for the CFD software, ANSYS CFX 17.0. Specifically, the applicant described how the APR1400 CFD analysis approach was benchmarked against several experiments and analyses of similar conditions studied in the literatures to verify its suitability and how the potential impact of the mesh size and time step on convergence has been properly considered in its CFD analysis.

In Appendix B, “Sample Correlation Application,” of the technical report, the applicant applied the simplified methodology to several specific SSCs included in the 3D CFD models to verify that its use is appropriate. In Table B-2, “Comparison of Correlation Predictions to CFD Results,” in Appendix B of the technical report, the applicant provides a summary table of the comparison of the peak pressures resulting from correlation predictions to those of the 3D CFD model. The applicant also presented two examples using the simplified methodology to determine the peak blast wave pressure for cases unanalyzed by CFD.

Based on a comparison of the applicant’s methodology to the pertinent staff’s guidance within Appendix A of SRP Section 3.6.2, the staff determined that the applicant’s methodology for determining the blast wave effects on the impacted SSCs is technically justified and therefore, is acceptable. Specifically, the applicant has provided sufficient information to demonstrate the validity and the applicability of the test data and methodology contained in the referenced open literature to the APR1400 HELB fluid conditions and geometric configurations. In addition, the applicant’s CFD analysis includes numerous assumptions which are technically justified and conservative. Moreover, the CFD analysis was benchmarked against several experiments and analyses of similar conditions studied in the literatures to verify its suitability. The applicant has provided sufficient information to demonstrate that appropriate mesh size and time step have been properly considered to ensure the convergence in its CFD analysis. Furthermore, the results of the comparison of correlation predictions to the results from the 3D CFD model have demonstrated the simplified methodology is acceptable and conservative for determining the peak blast wave pressure for cases unanalyzed by CFD. Accordingly, the staff found the applicant’s methodology and approach to evaluate the blast wave effects acceptable because the applicant has adequately addressed the staff’s concern on the blast wave effects as identified in Appendix A of SRP Section 3.6.2.

3.6.2.4.3 *Pipe Rupture Analysis Report*

DCD Tier 2, Section 3.6.2.1.1, “General Requirements,” states that the effects of postulated high-energy and moderate-energy line failure are evaluated to ensure the plant can be shut down safely and maintained in cold safe shutdown when postulated pipe failure occurs. It further provides an outline of the pipe rupture analysis report including identification of the high-energy lines and their associated postulated break locations, identification of essential targets and their associated protection features, summary of sub-compartment pressure and temperature analysis resulting from a postulated one square foot break on the main steam and main feed lines within the pipe break exclusion zone, and the environmental analysis of the high-energy and moderate-energy piping systems.

The staff reviewed the outline of the pipe rupture analysis report as described in DCD Tier 2, Section 3.6.2.1.1, in comparison to the pertinent Staff guidance in SRP Section 3.6.2, and determined that with the exception related to the criteria for postulating crack locations, the applicant's pipe rupture analysis report will provide sufficient information to demonstrate the acceptability and adequacy of the applicant's pipe break hazard analysis for APR1400 design.

At a public meeting on June 30, 2015, the staff requested the applicant clarify whether the postulated crack locations for both high-energy lines and moderate-energy lines are to be identified in the pipe rupture analysis report. In a letter dated August 4, 2015 (ML15216A451), the applicant provided its responses to the above question including a markup of DCD Tier 2, Section 3.6.2.1.1, and Section 3.6.2.4.1.2. In its response, the applicant stated that crack locations for high- and moderate-energy piping will be identified in the pipe rupture hazard analysis report. The staff noted that the planned DCD Tier 2, Section 3.6.2.1.1, and Section 3.6.2.4.1.2, markups are revised accordingly. Based on its review of the information provided by the applicant, the staff determined that the outline of the pipe rupture analysis report as described in the above planned DCD markup should provide sufficient information to demonstrate the acceptability and adequacy of the applicant's pipe break hazard analysis for APR1400 design and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

From August 31, 2015, to September 9, 2015, the staff conducted an audit of the detailed APR1400 pipe rupture hazards analyses. A key document included in the audit was APR1400-E-N-NR-14004, "Summary Report of High-Energy Piping Rupture Analysis." In this report, the applicant indicated that scope of the report is limited to piping within the reactor containment building and the main steam valve house according to the graded approach of APR1400 piping design for the DC application (as described in Tier 2, Section 14.3.2.3, "ITAAC for Piping Systems and Components," of the DCD). Based on the information evaluated in the audit, the staff concluded that the supporting documents were prepared in accordance with the methodology and criteria described in the APR1400 DCD and are in conformance with the applicable SRP. However, it should be noted that the PRHA, at the time of the audit, presented preliminary results (e.g., the fatigue usage factor is not considered in determining intermediate break locations for ASME Class 1 piping). Also, assessment of the dynamic effects of jet impingement and blast waves was not yet complete at the time of the audit and was therefore excluded from this audit. As mentioned in SER Section 3.6.2.4.2, the applicant subsequently submitted APR1400-E-N-NR-17001, Revision 1, which describes the applicant's methodology/approach for assessing the dynamic effects of jet impingement and blast waves for the staff's review. The staff's review findings of this technical report are addressed in SER Section 3.6.2.4.2, above. In addition, in its response to RAI 41-7957, Question 03.06.02-2 (ML17296A493), the applicant provided its response based on Revision 2, to the PRHA summary report which updated the results of the PRHA analyses. The staff's review findings of this revised PRHA summary report are addressed below.

Inspections, Tests, Analyses, and Acceptance Criteria

DCD Tier 2, Section 14.3, discusses the bases, processes, and selection criteria used to develop Tier 1 information. It specifies a graded approach commensurate with the safety significance of the SSCs. DCD Tier 2, Section 14.3.2.3, specifically describes the use of a graded approach in completing APR1400 piping analysis and pipe rupture hazards analyses at

the design certification stage. It identifies the scope of the graded approach including ASME BPV Code Section III, Class 1, piping (RCS main loop, pressurizer surge line, direct vessel injection line, and shutdown cooling line) and Class 2, and 3, piping systems (main steam and main feedwater piping located inside containment).

The staff found the concept of employing a graded approach for the piping analysis and pipe rupture hazards analysis for the design certification application acceptable. The details the regulatory basis for the determination is described in SER Section 14.3.3. The level of detail of the piping design (including the pipe rupture analysis) review is to be commensurate with the importance of the safety function to be performed. The staff will evaluate information provided in the design certification application (e.g., summary information on the analysis approach and results, as well as methodology) to ensure that sufficient information is provided by the applicant to demonstrate that the APR1400 design is in compliance with the GDC 4, requirement such that SSCs important to safety are designed to accommodate and protected against the effects of postulated pipe failures.

DCD Tier 2, Section 3.6.2, primarily addresses the methodology for pipe rupture hazards analysis. To support a safety determination, the staff needed additional information on the approach to and results of analyses completed at the design certification stage. Therefore, the staff issued RAI 41-7957, Question 03.06.02-2 (ML15174A383), requesting that the applicant provide summary information on the PRHA methodology/analysis approach and results to demonstrate that the APR1400 design is in compliance with the GDC 4, requirement such that SSCs important to safety are designed to accommodate and protect against the effects of postulated pipe failures. In its revised responses to RAI 41-7957, Question 03.06.02-2 (ML17296A493), the applicant provided markups of Revision 1 to DCD Tier 2, Sections 3.6.1.1.1 and 3.6.2.1.1; Section 3.6.2.2, 3.6.2.3.2.1.1, 3.6.2.3.2.1.2, 3.6.2.4.2, 3.6.2.4.3, and 3.6.2.4.4; and Section 3.6.5, as well as DCD Tier 1, Table 1.9.2. In addition, the applicant proposed to add Table 3.6-8, "High-Energy Line and Break Location," and Table 3.6-9, "System-Specific High-Energy Line Break Protection" with their associated Figures 3.6-37 to 3.6-44 to the DCD Tier 2, Section 3.6.2. Moreover, the applicant provided an associated PRHA summary report, APR1400-E-N-NR-14004, Revision 2 (ML17317A335).

The PRHA summary report summarizes the methodologies/criteria used in determining the postulated break/crack locations for the portions of high- and moderate-energy piping systems based on the APR1400 graded approach of piping design for the design certification application. The PRHA summary report also summarizes the applicant's methodology for evaluating the pipe whipping effects as described in the APR1400 DCD.

In addition, the PRHA summary report refers to technical report, APR1400-E-N-NR-17001, Revision 1, for the methodologies/approach used for assessing the dynamic effects of jet impingement and blast wave loading resulting from postulated high-energy line breaks. The PRHA summary report presents the results of the applicant's PRHA analyses. In particular, in Appendix A of the PRHA summary report, the applicant provides the summary table for the high-energy line and break location which identifies the applicable portion of the high-energy piping, the break location and the basis for postulating the break (e.g., terminal end), and a reference to the respective high-energy line isometric drawing with the break locations identified.

In the system-specific high-energy line break protection table, the applicant presents the break location the type of each break (e.g., circumferential break), the break location isometric drawing figure number, and the essential targets impacted by the respective break as well as their associated protection methods. For the protection methods, protection devices such as pipe whip restraints to protect the effect of pipe whipping are to be employed. For certain postulated break locations, the applicant states that instead of installing a protection device, the impacted essential target is to be designed to accommodate the applicable dynamic effects (e.g., pipe whipping, jet impingement, or blast wave loading).

Based on its review of the above information, the staff found that the applicant's response to RAI 41-7957, Question 03.06.02-2, and its associated PRHA summary report acceptable because the report provides sufficient information to demonstrate that the PRHA are performed in accordance with the methodology and criteria described in the APR1400 DCD and are in conformance with the applicable SRP for which the staff found acceptable. In addition, the results presented in the PRHA summary report demonstrate that the APR1400 design is in compliance with the GDC 4 requirement such that SSCs important to safety are designed to accommodate and protected against the effects of postulated pipe failures. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 41-7957, Question 03.06.02-2, is resolved and closed.

It should be noted that in Section 4.6, "SubCompartment Pressurization," Section 5.1, "Flooding," and Section 5.2, "Pressure and Temperature for Environmental Qualification" of the PRHA summary report, the applicant also presents the methodology and the results of its subcompartment pressurization, flooding analysis, and pressure and temperature environmental qualification respectively. However, the review of those topics are not within the review scope of SRP Section 3.6.2, therefore their review are addressed in SER Sections 3.4.1, 3.11 and 6.2. As stated above, DCD Tier 2 Section 14.3.2.3, states that the scope of the graded approach for Class 2, and 3, piping includes main steam and main feed water piping located inside containment. However, it should be noted that in order to enable decoupling of postulated pipe break effects, the analyses for main steam and main feedwater lines should extend to the first anchor beyond the outboard isolation valve that designates a class break.

At a public meeting on April 14-15, 2015, the applicant indicated that the analyses would in fact be extended to this location. Therefore, the staff issued RAI 41-7957, Question 03.06.02-1 (ML15174A383), requesting the applicant to revise the DCD discussion for consistency with its previous presentation or justify the exclusion of this portion of main steam and main feedwater lines from the graded approach.

In its response to RAI 41-7957, Question 03.06.02-1 (ML16025A248), the applicant provided a markup of DCD Tier 2, Section 14.3.2.3. In its response and the DCD mark-up, the applicant clarified that the piping analyses and the pipe break hazards analyses for main steam and main feedwater lines outside containment are based on the graded approach and are extended to the first anchor beyond the outboard isolation valves in the main stem valve house.

Based on its review of the information provided by the applicant, the staff determined that the applicant's planned DCD markup clearly describes the scope of the graded approach for main steam and main feedwater piping outside containment and is consistent with its previous presentation at the April 14-15, 2015, meeting for which staff found to be acceptable. Based on

the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 41-7957, Question 03.06.02-1, is resolved and closed.

DCD Tier 2, Section 14.3.2.3, discusses the development of several as-built ITAAC. The DCD Tier 1 information related to protection against pipe rupture effects are included in numerous system-based sections and their associated ITAAC tables. The discussion of the staff's evaluation of these ITAAC and their associated issues is contained in SER Section 14.3.3.4.5.

3.6.2.5 Combined License Information Items

DCD Tier 2, Section 3.6.4, specifies action items for COL applicants related to pipe break hazard analysis for site-specific high- and moderate-energy piping systems, and are summarized below.

Table 3.6.1-2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.6(1)	The COL applicant is to identify the site-specific SSCs that are safety-related or required for safe shutdown that are located near high- and moderate-energy piping systems and that are susceptible to the consequences of piping failures.	3.6.1.3
COL 3.6(2)	The COL applicant is to provide a list of site-specific high- and moderate-energy piping systems including layout drawings and protection features and the failure modes and effects analysis for safe shutdown due to postulated high-energy line breaks.	3.6.1.3

As indicated in the above table, the applicant specifies that the COL applicant is to identify the site-specific SSCs that are safety-related or required for safe shutdown that are located near high- and moderate-energy piping systems and that are susceptible to the consequences of piping failures. In addition, the applicant specifies that the COL applicant is to provide a list of site-specific high- and moderate-energy piping systems including layout drawings and protection features and the failure modes and effects analysis for safe shutdown due to postulated high-energy line breaks.

The staff finds the COL information items as described in DCD Tier 2, Section 3.6.4, "Combined License Information," and Table 1.8-2, "Combined License Information Items," are sufficient for the evaluation of postulated pipe rupture effects for site-specific SSCs. Furthermore, the staff finds the above COL information item acceptable, as site-specific SSCs are unique to the COL applicant and the evaluation of the effects of postulated pipe ruptures should be addressed at the time of the COL application. The staff concluded that no additional COL information items were needed.

3.6.2.6 Conclusion

The staff concludes that the applicant postulated pipe ruptures appropriately, designed SSCs which are important to safety to accommodate and protect against the associated dynamic effects, and, therefore, meet the relevant requirements of GDC 4.

The applicant appropriately identified/postulated pipe rupture locations, and designed piping restraints and measures to deal with the subsequent dynamic effects of pipe-whip and jet impingement to provide adequate protection for the SSCs which are important to safety.

The applicant's proposed piping and restraint arrangement and applicable design considerations for high- and moderate-energy fluid systems inside and outside of containment, including the RCPB, provide adequate assurance that SSCs important to safety that are in close proximity to the postulated pipe rupture will be appropriately protected. The proposed design appropriately mitigates the consequences of pipe ruptures so that the reactor can be safely shut down and maintained in a safe shutdown condition in the event of a postulated rupture of a high- or moderate-energy piping system inside or outside of containment.

3.6.3 Leak-Before-Break Evaluation Procedures

3.6.3.1 Introduction

This section describes and evaluates the design provisions and basis for the use of leak-before-break (LBB) methods for the APR1400 as they relate to eliminating from the design basis the dynamic effects of pipe rupture for selected piping systems. The staff's review ensures that consideration has been given to piping failure mechanisms and degradation mechanisms that could adversely challenge the integrity of the piping. The details of the actual as built configuration will be evaluated by the staff to ensure consistency with the final bounding LBB analyses as part of its review of an applicant's combined license (COL) application and completion of associated inspections, tests, analyses, and acceptance criteria (ITAAC).

3.6.3.2 Summary of Application

DCD Tier 1: DCD Tier 1 Section 2.3 addresses the design description of piping, systems, and components, including requirements specific to LBB. For applicable high-energy piping, the APR1400 design performs an LBB evaluation so that the dynamic effects of pipe rupture can be eliminated. The descriptions of DCD Tier 1 Chapter 2 address LBB design requirements for the applicable systems.

DCD Tier 2: DCD Tier 2 Section 3.6.3 describes the LBB methods and procedures. In addition, this section describes how 10 CFR Part 50, Appendix A, GDC 4 is applied.

ITAAC: The inspections, tests, analyses, and acceptance criteria (ITAAC) associated with DCD Tier 2, Section 3.6.3 are given in DCD Tier 1, Tables 2.4.1-4 and 2.4.3-4.

3.6.3.2.1 Application of LBB, Design Criteria for LBB and Potential Failure Mechanisms for Piping

Consistent with SRP Section 3.6.3, the application of LBB is limited to high energy, American Society of Mechanical Engineers (ASME) Code Class 1 or 2 piping or the equivalent. Specific

design criteria must be established to ensure successful application of LBB methods. Also, the evaluation must demonstrate that specific potential failure mechanisms are not credible sources of potential pipe rupture. In DCD Tier 2, Sections 3.6.3.1 through 3.6.3.3, the applicant indicated the following:

- Section 3.6.3.1 addresses the piping systems to which LBB criteria are applied. The LBB method is applied to high energy systems with well-defined loading combinations including: reactor coolant loop (RCL) piping, (with the hot leg (HL) and cold leg (CL) evaluated separately), surge line (SL), direct vessel injection (DVI) line (main run inside containment), and shutdown cooling (SC) line (main run inside containment).
- Sections 3.6.3.4 and 3.6.3.5 address the design criteria for LBB. Specifically, the applicant includes a list of design features addressing: preservice inspection (PSI); vibration fatigue; material toughness; leak detection systems that meet the requirements of Regulatory Guide (RG) 1.45, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage," stresses within the piping evaluation diagrams (PED); verification of final as-built piping conditions (COL 3.6(3)); inservice Inspection (ISI) and testing of snubbers; evaluation of erosion, erosion/corrosion and erosion cavitation; and evaluation of adjacent structures and components designed for the SSE event to assure low probability of indirect piping failure.
- Section 3.6.3.4 addresses the evaluation of potential failure mechanisms for piping and other degradation sources to assure acceptability of the LBB criteria. The evaluation is based on the guidance in SRP Section 3.6.3 and includes a detailed evaluation of failure mechanisms and degradation sources that could challenge the integrity of the piping to ensure that failure by these mechanisms is not credible. The following failure mechanisms and degradation sources were evaluated: water hammer, creep damage, wall thinning induced by erosion/corrosion, stress corrosion cracking (SCC), fatigue, thermal aging, and other mechanisms. The other mechanisms evaluated included cleavage type failure susceptibility, failures of surrounding SSCs and damage from missiles.

3.6.3.2.2 *Analytical Methods and Criteria*

In DCD Tier 2 Section 3.6.3.5, the applicant addresses the methods and criteria used for LBB analysis and states that these are consistent with NUREG-1061, "Evaluation of Potential for Pipe Breaks," and SRP Section 3.6.3. The applicant stated that LBB PEDs are prepared for each applicable piping system. These diagrams provide the design guidelines for meeting the allowable standards for stress limits and LBB acceptance criteria. The maximum stresses in the piping must be on or below the PED to satisfy the LBB criteria. The applicant states that the LBB evaluation is based on the fracture mechanics of cracks and analysis of break mechanisms which compare the selected leakage cracks with critical crack sizes.

In DCD Tier 2 Section 3.6.3.2, the applicant states that the sizes of the postulated leakage flaws are sufficiently large so that leaks can be detected by a sufficient margin. A leak rate of 10 times the capability of the leak detection system is postulated for normal operating load combinations. The applicant also addresses the stability of the critical crack size and the

methods used to determine the critical crack size. The applicant states that the critical crack size is determined by adding maximum individual loads by absolute summation and that a margin of 1.0 on the load is used. The applicant also states that a margin of two applies to the margin between the critical flaw size and the leakage size flaw. These assumptions are consistent with the guidance in SRP Section 3.6.3. DCD Tier 2 Section 3.6.3.5 describes the leak detection capability and the leak detection methods in supporting LBB. The methods or indications used for detecting the reactor coolant leak are the RCS inventory monitoring, sump level and flow monitoring, and measurement of airborne radioactive particulates and gases. The RCS primary water inventory balance method is used to detect leakage rates of 1.89 L/min (0.5 gpm) or less. In SER Section 5.2.5, "RCPB Leakage Detection," the staff concluded that the APR1400 design conforms to the guidance in RG 1.45 for RCPB leakage detection and therefore, meets the requirements in GDC 30, "Quality of Reactor Coolant Pressure Boundary."

In DCD Tier 2 Section 3.6.3.5.2.3, the applicant describes the methodology and calculation steps used in developing the PEDs. The applicant stated that the Pipe Crack Evaluation Program (PICEP) software was used for the LBB analysis. The evaluation of piping and the LBB results are contained in DCD Tier 2, Figures 3.6-1 through Figure 3.6-36.

DCD Tier 2, Subsection 3.6.3.5.5 describes the data which is used to form the basis for developing the LBB PEDs and is summarized in DCD Tier 2, Tables 3.6-4 and 3.6-5.

3.6.3.3 *Regulatory Basis*

The staff reviewed the APR1400 DCD including Section 3.6.3, "LBB Evaluation Procedures," and the proposed inspection, test, analysis, and acceptance criteria (ITAAC) in DCD Tier 1 Section 2.3.1, in accordance with SRP Section 3.6.3, "Leak-Before-Break Evaluation Procedures." The applicant's LBB analysis is acceptable if it meets the regulatory requirements and guidance relevant to LBB and the safety function. These requirements provide the basis for the acceptance criteria in the staff's review and are summarized in the following paragraphs:

- Part 50 of 10 CFR, Appendix A, GDC 4, as it relates to the exclusion of dynamic effects of the pipe ruptures that are postulated in SRP Section 3.6.2. The design basis for the piping means those conditions specified in the FSAR, as amended, and which may include regulations in 10 CFR Part 50, applicable sections of the SRP, regulatory guides, and industry standards such as the ASME Code.
- LBB should only be applied to high energy, ASME Code Class 1 or 2 piping or the equivalent. Applications to other high energy piping will be considered based on an evaluation of the proposed design and ISI requirements as compared to ASME Code Class 1 and 2 requirements.
- Approval of the elimination of dynamic effects from postulated pipe ruptures is obtained individually for particular piping systems at specific nuclear power units. LBB is applicable only to an entire piping system or analyzable portion thereof. LBB cannot be applied to individual welded joints or other discrete locations. Analyzable portions are typically segments located between piping anchor points. When LBB technology is applied, all potential pipe rupture locations are examined. The examination is not limited to those postulated pipe rupture locations determined from SRP Section 3.6.2.

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

SRP acceptance criteria adequate to meet the relevant requirements of the NRC regulations identified above include:

- Compliance with GDC 4 requires that components 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 LOCA. Components important to safety should be protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids that may result from equipment failure or events and conditions outside the nuclear power unit. Meeting the requirements of GDC 4 provides assurance that SSCs important to safety will be protected from the dynamic effects of pipe rupture and capable of performing their intended safety function.
- LBB analyses should demonstrate that the probability of pipe rupture is extremely low under conditions consistent with the design basis for the piping. A deterministic evaluation of the piping system that demonstrates sufficient margins against failure, including verified design and fabrication and an adequate ISI program, can be assumed to satisfy the extremely low probability criterion.

Other LBB specific acceptance criteria and review procedures are listed in SRP Section 3.6.3.

3.6.3.4 *Technical Evaluation*

The staff focused its review on the LBB analyses and evaluations to be used for the APR1400 reactor. The staff used the applicable guidance and requirements found in SRP Section 3.6.3 to complete its review. The results and conclusions are provided below.

The staff examined the sections of the DCD which discussed and defined the LBB evaluation procedures and analyses to determine if the proposed methods are sufficiently comprehensive and complete to demonstrate compliance with the applicable regulations, requirements, standards, and guidance. The staff performed a consistency check to verify that the LBB requirements and commitments were consistent through the various sections of the DCD. COL applicants referencing the APR1400 design need to fully describe the site-specific piping system configuration. The as-built conditions must be verified to assure that the design methods used for LBB evaluations are consistent with the final as-built conditions, including material specifications, pipe geometry, support conditions and locations, and weights of components such as valves.

3.6.3.4.1 *Potential Piping Failure Mechanisms*

The staff reviewed the potential for failure from various degradation mechanisms that could occur over the service life of the candidate LBB piping systems. NUREG-1061, "Evaluation of Potential for Pipe Breaks," Volume 3, identifies limitations applicable for LBB application to piping systems. In addition, the staff assessed failure mechanisms relating to LBB application

including water hammer, creep damage, erosion, corrosion, fatigue, and deleterious effects of environmental conditions. Piping systems subject to failure from these mechanisms are not candidates for LBB, because the basic assumptions for LBB may be invalidated. As an example, corrosion and fatigue could result in flaws whose crack morphology may not be bounded by the postulated LBB through-wall flaw, and water hammer may result in dynamic loads that are not considered in the LBB analysis. The staff also evaluated indirect failure mechanisms for the design that could lead to pipe rupture. These include seismic events and system over-pressurizations due to accidents resulting from human error, fires, or flooding which cause electrical and mechanical control systems to malfunction. Missiles from equipment, damage from moving equipment, and failures of SSCs in close proximity to the piping are evaluated as well.

DCD Tier 2 Section 3.6.3.4, "Potential Failure Mechanisms," addresses all the degradation mechanisms identified above. Certain additional degradation mechanisms are also addressed by the applicant in DCD Tier 2, Section 3.6.3.4. These degradation mechanisms include SCC, thermal aging, and thermal stratification.

Erosion/Corrosion

The austenitic stainless steel material used to fabricate the RCL, SL, DVI line, and SC line is resistant to corrosion, and the applicant affirmed that the Electric Power Research Institute (EPRI) Guidelines for water chemistry will be implemented (see SER Sections 5.2.3 and 9.2.4). In addition, the applicant stated that additional wall thickness is specified to accommodate a limited amount of wall thinning without violating ASME Code requirements, the bulk fluid velocity is limited to prevent excessive erosion of the pipe wall, and the velocity guidelines may be increased on a case-by-case basis through the use of engineering evaluations that address the erosion/corrosion aspects and piping material selected in the design. Based on the information provided above, the staff finds the approach to minimize erosion/corrosion acceptable.

Water Hammer

In the DCD Tier 2 Section 3.6.3.4.2, the applicant addresses susceptibility to failure from water hammer for each of the piping systems being applied for LBB. For the RCL and the SL, the applicant stated there is a low potential for water hammer in the subcooled water solid portions of the RCS because the RCS are designed to preclude void formation. Safety valve discharge loads associated with the pressurizer have been identified and included in the component design basis as well.

For the DVI line, the applicant states that the most likely cause for water hammer is leaking check valves, allowing hot water to enter a low-pressure region and then flash into steam bubbles. The steam pocket formed would permit a steam pocket collapse type of water hammer to occur if it were suddenly pressurized by the addition of water to the low-pressure piping.

The applicant referenced NUREG/CR-2781, "Evaluation of Water Hammer Events in Light Water Reactor Plants," and NUREG/CR-2059, "Compilation of Data Concerning Known and Suspected Water Hammer Events in Nuclear Power Plants, CY 1969-May 1981," which identifies four water hammer events and database respectively involving the Safety Injection System (SIS). The applicant stated that EPRI NP-6766, "Water Hammer Prevention, Mitigation,

and Accumulation, Volume 1: Plant Water Hammer Experience,” research report on water hammer included these four events and two more related to the SIS. Five of these events occurred in piping upstream of the injection check valves due to steam pocket collapse, filling of a voided line, and one of an unknown cause. The sixth event occurred in the low head safety injection suction pump piping due to an unknown cause.

The applicant stated that the COL applicant is to provide the procedure for initial filling and venting to avoid the known causes for water hammer for each piping system designed for LBB (COL 3.6(4)). High-point vents provide for the proper venting of lines and pumps.

The applicant stated the further protection against water hammer is provided by monitoring the pressure in the injection line and flushing upon high pressure. Pressure indication and alarms are provided to alert the operator of an increase in pressure to 6.89 MPa (1000 psig) (from a normal pressure of approximately 4.27 MPa (620 psig)).

The applicant stated that normal valve operation, pump startup, and pump trip create negligible fluid transient loads for the DVI system, and therefore protect the DVI system from water hammer events. The sixth event, as reported in the EPRI document, is not a concern for the APR1400 because the SIS does not have a low-head safety injection pump.

The applicant stated that there is little potential for water hammer loading due to rapid valve opening or closing because there are no fast-acting valves in the SC line, and a steam bubble is unlikely to form in the line. Under normal power operation, the valves in the line are closed and the fluid in the line is at ambient temperature. Therefore, a low vapor pressure and steam bubble formation does not occur. During SC system operation, the system is open to the RCS and has the same vapor pressure as the RCS, which would be subcooled due to the hydrostatic head formed by the water and steam in the pressurizer. Therefore, steam bubble formation is precluded by the characteristics inherent to the system.

By letter dated July 2, 2015 (ML15183A403), the applicant provided supplemental information to clarify specific items regarding the evaluation of potential piping failure mechanisms that the staff had identified early in the DCD review. The supplemental information is provided below.

- Prevention of rapid valve motion:

Valve discharge loads associated with the pressurizer have been identified and included in the component design basis. There are no fast-acting valves in the DVI and SC piping systems. The stroke times of the valves on DVI and SC lines are approximately 30 to 80 seconds. Therefore, there is little potential to water hammer loading due to rapid valve movement as described in DCD Tier 2 Section 3.6.3.4.2.3.
- Proper-filling and venting of water-filled lines and components:

The reactor coolant gas vent system (RCGVS) is used to vent/discharge non-condensable gases and steam from the high points of the RCS. Non-condensable gases from the reactor vessel closure head and the pressurizer steam space will be vented during plant startup process to fill the RCS. For DVI and SC lines, high-point vents are designed to prevent water hammer by

providing proper venting capability of the lines. The COL applicant is to provide the appropriate procedure for initial filling and venting of the piping.

- Introduction of voids into water-filled lines and components:

Voids are vented appropriately during plant startup and the RCL is designed to operate at a pressure greater than the saturation pressure of the coolant. The RCS is operated at higher pressure than other connecting systems. Therefore, there is little potential of void introduction into the RCL piping and SL from the connecting systems. For DVI and SC lines, high-point vents are designed to prevent water hammer by providing proper venting of the lines. The cover gas of the SIT is initiated after the tanks are filled with water, so the possibility of gas intrusion into the water filled piping in the DVI line does not need to be assumed. The COL applicant is to provide the appropriate procedure for initial filling and venting of the piping.

- Introduction of steam or heated water that can flash into water filled lines:

The RCL is designed to operate at a pressure greater than the saturation pressure of the coolant and there is no valve in the loop. The RCS is operated at a higher pressure than other connecting systems. Therefore, there is little possibility of introduction of steam or heated water into the RCL piping and SL. For DVI lines, high temperature RCS leakage to cold DVI lines can be monitored by pressure indication and alarms installed downstream of the DVI check valve. Therefore, the main control room operator can take action to prevent potential water hammer due to check valve leakage and the probability of water hammer is not to be assumed. Under normal power operations, the valves in the lines are closed and the fluid in the lines is at ambient temperature. Thus, a low vapor pressure and steam bubble formation do not occur. During SC operation, the system is open to the RCS and has the same vapor pressure as the RCS, which would be subcooled due to the hydrostatic head formed by the water and steam in the pressurizer. Therefore, steam bubble formation is precluded by the characteristics inherent to the system.

- Introduction of water into steam filled lines or components:

The RCL is designed to operate at a pressure greater than the saturation pressure of the coolant. Therefore, there is little possibility of introduction into the RCL piping and SL and of water hammer occurrence. Because there are no steam filled lines or components in DVI/SC systems, this issue is not a cause of water hammer in the systems.

- Proper warm-up of steam-filled lines:

Because there are no steam filled lines in the APR1400 LBB applied piping, this issue is not a cause of water hammer in the systems.

- Proper drainage of steam-filled lines:

Because there are no steam filled lines in the APR1400 LBB applied piping, this issue is not a cause of water hammer in the systems.

- The effects of valve alignments on line conditions:

Because there are no steam filled lines in the APR1400 LBB applied piping, this issue is not a cause of water hammer in the systems.

Based upon the information provided above, the staff finds the approach to control failure of the LBB applied piping due to steam and water hammer events acceptable.

Creep

Creep and creep fatigue are not concerns for ferritic steel piping at operating temperatures below 370°C (700°F), and for austenitic stainless steel piping at operating temperatures below 425°C (800°F). The operating temperatures for the APR1400 design are below these limits and therefore, creep is not a concern for these piping systems.

Susceptibility to Failure from Corrosion

To prevent intergranular stress corrosion attack on austenitic stainless steel piping, fabrication and operation controls are implemented. Primary water chemistry is controlled to minimize contaminants, and the dissolved oxygen is at a level that would normally preclude intergranular SCC and transgranular SCC. Based on this information, the staff considers these pipes to have a very low level of susceptibility to failure from corrosion.

In DCD Tier 2 Section 3.6.3.4.4, the applicant states that according to EPRI MRP-111, "Resistance to Primary Water Stress Corrosion Cracking of Alloy 690, 52, and 152 in Pressurized Water Reactors," primary water stress corrosion cracking (PWSCC) in dissimilar metal Alloy 52/152 butt welds is unlikely. However, Alloy 52 welds are not completely immune to PWSCC. Contributing factors which could increase an Alloy 52 butt welds susceptibility to PWSCC include factors such as dilution effects in dissimilar metal welds, weld residual stresses, heat input which may be controlled by the implementation of specific welding process/parameters. By letter dated July 2, 2015 (ML15183A403), the applicant provided supplemental information to clarify specific items regarding fabrication processes to control SCC susceptibility that Staff had identified early in the DCD review.

The applicant stated that the following two sentences will be added to DCD Tier 2 Section 3.6.3.4.4:

Welding procedures and repair procedures will be qualified by the COL applicant to minimize tensile stresses on the internal diameters and dilution effects. Weld repairs that will be in contact with the fluid will be made such that there will be compressive stress conditions on the wetted surface.

In addition, the applicant stated that the following COL information item will be added to DCD Tier 2 Section 3.6.4 and Table 1.8-2:

COL 3.6(5) - The COL applicant is to provide the information on the as-welded and repair conditions of Alloy 52/52M/152 concerning the residual stress and dilution effects of welds.

Based on the information provided, the staff considers the measures and the proposed changes to the DCD to be acceptable. The staff confirmed that the additional information above was incorporated into the DCD.

Susceptibility to Fatigue Cracking

In DCD Tier 2 Section 3.6.3.4.7, the applicant addresses susceptibility to failure from fatigue cracking. The applicant states that the RCL, SL, DVI, and SC piping is designed to meet ASME Section III, Subsection NB fatigue criteria. The applicant further states that the design basis transients are identified in DCD Section 3.9.1 and included in the detailed stress analysis. Thermal stratification and turbulence penetrations are also considered in the detailed stress analysis.

By letter dated July 2, 2015 (ML15183A403), the applicant provided supplemental information to clarify specific items regarding controls that will be in place to address the potential for vibration-induced fatigue cracking or failure and to explain why vibrational fatigue is not an issue. The applicant stated that vibration-induced fatigue cracking within the RCL is primarily due to reactor coolant pump (RCP) operation. The RCP-induced vibrations are minimized by limiting pump shaft and frame vibrations during hot functional testing and operation. In addition, vibrations are tested during initial test programs as identified in DCD Tier 2 Section 3.9.2.1. During the operation, RCP vibration monitoring systems monitor the pump shaft and frame vibrations and alarms are provided to the operators in the Main Control Room. The applicant also stated that SIS and SC system piping qualified for LBB are not operated during Plant Full Power Operation Mode. Therefore, the implementation of these programs will control vibration or vibration fatigue problems of these piping systems. The staff confirmed that the additional information above was incorporated into the DCD.

Based on the information provided, the staff considers the measures and clarifications that will be implemented to minimize fatigue cracking susceptibility to be acceptable.

Susceptibility to Failure from Indirect Causes

In DCD Tier 2 Section 3.6.3.4.5, the applicant states that pipe degradation or failure from indirect causes such as fires, missiles, and component failure is prevented by designing, fabricating, and inspecting to criteria that provide reasonable assurance of a low probability of the event or its impact on safety-related structures.

By letter dated July 2, 2015 (ML15183A403), the applicant provided supplemental information to clarify specific items regarding a detailed description of the programs in place to prevent pipe degradation or failure from indirect causes. The staff confirmed that the following information was incorporated into the DCD:

- Seismic events: LBB applied piping are designated as seismic Category I and are described in DCD Tier 2 Section 3.2.

- System over-pressurization: Over-pressure protection of the RCS, primary side of auxiliary or emergency systems connected to the RCS, and secondary side of SG is described in DCD Tier 2 Section 5.2.2.
- Human Error: DCD Tier 2 Chapter 18 describes human factors engineering programs to support the operator and minimize the potential for operator errors.
- Fires: Fire prevention and protection are described in DCD Tier 2 Section 9.5.1.
- Flooding: DCD Tier 2 Section 3.4 addresses flooding and flood protection.
- Missiles: DCD Tier 2 Section 3.5 addresses missile protection.
- Damages from moving equipment: The containment polar crane is designed to maintain its integrity without dropping its load during an SSE. DCD Tier 2 Section 9.1.5 describes the overhead heavy load handling system.
- Failures of SSCs: The SSCs in close proximity to the LBB applied piping are safety-related and seismically designed and are addressed in DCD Tier 2 Section 3.2.

Based on the information provided above, the staff finds the programs in place to prevent pipe degradation or failure from indirect causes to be acceptable.

Thermal Aging

In DCD Tier 2 Section 3.6.3.4.8, the applicant addresses susceptibility to failure from thermal aging. The materials in the RCL are forged carbon steel and carbon steel weld metals and are not known to be subject to thermal aging. The SL, DVI, and SC piping is austenitic stainless steel and also has low susceptibility to thermal aging. The welds in the austenitic stainless steel piping are fabricated using the gas tungsten arc welding (GTAW) process, and the weld metals have low delta ferrite. A further description is provided in DCD Tier 2 Section 5.2.3.4.5. The staff finds the material used in the fabrication of these systems to be acceptable as they are not susceptible to thermal aging.

Susceptibility to Cleavage-Type Failure

DCD Tier 2 Section 3.6.3.4.6 addresses susceptibility to cleavage type failures. The applicant states that cleavage type failures are not generally a concern for the system operating temperatures and materials used for the RCL, SL, DVI, and SC piping. Reasonable assurance regarding prevention of brittle cleavage-type failure is provided by fracture toughness testing or ASME Section III, Appendix G analysis, and maintained during the full scope of system operation based on the pressure-temperature limit curve. Material tests (ASME Section III required toughness tests and J-Resistance (J-R) tests) show the materials for these systems are highly ductile and highly resistant to cleavage-type failures at operating temperatures.

The staff finds the applicant's description to prevent susceptibility to cleavage type failure to be acceptable.

Inspections

In DCD Tier 2 Section 3.6.3.4.9.2, the applicant discusses the PSI and ISI that will be applicable to the piping systems where the LBB methodology is applied. PSI and ISI will be in accordance with ASME Sections III and XI for ASME Class 1 and 2 piping. The applicant stated that 100 percent of all welds will undergo PSI.

In accordance with ASME Section XI, Division 1, Subarticle IWA-1500, and the requirements of 10 CFR 50.55a(g)(3)(i), biological shielding around the reactor coolant piping is designed to provide access to the circumferential and longitudinal welds for examination, as well as the transition piece-to-nozzle welds. The piping systems are provided with removable insulation in all the areas of all welds and adjacent base metal requiring examination. Volumetric examinations using the ultrasonic technique will be utilized.

Based on the information provided above, the staff concludes the inspection requirements are acceptable.

3.6.3.4.2 Leak-Before-Break Analysis

In DCD Tier 2 Section 3.6.3.5, the applicant states that the guidance for the methods and criteria to develop the PEDs is provided in SRP Section 3.6.3 and NUREG-1061, "Evaluation of Potential for Pipe Breaks," Volume 3. It is a regulatory requirement that LBB be applied to an entire piping system or an analyzable portion thereof, typically segments located between anchor points. A survey of the piping is performed to determine the locations that have the least favorable combination of stress and material properties for base metal, weldments, nozzles, and safe ends. The applicant stated that there are two major aspects to leak rate based on crack detection in addition to the crack opening size: leak detection capability and flow rate correlation for leakage through a crack.

Leak Detection System

In DCD Tier 2 Section 3.6.3.5.2.1, the applicant states that RG 1.45 recommends a leak detection system that is capable of detecting a leakage rate of 3.785 L/min (1.0 gpm) or less to the reactor containment. The leak detection capability for the APR1400 DCD is 1.89 L/min (0.5 gpm). Diverse measurement means are provided for leakage detection, including RCS inventory monitoring, sump level and flow monitoring, and measurement of airborne radioactive particulates and gases. The RCS primary water inventory balance method is used to detect leakage rates of 1.89 L/min (0.5 gpm) or less. DCD Tier 2 Section 5.2.5 provides additional information about the leak detection capability.

Inputs for Development of Piping Evaluation Diagram

The applicant stated that the leakage crack length for a required 18.9 L/min (5 gpm) flow depends upon the pipe loading, thermodynamic conditions, and assumed crack surface roughness conditions. The elastic-plastic estimation method of EPRI Report No. NP-1931, "An Engineering Approach for Elastic-Plastic Fracture Analysis," is used to find the crack opening displacement for a given loading. The PICEP program is used to calculate the flow for a given crack length and loading. Crack morphology parameters used for the PICEP program are shown in DCD Tier 2 Table 3.6-7. For the purpose of generating analysis data for PEDs, a plot of moment versus crack length for an 18.9 L/min (5 gpm) flow is made using PICEP. This is

done for each of the pipelines being evaluated for LBB. Each curve provides the relationship between normal operating loads (i.e., deadweight, thermal expansion, and pressure) and the crack length that gives an 18.9 L/min (5 gpm) flow.

At the interface between nozzle and SL, consideration of the nozzle requires an iterative procedure to find an appropriate crack length which leaks at 18.9 L/min (5 gpm) and employs both the finite element model used for the crack stability analysis and the PICEP program. Since the stiffness of the nozzle is included in the stability analysis, it is also included in the leakage calculation. The iterative procedure used for calculating crack length at the nozzle/pipe interface is as follows:

- a. Assume a crack in finite element model.
- b. Apply normal operating loads to finite element model and calculate the crack opening area.
- c. Using PICEP program with the same crack length, vary the applied moment until the crack opening area becomes the same area as calculated with the finite element model.
- d. If the calculated flow by PICEP program is greater than 18.9 L/min (5 gpm), the crack length is decreased and go to step "a." If the calculated flow is less than 18.9 L/min (5 gpm), stop.

The moment vs. crack length curves for the RCL, SL, DVI line, and SC line listed in DCD Tier 2 Section 3.6.3.1 are shown in DCD Tier 2 Figures 3.6-15 through 3.6-22. These curves are the crack lengths associated with the 18.9 L/min (5 gpm) flow.

The PEDs for the LBB analysis are described in DCD Tier 2 Section 3.6.3.5.5. The applicant states that the following data forming the basis for developing LBB PEDs are summarized in Table 3.6-4 and Table 3.6-5:

1. Pipe size (diameter and thickness)
2. Materials
3. Weld type
4. Material properties
5. Normal operating temperature
6. Normal operating pressure
7. Leak detection capability

DCD Tier 2 Section 3.6.3.5.5 appears to be fully consistent with the LBB evaluation procedures of the SRP Section 3.6.3. However, the staff was initially unable to review many details of how these procedures were implemented. An RAI was prepared to clarify details of the submittal and to request additional information to complete its review.

The staff issued RAI 237-8312, Question 03.06.03-1 (ML15282A002), requesting the applicant to re-evaluate the J-R data to derive a description which includes J_{Ic} . In its response, the applicant stated that the LBB evaluation for the APR1400 is performed using the PICEP code for calculating the leakage crack length pertaining to 5 gpm, and includes a margin of 10 times on the leakage detection capability of 0.5 gpm. The PICEP code uses the tensile properties of material to calculate the crack length, but it does not require the initiation fracture toughness, J_{Ic} , of materials. For this reason, the J_{Ic} data of the test materials for the APR1400 LBB evaluation was not produced. Based on the review of the response, the staff considers the applicant's response acceptable since it provided the necessary information and justification for not including the J_{Ic} ; therefore, this issues is resolved and closed.

In the same RAI, the staff requested the applicant to provide the specimen size (including specimen geometry and notch depth) data along with tabular J-delta (a) data. In its response, the applicant provided the specific specimen geometry of the J-R test as follows:

- Specimen configuration: ASTM standard specimen for fracture toughness test of 1T-CT.
- Specimen orientation: L-C orientation.
- Initial crack length: approximately 50 percent of the width of the specimen.
- Fatigue pre-crack is applied.
- Side-groove of 10 percent of the specimen width on both sides of the specimen.
- Test method: ASTM E1820.

The applicant provided the J-delta (a) data in a proprietary table. The J-delta (a) data for the SL of the APR1400 is the test data from Shin-kori 3&4 nuclear power plants, which were the first plants of the APR1400 type in Korea. The proprietary graph provided also contains test results of the SL materials including welds. Each curve of the graph is the lower bound curve for the test results for each of the parts. The lower bound curve (marked as "PED") in the graph was used in producing the PED for the SL of the APR1400.

The J-delta (a) used for the evaluation of the main loop piping of the APR1400 was provided in a proprietary table. The tabular J-delta (a) data is not the test data, but is fitted data which is used in producing the PED. Because there is sufficient margin in the LBB evaluation for the main loop piping, the J-R curve that is lower than the actual test data from the previous Korean plant was used. The graph provided in a proprietary submittal contains the test results of various Korean plants for the main loop piping materials, including welds. Each curve of the graph is the fitted lower bounding curve of the test results of the main loop piping for each Korean plant. The curve marked "APR1400 (DC)" in the graph envelops all curves previously used for the Korean plants and was used in producing the PED for the APR1400. Based on the review of the response, the staff considers the applicant's response acceptable because it provided the requested information; therefore, RAI 237-8312, Question 03.06.03-1 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-2 (ML15282A002), requesting the applicant to indicate whether the tabulated material properties were identified for room temperature or operating temperature while performing the LBB calculations. In its response to RAI 237-8312,

Question 03.06.03-2 (ML15335A584), the applicant stated that the tabulated materials properties used in the evaluation for LBB are for operating temperatures. Specifically, the material properties near the upper range of the normal operating temperature (600 °F) and at the plant hot standby temperature of 350 °F are used in the LBB evaluation for the APR1400 RCS piping and SL. The staff considers the applicant's response to the RAI acceptable because the applicant is using operating temperatures in its LBB calculations; therefore, RAI 237-8312, Question 03.06.03-2 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-3 (ML15282A002), the staff requested the applicant to provide additional details to show how the Ramberg-Osgood parameters were calculated while performing the LBB calculations. In its response to RAI 237-8312, Question 03.06.03-3 (ML15335A584), the applicant identified that the tensile properties in the form of Ramberg-Osgood parameters were used in calculating leakage crack length at a leak rate of 5 gpm. The applicant also provided the Ramberg-Osgood equation used. The applicant then provided a proprietary methodology that was used to construct the LBB PED. The staff considers the response acceptable because the applicant provided additional detail on how the Ramberg-Osgood parameters were calculated; therefore, RAI 237-8312, Question 03.06.03-3 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-4, (ML15282A002), requesting the applicant to confirm that the crack face pressure was also included for the calculation of effective bending moment. In its response to RAI 237-8312, Question 03.06.03-4 (ML15335A584), the applicant stated that the loadings applied to each line are described in DCD Tier 2 Section 3.6.3.5.4.2. The internal pressure appropriate to the normal operating (NO) conditions of each piping system is applied to the inner surface of the pipe. Half of the internal pressure is applied to the crack face to take into account the pressure drop across the crack.

In the same RAI, the staff requested the applicant to provide values for the applied bending moment, axial and all other forces applied in the Finite Element Analysis (FEM) in order to support the staff's independent evaluation. In its response, the applicant stated the LBB PED is prepared prior to the piping design and analysis and is used to evaluate critical points in the piping. The PED is constructed to allow the maximum design load to be plotted versus the NO load. The LBB piping evaluation diagram requires performing two complete LBB evaluations. The evaluations are for two NO loads that span the typical loadings for the line under consideration. The loading applied to each line in the finite element model is described in DCD Tier 2 Section 3.6.3.5.4.2. The internal pressure appropriate to the NO conditions of each piping system is applied to the inner surface of the pipe. One-half the internal pressure is applied to the crack face to account for the pressure drop across the crack. An axial end load traction, (which when integrated over the pipe cross-sectional area, is equal to the continuity axial force), is applied to the far end of the pipe. Bending moments are applied as a linearly varying traction to the far end of the pipe. The pressure applied to each piping system is listed in DCD Tier 2 Table 3.6-5. The staff considers the response acceptable because the applicant provided the requested values; therefore, RAI 237-8312, Question 03.06.03-4, is resolved and closed.

After reviewing the data provided in the tables for the DVI piping system, the staff issued a follow-up RAI discussed below.

In RAI 525-8685, Question 03.06.03-8 (ML1625A005), the staff noted that in the response to RAI 237-8312, Question 03.06.03-4 (ML15282A002), the applicant provided a proprietary table of normal operating (NO) loads that were used to construct the LBB PED. The staff requested the applicant to identify the correct value because the tabulated value for the direct vessel injection (DVI) line, Group 2 NO load does not agree with the values of DCD Tier 2 Figure 3.6-35 of the APR1400 DCD. In its response, the applicant identified the correct values and updated the proprietary table. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 525-8685, Question 03.06.03-8 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-5 (ML15282A002), requesting the applicant to provide a plot of crack opening displacement (COD) versus crack size (c) for the target 5 gpm leak rate to support an evaluation of the parameters influencing the leak rate calculations. In its response to RAI 237-8312, Question 03.06.03-5 (ML15335A584), the applicant provided the proprietary plots of crack opening displacement versus crack size (c) for the target 5 gpm leak rate. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 237-8312, Question 03.06.03-5 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-6 (ML15282A002), requesting the applicant to provide the values used as inputs in the PICEP Code while performing the LBB calculations and, if possible, to provide the PICEP source code. In its response to RAI 237-8312, Question 03.06.03-6 (ML16096A156), the applicant provided the staff with the PICEP source code and the proprietary executable file and input file that was used to develop the PED curves. The staff considers the response to the RAI acceptable because the applicant provided the requested source code; therefore, RAI 237-8312, Question 03.06.03-6 is resolved and closed.

While reviewing the PICEP source code and the information and values, the staff was unable to confirm the SL calculations. The staff issued RAI 525-8685, Question 03.06.03-9 (ML16275A005) requesting the applicant to provide confirmation of the SL calculations. In this RAI, the staff noted that examination of the PICEP input file for the SL ("PICEP_SL.IN") shows that the input for a fluid temperature was 550 °F (287.8 °C). However, the APR1400 DCD states that the temperature should be 615 °F for the hot leg and 653 °F for the pressurizer end of the SL. In addition, PICEP.IN Card 7 gives the number of 45 degree turns/inch as 0.61 and the entry loss coefficient as zero. The SL pressurizer end and the hot leg end are the same pipe sizes and have the same NO1 loads for determining the leakage crack length but the 5 gpm leakage crack length for the high temperature pressurizer end is smaller than that for the lower temperature hot leg end (DCD Fig. 3.6.3-15 (HL) and 3.6.3-17 (PZR)). Therefore, the staff requested the applicant to confirm the input values and calculations in the DCD. In its response to RAI 525-8685, Question 03.06.03-9 (ML17333A369), the applicant provided the proprietary information. The staff performed its confirmatory analysis of the LBB PED and finds it to be satisfactory; therefore, RAI 525-8685, Question 03.06.03-9, is resolved and closed.

The staff issued RAI 525-8685, Question 03.06.03-10 (ML16275A005), requesting the applicant to confirm the input values and calculations in the DCD because it could not confirm the calculations as shown in the PICEP input file for the Shutdown Cooling (SC) Group 3, as shown in DCD Tier 2 Figure 3.6.3-22. In its response to RAI 525-8685, Question 03.06.03-10 (ML17333A369), the applicant provided the PICEP input file calculations for SC Group 3. Based on the response, the staff performed confirmatory LBB analysis for the following lines: hot leg (HL), cold leg (CL), SL - HL interface (SL-HL), SL - intermediate pipe (SL-I), SL -

pressurizer interface (SL-PZR), direct vessel injection - 2 (DVI-2), and shutdown cooling - 3 (SC-3).

The applicant submitted stress-strain curves and material J-resistance (J-R) curves, as well as their calculated descriptions, for the materials under consideration. Two different stress-strain curves were submitted for the HL, CL, SL, DVI line and SC line, one of which the applicant used for leakage crack length calculation and the second for crack stability analysis. The staff digitized the stress-strain curve data points and performed an analysis of the Ramberg-Osgood coefficients. The applicant also submitted J-R curves and J-R analyses for the materials under consideration. The applicant's J-R analysis assumed an initiation J, J_{ic} , of zero. The staff digitized the $J \Delta a$ data points and performed an analysis of J_{ic} in accordance with ASTM E-1820-11, "Standard Test Method for Measurement of Fracture Toughness," then fit the data points above the 1.5 mm exclusion line to the equation $J = J_{ic} + C1(\Delta a)^{C2}$. The staff's Ramberg-Osgood and J-R values were used in the confirmatory analyses.

The staff's confirmatory analyses for the HL, CL, DVI-2, SL-I and SC-3 lines bounded the applicant's PED analyses. The evaluation of the SL-HL and SL-PZR interfaces considered three material properties for each interface: SL, dissimilar metal weld, and safe end. The staff's confirmatory analysis for both the SL-HL and SL-PZR interfaces bounded the applicant's PED analysis for each property material set.

Based on the proprietary information provided, the staff performed its confirmatory analysis of the LBB PED. The staff concludes that there is reasonable assurance the applicant's LBB analysis bounds the normal operation and normal operation + safe shutdown earthquake design conditions and finds the applicant's LBB analysis acceptable. Therefore, RAI 525-8685, Question 03.06.03-10 is resolved and closed.

The staff issued RAI 237-8312, Question 03.06.03-7 (ML15282A002), requesting the applicant to provide the parameter values used for the crack surface description; specifically, the cracking mechanism assumed, and where these values were obtained. In its response to RAI 237-8312, Question 03.06.03-7 (ML15335A584), the applicant stated that the crack morphology parameters are described in DCD Tier 2 Section 3.6.3.5.2.3. The parameters considered in calculating the leakage crack length were determined in accordance with NUREG-1061, Volume 3. The crack morphology required in NUREG-1061, Volume 3, considers surface roughness, while PICEP considers surface roughness, number of 45 degree turns and entrance loss coefficient. The values were provided in a proprietary table. The values were validated and verified with testing when PICEP was developed. In addition, the applicant stated that air fatigue crack morphology is considered in the calculation for determining the leak rate.

The staff considers the response to the RAI acceptable because the parameter values used for the crack surface were provided; therefore, RAI 237-8312, Question 03.06.03-7 is resolved and closed.

3.6.3.5 Combined License Information Items

DCD Tier 2, Section 3.6.3, contains the following COL information items.

Table 3.6.3 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.6(1)	The COL applicant is to identify the site-specific SSCs that are safety related or required for safe shutdown that are located near high and moderate-energy piping systems and that are susceptible to the consequence of piping failures.	3.6.1.3
COL 3.6(2)	The COL applicant is to provide a list of site-specific high and moderate-energy piping systems including layout drawings and protection features and the failure modes and effects analysis for safe shutdown due to the postulated HELBs.	3.6.1.3
COL 3.6(3)	The COL applicant is to confirm that the bases for the LBB acceptance criteria are satisfied by the final as-built design and materials of the piping systems as site-specific evaluations, and is to provide the information including LBB evaluation report for the verification of LBB analyses.	3.6.3
COL 3.6(4)	The COL applicant is to provide the procedure for initial filling and venting to avoid the known causes for water hammer in each piping system designed for LBB.	3.6.3.4.2
COL 3.6(5)	The COL applicant is to provide the information on welding Alloy 52/52M/152 concerning the residual stress and dilution effects of welds.	3.6.3.4.4

3.6.3.6 Conclusion

On the basis of its review, the staff concludes that the APR1400 LBB evaluation procedures and methods in the APR1400 DCD with the COL action items, are acceptable, and comply with the acceptance criteria in SRP Section 3.6.3.

Compliance with the criteria in Section 3.6.3 of the SRP constitutes an acceptable basis for satisfying the LBB requirements of 10 CFR Part 50, Appendix A, GDC 4, and applicable requirements and acceptance criteria. Therefore, the dynamic effects of pipe rupture for the applicable piping may be eliminated from design consideration. The provisions for LBB were based on sound engineering principles as well as operating experience at nuclear power plants and are based on the following:

- That water hammer, corrosion, creep, fatigue, erosion, environmental conditions, and indirect sources are remote causes of pipe rupture.
- That deterministic fracture mechanics evaluation method has been completed and approved by the staff.

- That leak detection systems are sufficiently reliable, redundant, diverse, and sensitive, and that margin exists to detect the through wall flaw used in the deterministic fracture mechanics evaluation.

The staff reviewed and finds the COL information items related to the LBB method acceptable. The staff will review the plant-specific aspects of LBB methodology for COL applications referencing the APR1400 reactor certified design as part of the COL application review process. In addition, the staff has reviewed the ITAAC applicable to the LBB requirements and finds that the ITAAC meet the requirements of 10 CFR 52.47(b)(1) and are adequate to ensure that the indicated piping systems will meet the LBB acceptance criteria.

3.7 Seismic Design

3.7.1 Seismic Design Parameters

3.7.1.1 Introduction

APR1400 DCD Tier 2, Section 3.7.1, "Seismic Design Parameters," addresses the design earthquake ground motion used for the seismic analysis and design of seismic Category I structures of the APR1400 standard design. The design ground motion for the DCA is established as site-independent, smooth, postulated response spectra and will become the certified seismic design response spectra (CSDRS) when the staff certifies the standard design under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The staff considers two levels of design ground motion in this section of the SER: (1) operating-basis earthquake (OBE) and (2) SSE. The review of design ground motion also includes an assessment of the synthetic acceleration time histories that envelop the CSDRS. Other seismic design parameters reviewed in this section include the percentage of critical damping values for various nuclear safety-related SSCs and the supporting media for the seismic Category I structures.

The APR1400 DCD Tier 2 references draft Revision 4 of SRP Section 3.7.1, issued in December 2012. The staff's review of DCD Tier 2 Section 3.7, follows the guidance provided in the final version SRP Section 3.7.1, Revision 4, issued in December 2014. The staff recognizes that the NRC issued SRP Section 3.7.1, Revision 4, less than 6 months prior to the docket date of the APR1400 application in March 2015, and therefore, the applicant is not required under 10 CFR 52.47(a)(9) to evaluate its application against this revision. However, the principal difference between the draft and final versions of SRP Section 3.7.1, Revision 4, lies in the enhanced guidance on the assessment of power spectral density (PSD) functions of the synthetic acceleration time histories, which are used as seismic input motions to the analyses of the seismic Category I structures.

The staff reviewed DCD Tier 2 Section 3.7.1, and performed an independent analysis (see Section 3.7.1.4.1 below) based on SRP Section 3.7.1, Revision 4, to confirm the applicant's conclusion on the power sufficiency of its synthetic acceleration time histories.

3.7.1.2 Summary of Application

DCD Tier 1: The DCD Tier 1 information associated with this section is found in DCD Tier 1, Section 2.1, "Site Parameters," and DCD Tier 1, Section 2.2, "Structural and System Engineering."

DCD Tier 2: In DCD Tier 2, Section 3.7.1, the applicant provided information on the design ground motion, percentage of critical damping values, and supporting media. The associated seismic design parameters are used in the analyses of seismic Category I SSCs, which are covered by the review under SRP Section 3.7.2, “Seismic System Analysis,” and SRP Section 3.7.3, “Seismic Subsystem Analysis.” DCD Tier 2, Section 3.7.1 references Technical Report APR1400-E-S-NR-14001, Revision 1, “Seismic Design Bases,” dated February 2017 (ML17094A154), and incorporates by reference Technical Report APR1400-E-S-NR-14004, Revision 2, “Evaluation of Effects of HRHF Response Spectra on SSCs,” dated February 2017 (ML17094A116). DCD Tier 2, Appendix 3.7A, “Soil-Structure Interaction Analysis Methodology and Results,” and Appendix 3.7B, “Evaluation for High Frequency Seismic Input,” provide additional details on the seismic design parameters, as well as seismic analyses pertaining to the staff’s review under SRP Section 3.7.2.

DCD Tier 2 Section 3.7.1 indicates that seismic Category I SSCs are designed for the SSE, in accordance with GDC 2 of Appendix A to 10 CFR Part 50. The OBE for APR1400 is specified at one-third of the SSE, therefore, an explicit analysis and design of the seismic Category I SSCs against the OBE is not necessary, in accordance with Appendix S to 10 CFR Part 50.

DCD Tier 2 Section 3.7.1 describes the design response spectra of the site-independent SSE, that is, the CSDRS, and the corresponding design ground motion time histories that were developed to envelop the CSDRS. The APR1400 CSDRS are specified for 2-, 3-, 4-, 5-, 7-, and 10-percent damping values, as provided in DCD Tier 2 Table 3.7-1. The DCD Tier 2 Section 3.7.1 and APR1400-E-S-NR-14001, Revision 0, provide details on the establishment of the CSDRS and the development of the design acceleration time histories. The CSDRS, as shown in DCD Tier 2, Figures 3.7-1 and 3.7-2, for the horizontal and vertical directions are based on the design spectra in RG 1.60, “Design Response Spectra for Seismic Design of Nuclear Power Plants,” Revision 2, issued July 2014, with enrichment in the high frequency range.

DCD Tier 2 Section 3.7.1 incorporates by reference APR1400-E-S-NR-14004, Revision 1, which describes the hard rock, high frequency (HRHF) response spectra and the corresponding synthetic time histories. DCD Tier 2 Appendix 3.7B describes the evaluation methodology and the results of the assessment of APR1400 for its suitability for the HRHF input motions. The APR1400 HRHF response spectra, as shown in DCD Tier 2, Figures 3.7-12 and 3.7-13, for the horizontal and vertical directions are developed based on Electric Power Research Institute (EPRI) TR 1023389, “Evaluation of Seismic Hazard at Central and Eastern US Nuclear Power Plant Sites,” dated June 2011. DCD Tier 2 indicates that the HRHF response spectra exceed the CSDRS for frequencies higher than approximately 10 Hertz (Hz). It should be noted that the APR1400 HRHF response spectra are not considered part of the CSDRS.

This DCD section also describes critical damping values for various nuclear safety-related SSCs, which are based on RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, issued March 2007. In addition, this section describes the supporting media for seismic Category I structures, which include eight soil profiles (shown in DCD Tier 2, Figure 3.7-23) and one fixed-based condition. The seismic Category I structures for the APR1400 standard design include the nuclear island (NI) structures (the reactor containment building (RCB) and the auxiliary building (AB)), the EDGB, and a diesel fuel oil tank (DFOT) room, which are embedded to various depths (2–16.4 m (6 ft. 8 in. – 53 ft. 8 in.)).

ITAAC: There are no ITAAC for this area of review.

Technical Specifications: There are no Technical Specifications for this area of review.

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

Technical Reports: The technical reports associated with DCD Tier 2, Section 3.7.1 are as follows:

- APR1400-E-S-NR-14001, "Seismic Design Bases," Revision 1, February 2017.
- APR1400-E-S-NR-14004, "Evaluation of Effects of HRHF Response Spectra on SSCs," Revision 2, February 2017.

Cross Cutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): 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.

3.7.1.3 Regulatory Basis

SRP Section 3.7.1 describes the relevant requirements of the NRC regulations for seismic design parameters and the associated acceptance criteria. The specific requirements include the following:

- Part 50 of 10 CFR, Appendix A, GDC 2, requires that the design basis shall reflect appropriate consideration of the most severe earthquakes 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 historical data have been accumulated.
- Part 50 of 10 CFR, Appendix S, requires that for SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motion. If the OBE is set at one-third or less of the SSE, an explicit analysis or design is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that the applicable stress, strain, and deformation limits are satisfied. Appendix S also requires that the horizontal component of the SSE ground motion in the free-field at the foundation level of the structures must be an appropriate response spectrum with a peak ground acceleration of at least 0.1 g.

- Section 52.47(a)(1) of 10 CFR, requires that a DC applicant provide site parameters postulated for the design and an analysis and evaluation of the design in terms of those site parameters.
- Section 52.47(b)(1) of 10 CFR, requires that a DC application contain the proposed ITAAC 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 DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act of 1954, as amended, and the Commission's rules and regulations.

In addition, the acceptance criteria and regulatory guidance associated with the review of DCD Tier 2 Section 3.7.1, include the following:

- SRP Section 3.7.1, Revision 4, for reviewing seismic design parameters to ensure that they are appropriate and contain a sufficient margin so that seismic analyses (reviewed under other SRP sections) accurately and/or conservatively represent the behavior of SSCs during postulated seismic events (ML14198A460),
- RG 1.60, Revision 2, to determine the acceptability of design response spectra for input into the seismic analysis of nuclear power plants (ML13210A432),
- RG 1.61, Revision 1, to determine the acceptability of damping values used in the dynamic seismic analyses of seismic Category I SSCs (ML170260029),
- DC/COL-ISG 01, "Interim Staff Guidance on Seismic Issues of High Frequency Ground Motion," (ML081400293),
- DC/COL-ISG-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analysis," (ML100570203),
- NUREG/CR 5347, "Recommendations for Resolution of Public Comments on USI A 40, Seismic Design Criteria," issued May 1989, to determine the acceptability of the development of target power spectral density (PSD) functions, and
- NUREG/CR 6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines," issued October 2001, to determine the acceptability of the ground motion characteristics.

3.7.1.4 *Technical Evaluation*

In accordance with SRP Section 3.7.1, Revision 4, the staff evaluated DCD Tier 2, Revision 0, Section 3.7.1; DCD Tier 2, Appendices 3.7A and 3.7B; and the KHNP technical reports APR1400-E-S-NR-14001, Revision 0, and APR1400-E-S-NR-14004, Revision 1, as related to seismic design parameters. The reviewed information includes: (1) the design ground motions, (2) percentage of critical damping values, and (3) supporting media for seismic Category I structures. In particular, the evaluation of the design ground motions covers the CSDRS and the corresponding CSDRS-compatible design ground motion time histories, and the HRHF

seismic input response spectra and the HRHF response spectra-compatible ground motion time histories.

The seismic analysis of the APR1400 seismic Category I SSCs uses these seismic design parameters to develop the seismic demands used for the APR1400 standard design. Meeting the SRP Section 3.7.1 criteria ensures that the seismic design parameters are adequately developed; that is, use of these seismic design parameters in the seismic analysis of the APR1400 seismic Category I SSCs will allow for a conservative estimate of the seismic demands for use in the design of the APR1400 seismic Category I SSCs.

This section presents the results of the staff's technical evaluation of APR1400 DCD Tier 2, Section 3.7.1. Section 3.7.2 of this SER presents the staff's evaluation of the seismic system analysis of the APR1400 seismic Category I structures and major plant systems. Section 3.7.3 of this SER presents the staff's evaluation of the seismic subsystem analysis for the APR1400 substructures and subsystems.

3.7.1.4.1 *Design Ground Motion*

DCD Tier 2, Section 3.7.1, indicates that APR1400 seismic Category I SSCs are designed for the SSE, which represents the maximum potential vibratory ground motion at the generic plant site. The OBE for APR1400 is specified at one-third of the SSE. DCD Tier 2 further indicates that, in accordance with Appendix S to 10 CFR Part 50, an explicit response analysis or design of the seismic Category I SSCs for the OBE is not necessary. The staff concludes that the approach for the specification of OBE and exclusion of the seismic analysis and design for OBE is acceptable, because it complies with the Commission regulations.

Certified Seismic Design Response Spectra (CSDRS)

In DCD Tier 2 Section 3.7.1.1.1, "Design Ground Motion Response Spectra," the design response spectra, which would become the CSDRS once the APR1400 DC application is certified, are prescribed at the finished grade in the free field for three mutually orthogonal directions—two horizontal and one vertical. DCD Tier 2, Figures 3.7-1 and 3.7-2, show the APR1400 horizontal and vertical CSDRS, respectively. The CSDRS are the same in the two horizontal directions. DCD Tier 2, Table 3.7-1 provides the control points defining the CSDRS. DCD Tier 2 indicates that the APR1400 CSDRS are developed based on the RG 1.60 response spectra anchored at 0.3 g in both the horizontal and vertical directions, with enrichment in the high-frequency range. More specifically, the APR1400 CSDRS are the same as the RG 1.60 response spectra at or below 9 Hz; above 9 Hz, the APR1400 CSDRS are specified higher than the RG 1.60 response spectra based on the following procedure:

- The zero period acceleration (ZPA) frequency increases from 33 Hz to 50 Hz.
- A control frequency at 25 Hz is added, and the spectral values at 25 Hz are 1.30 times the RG 1.60 values for all directions.
- Intermediate spectral values are obtained by linear interpolation on the log-log scale.

The staff finds the applicant's approach to specifying the CSDRS is consistent with the NRC SRP Acceptance Criterion 3.7.1.II.1.A.ii and is, therefore, acceptable.

The CSDRS are specified at damping levels of 2-, 3-, 4-, 5-, 7-, and 10-percent of critical damping. The RG 1.60 spectral shapes do not include damping levels at 3- and 4- percent. Since the CSDRS curves at 3- and 4- percent damping values can be used in the seismic analysis (especially in response spectrum analyses) and design of an SSC that has a damping value close to these two damping values, these two CSDRS curves should be prescribed conservatively or be consistent with other CSDRS curves based on the RG 1.60 spectral shapes. DCD Tier 2, Section 3.7.1.1.1 explains that the CSDRS at damping levels of 3- and 4- percent are developed by linearly interpolating the 2- and 5-percent-damped CSDRS curves. The linear interpolation was performed between spectral amplitude and natural logarithms of damping for each frequency following Equation 2.2-1 in Section 2.2, "Response Spectra," of American Society of Civil Engineers (ASCE) 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary." In addition, as shown by DCD Tier 2, Figures 3.7-6 through 3.7-8, the response spectra of the design ground motion at 3- and 4-percent damping envelop the corresponding CSDRS curves in a fashion similar to those for other damping values, demonstrating the consistency of the generated 3- and 4-percent-damped CSDRS curves with other CSDRS curves. Therefore, the staff finds that the 3- and 4-percent-damped CSDRS curves are acceptable because (1) the method to generate them is a widely applied and codified method, (2) the method satisfies the intent of SRP Acceptance Criterion 3.7.1.II.1.A.ii, and (3) the DCD Tier 2 figures described above show the consistency among the CSDRS curves.

In accordance with the requirements of Appendix S to 10 CFR Part 50, SRP Acceptance Criterion 3.7.1.II.1.A.ii states that, for a DC application, both the postulated CSDRS and the CSDRS at the foundation level in the free field must bound the minimum required response spectrum (MRRS) anchored to 0.1 g. The MRRS should be a smooth, broadband response spectrum, similar to the RG 1.60 spectrum. For the APR1400, the MRRS for the horizontal direction is defined as the CSDRS anchored to 0.1 g. The staff finds this acceptable because the APR1400 CSDRS for the horizontal direction is a smooth, broadband spectrum that envelops the RG 1.60 response spectrum. The foundation-level response spectra consistent with the CSDRS (CSDRS_{ff}) were determined for each of the APR1400 seismic Category I structures—the NI structures (the RCB and the AB), the EDGB, and the DFOT room. DCD Tier 2, Figures 3.7A-12 and 3.7A-13, present the CSDRS_{ff} generated from the horizontal design time histories that envelop the CSDRS. These figures show that the envelope of the CSDRS_{ff} for all eight APR1400 generic soil profiles bound the APR1400 MRRS for each of the three seismic Category I structures. However, since each generic soil profile can potentially be a valid COL site, the comparison of the envelope of CSDRS_{ff} is not sufficient to show that the CSDRS_{ff} for each soil profile satisfies the MRRS requirement of Appendix S to 10 CFR Part 50. Therefore, the staff issued RAI 253-8300, Question 03.07.01-5 (ML15293A567), requesting the applicant to include the comparison of the CSDRS_{ff} to MRRS for each of the eight soil profiles for the NI, EDGB, and DFOT room in DCD Tier 2. In its response to RAI 253-8300, Question 03.07.01-5 (ML16238A306), the applicant showed that the CSDRS_{ff} for each soil profile for all three seismic Category I structures bounds the APR1400 MRRS and provided the corresponding DCD Tier 2 markups.

Related to the CSDRS_{ff} issue described above, the staff reviewed APR1400-E-S-NR-14001, Revision 1. As shown in Figures 5-25 and 5-26 of the technical report, the staff identified that the CSDRS_{ff} for the NI shows large dips between 3 Hz and 20 Hz for soil cases S6 and S7, which is significantly different from the other soil cases. Figure 5-27 of the technical report shows that the CSDRS_{ff} in the vertical direction for these two soil cases are also different from

other soil cases but are not as significant. Figures 5-14 through 5-22 of the technical report show that the variation in the generic soil profiles among the eight layered soil profiles is gradual. In addition, Figure 5-24 of the technical report shows that the soil column fundamental frequency is approximately a linear function of the soil case on the log scale. The transfer functions shown in Figure 5-23 of the technical report indicate that amplification occurs at various frequency points below 50 Hz for all soil cases. Therefore, as part of RAI 253-8300, Question 03.07.01-5, the staff also asked the applicant to explain in detail: (1) the method used to calculate the $CSDRS_{ff}$, and (2) why soil cases S6 and S7 for the NI behave differently from the other soil cases. In its August 23, 2016, response, the applicant provided transfer functions for these two soil cases as well as transfer functions and response spectra at a soil interface for soil cases S1 and S2. The applicant indicated that all relevant calculations were performed using the SHAKE91 program, and the large dips for soil cases S6 and S7 are due to the existence of a soil interface close to the bottom of the NI foundation. As shown in Figures 30 and 31 of the RAI response, similar dips in response spectra are observed at the soil interfaces for soil cases S1 and S2, which are located below the foundation level. The dips in the response spectra at the soil interfaces for soil cases S1, S2, S6, and S7, demonstrate a consistent soil column behavior.

However, the transfer functions provided in Figures 1 through 18 of the applicant's earlier response to RAI 253-8300, Question 03.07.01-5 (ML16029A028), do not appear to resolve this issue because the figures are similar to each other in terms of response amplification. During an audit conducted on June 20–24, 2016 (ML17132A286), the staff reviewed the applicant's SHAKE91 input files for its site response analysis and found that the output transfer functions were specified in the analysis from the outcrop bedrock level to the outcrop foundation level, while those shown in Figures 1 through 18 of the earlier RAI response and the associated description indicated that these were at the outcrop foundation level relative to the free field ground surface. To resolve this inconsistency, the staff asked the applicant to revise the RAI response accordingly. In its revised response to RAI 253-8300, Question 03.07.01-5, (ML16238A306), the applicant addressed this inconsistency and added Figures 19 through 26 to show the transfer functions from the free field ground surface to the outcrop foundation level, which clearly explain the dips in response spectra.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 253-8300, Question 03.07.01-5 is resolved and closed.

DCD Tier 2 Section 3.7.1.1.1, indicates that seismic Category I and II SSCs that are not included in the APR1400 standard plant design can be designed at the COL stage using the site-specific SSE derived from the ground motion response spectra (GMRS), in accordance with RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," issued March 2007. DCD Tier 2, as modified in the applicant's response to RAI 252-8299, Question 03.07.02-14, (ML16126A321), also indicates in COL 3.7(3) that these SSCs include the ESWB (I), component cooling water heat exchanger building (I), TGB (II), compound building (II), and alternate alternating current gas turbine generator building (II). Since these buildings are not included in the APR1400 standard design, the staff's review of the site-specific SSE for the design of these buildings will be performed in the COL application stage.

DCD Tier 2 Section 3.7.1.1.1, indicates that the COL applicant is to determine the site-specific SSE and OBE for the site-specific seismic design of seismic Category I and II SSCs that are not

included in the APR1400 standard design, and to verify the appropriateness of the site-specific SSE and OBE (COL 3.7(1)). COL 3.7(2) indicates that the COL applicant is to confirm that the horizontal components of the site-specific SSE ground motion in the free-field at the foundation level of the structures that are not included in the APR1400 standard plant design satisfy a peak ground acceleration of at least 0.1 g. The staff determined that COL 3.7(1) and COL 3.7(2) are unnecessary, since the COL applicant is responsible under the NRC regulations to address site specific seismic Category I and II structures. In its letter dated November 30, 2015 (ML15334A153), the applicant will delete these two COLs information items and the associated text will be deleted from DCD Tier 2, Sections 3.7.1.1.1 and 3.7.5. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 252-8299, Question 03.07.02-14, is resolved and closed.

In summary, the staff finds the APR1400 CSDRS acceptable because (1) the CSDRS are smooth broadband response spectra, (2) the spectral curves for damping values not available in RG 1.60 were generated using a widely applied and codified method, (3) the CSDRS are specified consistently with the SRP Section 3.7.1 guidance for three mutually orthogonal directions, and (4) the CSDRS are in compliance with the requirement in the Appendix S to 10 CFR Part 50 on enveloping the minimum required response spectra anchored at 0.1 g.

Development of Target Power Spectral Density (PSD) Functions

Evaluation of Target PSD Functions Compatible with CSDRS

SRP Acceptance Criterion 3.7.1.II.1.B, Option 1 (single set of time histories), Approach 1, makes provisions to check the PSD functions of the design time histories against target PSD functions that are properly determined to be compatible with the CSDRS. Enveloping the CSDRS alone does not assure the enveloping design time histories have sufficient power over the entire range of frequencies of interest to seismic Category I SSCs. To determine the target PSD functions compatible with the APR1400 CSDRS, DCD Tier 2 Section 3.7.1.1.2, "Design Ground Motion Time History," and Section 3.2.4 of APR1400-E-S-NR-14001, indicate that for frequencies lower than 9 Hz, the target PSD function in the horizontal direction is specified as the same as that described in Appendix A to SRP Section 3.7.1 because the horizontal CSDRS is identical to the horizontal RG 1.60 spectrum below 9 Hz. For frequencies between 9 Hz and 50 Hz, the target PSD was developed using 30 simulated time histories, each matching the 2 percent damped CSDRS. DCD Tier 2 Table 3.7-3 presents the resultant piecewise log-log linear target PSD function for the horizontal CSDRS. It is not clear to the staff that, below 9 Hz, the assumed target PSD function based on SRP Section 3.7.1, Appendix A is conservative, as compared with one so developed following the same procedure as for the frequency range from 9 Hz to 50 Hz. A PSD function does not have a frequency by frequency independent relationship with the response spectra. Therefore, the target PSD function below 9 Hz may not have been specified properly. The staff found that further technical justification was needed for the assumption that the target PSD function from Appendix A to SRP Section 3.7.1 (which is for the RG 1.60 horizontal design response spectrum) is appropriate for the CSDRS below 9 Hz. For the vertical CSDRS, DCD Tier 2 Section 3.7.1.1.2 also explains that the target PSD was developed using a one-time scaling method, in which the horizontal target PSD function was scaled for one time (without iterations) with a frequency dependent factor that was calculated as the squared, frequency-by-frequency ratio of the vertical CSDRS to the horizontal CSDRS. This approach would be acceptable if the two response spectra are very close; however, the vertical CSDRS is not close to the horizontal CSDRS in low frequencies. To address these issues, the

staff issued RAI 182-8160, Question 03.07.01-1 (ML15253A000), requesting the applicant to provide technical justifications on the horizontal PSD function below 9 Hz and on the vertical PSD function.

In its response to RAI 182-8160, Question 03.07.01-1 (ML16207A077), the applicant presented a comparison of the SRP Section 3.7.1, Appendix A, target PSD function, and the target PSD function developed for the CSDRS based on 30 iteratively adjusted time histories and determined that below 9 Hz, the two values are close. Figures 3 and 4 of this RAI response also compare the vertical target PSD function with the vertical target PSD function obtained by using 30 simulated time histories. These figures show that these two vertical target PSD functions are generally close, but the former (by the one-time scaling method) is lower than the latter (by the simulation method) below 0.6 Hz and between 2 Hz and 12 Hz.

As part of the staff's confirmatory analysis to assess the power sufficiency of the design time histories, the staff also compared the applicant's target PSD functions and the target PSD functions that the staff determined following the procedure described in Appendix B of SRP Section 3.7.1, Revision 4. The comparison showed that the staff-developed horizontal target PSD is higher than the applicant's horizontal target PSD from 0.3 Hz to about 13 Hz, above which it becomes lower and the applicant's PSD function is more conservative. The staff-developed vertical target PSD is higher than the applicant's target PSD from 0.3 Hz to 50 Hz. However, the difference in the minimum target PSD functions, which are used for PSD assessment, is much smaller because the applicant used a factor of 0.8, which is larger than the factor of 0.7 that the staff used following the guidance of SRP Section 3.7.1, Appendix B. Therefore, the staff concluded that the applicant's target PSD functions are acceptable because: (1) the applicant provided adequate justification for the horizontal target PSD function below 9 Hz and for the vertical target PSD function, based on comparisons to those obtained using simulated time histories, (2) the applicant used a larger factor of 0.8 to develop the minimum target PSD functions, and (3) the staff's confirmatory analysis showed that the applicant's minimum target PSD functions are close to or more conservative in some frequencies than the minimum target PSD functions that the staff developed.

The committed changes also include other issues in this RAI discussed later in this SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 182-8160, Question 03.07.01-1, is resolved and closed.

Evaluation of Target PSD Functions Compatible with HRHF Response Spectra

DCD Tier 2 Section 3.7.1.1.3, "Hard Rock High Frequency Seismic Input Motions," and technical report APR1400-E-S-NR-14004, indicate that the target PSD functions compatible with the HRHF response spectra are generated using 30 simulated time histories that were iteratively adjusted so that each of them matches the HRHF response spectra. DCD Tier 2, Tables 3.7-5 and 3.7-6, present the piecewise log-log linear target PSD functions. These tables and DCD Tier 2, Section 3.7.1.1.3, as modified in the applicant's response to RAI 182-8160, Question 03.07.01-1, indicate that the target PSD functions are provided for frequencies from 0.3 Hz to 100 Hz, which are consistent with the HRHF response spectra. The staff reviewed the applicant's procedure and found that it is not the same as, but in effect is equivalent to, the procedure provided in Appendix B to SRP Section 3.7.1, Revision 4. In addition, in the staff's confirmatory analysis of the applicant's acceleration time histories, the staff independently developed target PSD functions compatible with the HRHF response

spectra following the guidance in Appendix B to SRP Section 3.7.1, Revision 4. The staff-developed target PSD functions were found to be very close to those the applicant developed, with the latter slightly higher at higher frequencies. Furthermore, the applicant applied a factor of 0.8 to develop the minimum target PSD functions, which is higher than the value of 0.7 in accordance with the guidance in Appendix B to SRP Section 3.7.1, Revision 4. Therefore, the applicant's minimum target PSD functions are higher and more conservative than the staff-developed minimum target PSD. Based on the above discussion and the results of the confirmatory analysis, the staff found the applicant's target PSD functions for the HRHF response spectra acceptable.

Design Ground Motion Time Histories

DCD Tier 2, Section 3.7.1.1.2, indicates that the design ground motion consists of three components: the two horizontal components (H1, for the east-west (E-W) direction, and H2, for the north-south (N-S) direction) and the vertical component (VT), and the associated time histories were developed to envelop the CSDRS in conformance with SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, draft Revision 4. The sections below present the staff's technical evaluation of the seed records and design ground motion time histories.

Seed Records for Developing CSDRS- and HRHF Response Spectra-Matched Time Histories

Technical Report APR1400-E-S-NR-14001, indicates that the initial seed time histories are a set of three ground motion components recorded from the magnitude 6.7 Northridge, CA, earthquake event that occurred on January 17, 1994. These seed records were used to generate the design ground motion time histories. It also indicates that these recorded time histories are statistically independent (i.e., with cross-correlation coefficients less than 0.16) and have response spectral shapes generally close to the CSDRS. The seed records consist of 1,828 data points with a sampling time interval of 0.02 seconds (s). In contrast, the design ground motion time histories have a time interval of 0.005 s to achieve a Nyquist frequency of 100 Hz. Since the Nyquist frequency of the seed time histories is only 25 Hz, the seed records do not have phase information for frequencies higher than 25 Hz. In addition, Figures 3-4 through 3-6 of APR1400-E-S-NR-14001, show that the seed records lack higher frequency contents, especially in the two horizontal directions that appear to have frequency contents only up to around 8–9 Hz. Therefore, the staff issued RAI 182-8160, Question 03.07.01-2 (ML15253A000), requesting the applicant to explain how the seed records were re-digitized to introduce phase information for frequencies higher than 25 Hz and provide a technical basis for the method used. In its revised response to RAI 182-8160, Question 03.07.01-2 (ML16251A259), the applicant explained that the seed time histories were linearly interpolated with a time increment of 0.005 s to introduce higher-frequency components. Figures 1 through 3 of the RAI response compare the seed time histories and the re-digitized time histories. Figures 4 through 15 of the response showed the Fourier amplitude and phase spectra of the re-digitized Northridge earthquake records and the Nahanni (Canada) earthquake records, the latter of which were used to develop the HRHF acceleration time histories. Based on the spectra shown in these figures from 0 Hz to 100 Hz, the applicant concluded that the phase spectra of the re-digitized time histories are sufficiently random in the higher-frequency range.

However, these figures include too many data points to reveal the local effects of the linear interpolation method on the phase spectra. To assess these effects more closely in the higher frequency range, the staff examined the APR1400 Northridge seed records by zooming in the

Fourier amplitude and phase spectra to small frequency windows centered at the multiples of 25 Hz. The results showed that the phase spectra for the two horizontal components appeared to be random within those small-frequency windows and, therefore, acceptable to the staff. However, for the phase spectrum in the vertical direction, the following observations were made:

- When no zero-padding was applied to the time histories in the vertical direction to increase the number of data points to a power of 2, two gaps, in which the phase angles did not change much, were seen around 25 Hz and 75 Hz in the phase spectrum. However, when zero-padding was applied, the gaps did not occur but the phase spectra become cyclic around these frequencies. As a comparison, zero-padding did not affect noticeably the phase spectra for the two horizontal directions.
- At frequencies around 25 Hz and 75 Hz, the phase spectra of the seeds with zero-padding were apparently cyclic and thus not truly random. The cyclic behavior was observed for seed records both before and after interpolation. Further, the cyclic behavior did not occur at other frequencies. Therefore, the staff concluded that the cyclic behavior was not from interpolation, but rather from an existing issue with the original seed records.
- For the Nahanni earthquake records used to generate the APR1400 HRHF acceleration time histories, cyclic behavior or gaps, or nearly constant phase angles (0 or $\pi/2$) were observed at frequencies close to 100 Hz. The staff notes that the Nahanni records have a sufficiently small time increment, so linear interpolation was not needed for their use as seed records to develop the HRHF acceleration time histories.

To confirm whether the above-observed behaviors (i.e., cyclic behavior, gaps, and constant phase angles) in the seed records affect the final CSDRS-matched time histories or the HRHF response spectra-matched time histories, the staff examined the Fourier amplitude and phase spectra of these spectrum-matched time histories and found that the behaviors observed above do not occur in these time histories. It appears that the spectral matching method, discussed during the June 20–24, 2016 audit (ML17132A286), is a time domain method, has changed the phase spectra from somewhat nonrandom to random. As such, the staff finds the seed records acceptable because their lack of high-frequency content, the gaps, and the cyclic behavior in their phase spectra do not affect the final acceleration time histories that are used as design ground motions or the HRHF ground motions.

The committed changes also include other issues in this RAI discussed later in this SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 182-8160, Question 03.07.01-2, is resolved and closed.

Low-Pass Filters for CSDRS-Matched Time Histories

During the staff's examination of the Fourier spectra of the CSDRS-matched design time histories, the staff also found that these time histories were apparently filtered with low-pass filters, with the corner frequencies less than 50 Hz. The issue was more evident in the N-S direction. During an audit on June 20–24, 2016 (ML17132A286), the applicant confirmed that in the development of synthetic acceleration time histories to match the APR1400 CSDRS for multiple damping values, low-pass filters were applied to the time histories because the baseline

correction and/or clipping of the time histories that were performed during the spectrum matching process introduced artificial high-frequency motion contents in the modified time histories. The actual corner frequencies chosen for the low-pass filters were 48 Hz for the N-S component, 49.5 Hz for the E W component, and 48.5 Hz for the VT component. The applicant also indicated that there was no particular reason for selecting the specific corner frequencies of the low-pass filters, other than the frequencies chosen to produce acceptable spectrum matching results in the high-frequency range near and above 50 Hz. To address the staff's concern on the potential effect of the corner frequencies lower than 50 Hz on structural response, the applicant explained in its response to RAI 182-8160, Question 03.07.01-2, that, because the PSD functions were estimated by smoothing over a frequency band width of ± 20 percent, which translates to ± 10 Hz for a center frequency of 50 Hz, any power gap between 48 Hz and 50 Hz was smoothed out. In addition, because of the bandwidth of the response transfer functions of the single-degree-of-freedom systems close to 50 Hz, the spectral response between 48 Hz and 50 Hz shows adequate spectral response amplitude in this frequency range, as indicated by the response spectra of the design time histories enveloping the CSDRS. The staff found the applicant's justification acceptable for its use of low-pass filters in the development of synthetic time histories because (1) the corner frequencies are very close to 50 Hz, differing by at most 2 Hz, so there has been no power deficiency in the design time histories due to smoothing (as also determined in the next section); and (2) the response spectra of the design time histories envelop the CSDRS.

Meeting the Criteria in SRP Section 3.7.1, Revision 4, Option 1, Approach 1

DCD Tier 2 Section 3.7.1.1.2 describes how the design time histories meet the SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, Draft Revision 4. Consistent with the DCD markup provided in the applicant's letter (ML15334A153), and the applicant's response to RAI 182-8160, Question 03.07.01 2 (ML15253A000); DCD Tier 2 Section 3.7.1.1.2 provides numerical values to show how the design time histories meet the acceptance criteria in SRP Section 3.7.1, Revision 4, Option 1, Approach 1, in the frequency range from 0.2 Hz to 50 Hz:

- The strong motion durations, defined as the time required for the cumulative Arias Intensity to rise from 5 to 75 percent, are longer than 6 s—9.2 s (E-W), 10.3 s (N-S), and 8.4 s (VT)—as shown in Table 3.7-2(a) of the DCD;
- The time increment is 0.005 s, small enough to provide a Nyquist frequency higher than 50 Hz;
- The absolute values of the correlation coefficients, 0.032 (E-W – N-S), 0.079 (E-W–VT), and 0.029 (NS–VT), are smaller than 0.16, showing that the acceleration time history pairs are statistically independent; and,
- For all damping values associated with the CSDRS, the response spectra of the design time histories envelop the CSDRS with no more than 5 frequency points below and no frequency point below by more than 10 percent, as shown in Tables 3.7-2(c) and (d) of the DCD, for all frequencies as specified in Table 3.7.1-1 of SRP Section 3.7.1, Revision 4.
- DCD Tier 2, Figures 3.7-6 through 3.7-8 show that the response spectra of the design time histories envelop the CSDRS. The design ground motion time histories have a total

duration of 20.48 s. As part of the staff's confirmatory analysis, the design time histories were also confirmed to meet the SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, Revision 4, regarding the design time histories enveloping the design response spectra.

SRP Section 3.7.1, Revision 4, Option 1, Approach 1, also provides guidance on development of target PSD functions and demonstration of acceleration time histories having no power deficiency over the range of frequencies important to the seismic Category I SSCs. The target PSD functions should be developed to be compatible with the design response spectra, and the PSD functions estimated from the time histories should be compared with the minimum target PSD functions to assess the power sufficiency. The staff evaluated the APR1400 target PSD functions, as described above in "Development of Target Power Spectral Density (PSD) Functions," and confirmed that the APR1400 minimum target PSD functions (i.e., 80 percent of the APR1400 target PSD functions) are close to or more conservative in some frequencies than those the staff developed in the confirmatory analysis and, therefore, are acceptable. The staff's evaluation of the method to estimate the PSD functions for the synthetic acceleration time histories and its assessment of the power sufficiency of the design acceleration time histories are provided below.

DCD Tier 2, Figures 3.7-9 through 3.7-11, show the PSD functions of the design acceleration time histories from 0.3 Hz to 50 Hz, which are above the corresponding APR1400 minimum target PSD functions and indicate there is no power deficiency in the design acceleration time histories. The DCD Tier 2 also indicates that the PSD functions were estimated using a frequency window of ± 20 percent for averaging, which is consistent with the SRP guidance. However, DCD Tier 2 Section 3.7.1.1.2 did not provide other details of the method used to estimate the PSD function from the synthetic design acceleration time histories (e.g., the selection of the strong motion duration). Therefore, the staff issued RAI 182-8160, Question 03.07.01-3 (ML15253A000), requesting the applicant to provide a description of the method for estimating the PSD functions of the CSDRS-matched time histories and a technical justification if the method is not consistent with the guidance provided in SRP Section 3.7.1.

In its response to RAI 182-8160, Question 03.07.01-3 (ML16274A433), the applicant provided the detailed procedure used to estimate the PSD functions from the design acceleration time histories. The staff found this procedure was identical to that for the PSD assessment of the HRHF response spectra-matched time histories. The procedure includes the following four steps:

1. Compute the Fourier spectrum of the entire time history.
2. Calculate the extended equivalent stationary duration as the time for the normalized cumulative Arias intensity to rise from 5 to 75 percent, and then divided by 0.7.
3. Estimate the PSD function using Equation (1) of SRP Section 3.7.1, Appendices A and B, using the extended equivalent stationary duration.
4. Smooth the PSD function by a ± 20 percent frequency window.

The first two steps are not consistent with the guidance in Appendix B to SRP Section 3.7.1, which states that the Fourier spectrum should be evaluated over the strong motion duration, which represents the duration of near maximum and nearly stationary power of the acceleration

time history. The same strong motion duration (without applying any factor) is used to calculate the one-side PSD function. To technically justify the acceptability of this method, in response to RAI 182-8160, Question 03.07.01-3, the applicant provided a comparison of the PSD functions estimated based on the entire acceleration time histories for the three directions and the corresponding extended equivalent stationary durations, with those estimated using an approach consistent with the guidance in Appendix B to SRP Section 3.7.1. The applicant's comparisons in Figures 22 through 24 and Figures 37 through 39 of the RAI response indicate that, except for the case of CSDRS (N-S), the applicant's original PSD estimates for the other five cases—CSDRS (E-W), CSDRS (VT), and the three cases for HRHF response spectra—are higher in some frequency bands than those calculated following the guidelines in Appendix B to SRP Section 3.7.1, with the largest difference to be by a factor of about 3. A higher PSD estimate from the acceleration time histories can potentially lead to an undetected case of power deficiency. The applicant revised DCD Tier 2, Figures 3.7-9 and 3.7-11, to reflect these comparisons as a technical justification of the method for its original PSD estimation.

One of the major goals of the staff's confirmatory analysis of the applicant's design acceleration time histories is to confirm the applicant's PSD assessment for power sufficiency. In the staff's confirmatory analysis, target PSD functions were developed for the APR1400 CSDRS and the minimum target PSD functions were obtained using a factor of 0.7 following the guidelines in Appendix B to SRP Section 3.7.1. The PSD functions of the APR1400 design acceleration time histories were also estimated following the guidance in Appendix B to SRP Section 3.7.1. The staff's confirmatory analysis showed that the estimated PSD functions of the design acceleration time histories are higher than the minimum target PSD functions, indicating sufficient power, over 0.3 Hz to 50 Hz, which is a frequency range consistent with the guidance in Appendix B to SRP Section 3.7.1. Based on the staff's evaluation of the applicant's technical justification in its response to RAI 182-8160, Question 03.07.01-3, and the staff's independent confirmatory analysis, the staff determined that the APR1400 design acceleration time histories have sufficient power over the frequency range of interest and, therefore, meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, on the assessment of power sufficiency.

In summary, the staff finds that the APR1400 design acceleration time histories are acceptable because they meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, by enveloping the APR1400 CSDRS for all damping values specified for the APR1400 standard design, and by containing sufficient power over the entire frequency range of interest to the APR1400 standard design.

The committed changes also include other issues in this RAI discussed later in this SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 182-8160, Question 03.07.01-3, is resolved and closed.

HRHF Seismic Input Motions

The applicant specified the HRHF response spectra and evaluated its effects on the APR1400 standard design in DCD Tier 2, Section 3.7.1.1.3 and Appendix 3.7B, and with more details in Technical Report APR1400-E-S-NR-14004, which is incorporated by reference in the DCD. DCD Tier 2, Figures 3.7-12, 3.7-13, 3.7B-1 through 3.7B-4 and Tables 3.7B-1 and 3.7B-2 provide the APR1400 HRHF response spectra for the horizontal and vertical directions over frequencies from 0.2 Hz to 100 Hz. Technical Report APR1400-E-S-NR-14004, Revision 1, indicates that the 5 percent damped APR1400 HRHF horizontal response spectrum is selected

as the 0.8 fractile hard rock horizontal “composite envelope GMRS” developed based on 60 Central and Eastern United States (CEUS) sites, which is described in EPRI TR-1023389, “Evaluation of Seismic Hazards at Central and Eastern US Nuclear Power.” The 5-percent damped HRHF vertical response spectrum is generated from the 5 percent-damped HRHF horizontal response spectrum by multiplying the vertical/horizontal (V/H) ratios for CEUS rock sites recommended in NUREG/CR-6728. For frequencies not listed in NUREG/CR-6728, the V/H ratios are obtained by a log-log amplitude-frequency linear interpolation. As shown in DCD Tier 2, Figures 3.7B-1 and 3.7B-2, the HRHF response spectra exceed the CSDRS at frequencies above approximately 10 Hz. The DCD Tier 2 indicates that the peak ground acceleration of the APR1400 HRHF response spectra is 0.46 g for both the horizontal and vertical directions.

The APR1400 HRHF response spectra are not specifically designated as part of the design basis but were used in the seismic evaluation of the APR1400 structures and equipment qualified for the CSDRS to evaluate the potential for the APR1400 standard design to sustain damage from high-frequency seismic input motions. The methodology and results of the applicant’s evaluation of the APR1400 standard design for the HRHF seismic input motions are presented in DCD Tier 2 Appendix 3.7B and APR1400-E-S-NR-14004. The staff evaluated this information in Section 3.7.2 of this SER.

DCD Tier 2 provides the HRHF response spectra at damping ratios of 2-, 3-, 4-, 5-, 7-, and 10-percent of the critical damping. In APR1400-E-S-NR-14004, the horizontal HRHF response spectra for damping ratios other than 5 percent were generated from the 5 percent-damped HRHF horizontal response spectrum by multiplying the 5 percent-damped spectral values by the spectral ratios for the CEUS rock sites given in Table 3-4 of Appendix C to SRP Section 3.7.1, draft Revision 4, which were developed based on the time histories records provided in NUREG/CR-6728. The horizontal HRHF response spectra for the 4 percent damping value was generated by interpolating between the spectral values for 3- and 5-percent damping ratios on a log scale for the damping ratio and a linear scale for the spectral acceleration. The staff found this interpolation method identical to the method evaluated above in the SER section, “Certified Seismic Design Response Spectra (CSDRS).” The vertical HRHF response spectra for damping ratios other than 5 percent were also generated by applying the same V/H ratios as for the 5-percent-damped vertical HRHF response spectra. Therefore, the staff finds the HRHF response spectra specified for damping values other than the 5 percent damping value acceptable because: (1) the linear interpolation method and the application of the spectral ratios developed based on NUREG/CR-6728 are all well-established approaches, and (2) the synthetic acceleration time histories envelop the APR1400 HRHF response spectra at all damping values (to be evaluated below).

DCD Tier 2 Section 3.7.1.1.3 indicates that the synthetic acceleration time histories were generated to envelop the HRHF response spectra for the two horizontal directions, H1H for the E-W direction and H2H for the N-S direction, and the vertical direction, to meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1. The initial seed time histories for the generation of acceleration time histories are recorded motions from the Nahanni earthquake. The APR1400 HRHF time histories have a total duration of 20.48 s. As modified by the applicant’s responses to RAI 182-8160, Question 03.07.01-2 (ML16251A259), DCD Tier 2 Section 3.7.1.1.3 provides numerical values to show how the HRHF response spectra-matched acceleration time histories meet the criteria in SRP Section 3.7.1, Option 1, Approach 1, in the frequency range from 0.2 Hz to 100 Hz:

- The strong motion durations defined as the time required for the cumulative Arias Intensity to rise from 5 percent to 75 percent are longer than 6 s - 6.1 s (E-W), 6.4 s (N-S), and 6.5 s (VT)—as shown in Table 3.7-4 (a) of the DCD;
- The time increment is 0.005 s, which translates to a Nyquist frequency of 100 Hz;
- The absolute values of the correlation coefficients—0.028 (E-W–N-S), 0.031 (E-W–VT), 0.036 (N-S–VT)—are smaller than 0.16, showing the acceleration time history pairs are statistically independent; and
- For all damping values associated with the HRHF response spectra, the response spectra of the HRHF time histories envelop the HRHF response spectra with no more than five frequency points below and no frequency point below by more than 10 percent, as shown in Tables 3.7-4 (c) and (d) of the DCD, for all frequencies as specified in Table 3.7.1-1 of SRP Section 3.7.1, Revision 4.

DCD Tier 2, Figures 3.7-17 through 3.7-19, show that the response spectra of the HRHF acceleration time histories envelop the HRHF response spectra.

The staff performed a confirmatory analysis of the HRHF acceleration time histories following the same approach as that for the CSDRS acceleration time histories. The staff confirmed the above numerical values for the applicant's HRHF acceleration time histories. Therefore, the staff finds the HRHF acceleration time histories meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, regarding the demonstration that the HRHF acceleration time histories envelop the HRHF response spectra.

DCD Tier 2, Figures 3.7-20 through 3.7-22, show the PSD functions of the HRHF acceleration time histories from 0.3 Hz to 100 Hz, which are above the corresponding APR1400 minimum target PSD functions for the HRHF response spectra by large margins, and indicate there is no power deficiency in the HRHF acceleration time histories. The same method to estimate the PSD functions for the CSDRS acceleration time histories was applied to estimate the PSD functions for the HRHF acceleration time histories. Therefore, the same issue exists for the inconsistency with the SRP guidance. This method uses the entire time history to calculate the Fourier spectrum and uses the extended equivalent stationary duration, while the guidance in Appendix B to SRP Section 3.7.1 states that the Fourier spectrum should be evaluated over the strong motion duration that represents the duration of near maximum and nearly stationary power of the acceleration time history. The applicant's method may overestimate the PSD at some frequencies because the total duration of the entire time history is normally significantly longer than the extended equivalent stationary duration. Therefore, the staff issued RAI 182-8160, Question 03.07.01 3 (ML15253A000), requesting the applicant to provide a technical justification for its method to estimate PSD functions.

In its response to RAI 182-8160, Question 03.07.01-3 (ML16274A433), the applicant compared its original PSD estimates with those calculated following the guidance in Appendix B to SRP Section 3.7.1. The staff found that the original PSD estimates are higher in some frequency bands, by as much as a factor of about 3. A higher PSD estimate from the acceleration time histories can potentially lead to an undetected case for power deficiency. The applicant will revise DCD Tier 2, Figures 3.7-20 and 3.7 22, to reflect this comparison, as a technical justification for the applicant's original PSD estimation.

The staff's confirmatory analysis of the applicant's HRHF synthetic acceleration time histories showed that their PSD functions are higher than the minimum target PSD functions, indicating sufficient power, over 0.3 Hz to 100 Hz, which is a frequency range consistent with the guidance in Appendix B to SRP Section 3.7.1. Based on the staff's evaluation of the applicant's technical justification provided in its response to RAI 182-8160, Question 03.07.01-3, and the staff's independent confirmatory analysis, the staff finds that the APR1400 HRHF acceleration time histories have sufficient power over the frequency range of interest and, therefore, meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, regarding the assessment of power sufficiency.

In summary, the staff finds that the APR1400 HRHF acceleration time histories are acceptable because these meet SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 1, by enveloping the APR1400 HRHF response spectra for all damping values specified for the APR1400 standard design, and by containing sufficient power over the entire frequency range compatible with the APR1400 HRHF response spectra.

Based on its review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 182-8160, Question 03.07.01-3, is resolved and closed.

Removal of the Evaluation of V/A and AD/V2 from the DCD Tier 2 and Technical Reports

DCD Tier 2, Sections 3.7.1.1.2 and 3.7.1.1.3, describe the characteristic values of the design time histories and the HRHF time histories, including the ratios V/A and $AD/V2$, where A , V , and D , are the peak ground acceleration, velocity, and displacement, respectively. DCD Tier 2 indicates that these ratios are consistent with the magnitude and distance of the appropriate controlling events defining the uniform hazard response spectra. The target values and the associated target ranges for these ratios were obtained from NUREG-0003, "Statistical Studies of Vertical and Horizontal Earthquake Spectra," issued January 1976, and NUREG/CR-6728. However, since the development of the CSDRS based on the RG 1.60 response spectra introduces significant high frequent content and does not involve appropriately defined controlling events and uniform hazard response spectra, the demonstration of the consistency of these characteristic values is not necessary for the APR1400 standard design. Similarly, since the HRHF response spectra do not involve specifically defined controlling events and uniform hazard response spectra (although they are defined for representative CEUS sites), the demonstration of the consistency of these characteristic values is not necessary for the APR1400 standard design. Rather, consistent with the SRP Section 3.7.1 guidance, the staff reviews the above characteristic values in COL applications for cases where site-specific seismic system analysis are required. Therefore, the staff issued RAI 253-8300, Question 03.07.01-7 (ML15293A567), requesting the applicant to provide justification as to why the aforementioned site-specific related information was included in the DCD. In its response to RAI 253-8300, Question 03.07.01-7 (ML16056A184), the applicant provided markups to remove the related descriptions and tables from the DCD Tier 2 and Technical Reports APR1400-E-S-NR-14001, Revision 0, and APR1400-E-S-NR-14004, Revision 1.

Based on the review of the DCD, APR1400-E-S-NR-14001, Revision 1, and APR1400-E-S-NR-14004, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, RAI 253-8300, Question 03.07.01-7, is resolved and closed.

3.7.1.4.2 *Percentage of Critical Damping Values*

DCD Tier 2 Section 3.7.1.2 states that the damping values used for the analysis of various safety-related SSCs are based on RG 1.61, Revision 1, and provides both SSE and OBE damping values in Table 3.7-7 of the DCD. An endnote to this table provides an alternative frequency-dependent damping model that may be used for response spectrum analysis of piping systems. The information as provided appears to be direct excerpts from RG 1.61. APR1400-E-S-NR-14001, provides similar levels of details on damping specification for the APR1400 standard design. In addition, as shown in DCD Tier 2, Tables 3.7A-1 through 3.7A-9, the material damping ratios for all eight strain-compatible soil profiles are much less than 15 percent, which is the upper limit allowed in the acceptance criteria in SRP Section 3.7.1. In its response to RAI 182-8160, Question 03.07.01-4 (ML16221A559), the applicant revised these DCD tables to reference generic soil profiles only. Based on the damping description being consistent with RG 1.61, Revision 1, the staff finds that the prescription of percentage of critical damping values meets the SRP Acceptance Criterion 3.7.1.II.2 and is therefore acceptable.

Based on the review of the DCD and APR1400-E-S-NR-14001, Revision 1, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 253-8300, Question 03.07.01-4, is resolved and closed.

3.7.1.4.3 *Supporting Media for Seismic Category I Structures*

The APR1400 seismic Category I buildings—namely the NI structures (the RCB and the AB), the EDGB, and a DFOT—are assumed to be founded on rock or competent soil, which should have a shear wave velocity (V_s) greater than or equal to 304.8 meters per second (m/s) (1,000 feet per second (ft/s)). The standard design considers nine subgrade cases, including eight generic soil profiles and one fixed-base condition. DCD Tier 2, Table 3.7A-1, through Table 3.7-9, as modified in the applicant's response to RAI 182-8160, Question 03.07.01-4, (ML16221A559), provide the layer thickness, weight density, damping, shear wave velocity, primary wave velocity, and Poisson's ratio for each layer of the eight generic soil profiles, respectively. DCD Tier 2, Figures 3.7-23 and 3.7A-3 through 3.7A-11 show the shear wave velocities for the eight soil profiles, ranging from 303.6 m/s (996 ft/s) to 1,934.9 m/s (6,348 ft/s) on the ground surface and reaching the bedrock at various depths. The shear wave velocity V_s of the bedrock is assumed to be 2,804.2 m/s (9,200 ft/s). The eight soil profiles and the fixed-base condition considered in the APR1400 standard design represent a wide range of subgrade conditions. The generic soil profiles provided in DCD Tier 2, Tables 3.7A-1 through 3.7-9, were used in the soil-structure interaction (SSI) analyses of the APR1400 seismic Category I structures. Similarly, DCD Tier 2 Table 3.7B-3 provides the generic soil profile for the evaluation of the effects of HRHF input motion on the APR1400 SSCs.

In its response to RAI 182-8160, Question 03.07.01-4 (ML15253A000), the applicant replaced the description of "low-strain" and "strain-compatible" soil profiles in the DCD Tier 2 with a description of "generic" soil profiles to avoid confusion because "strain-compatible" soil profiles are applicable only to COL applications pertaining to specific sites. For the same reason, the applicant also removed the description of soil degradation models from the DCD. The applicant also made corresponding changes to APR1400-E-S-NR-14001, Revision 0, and APR1400-E-S-NR-14004, Revision 1. Associated with these changes, the applicant proposed the following two COL information items:

COL 3.7(12): The COL applicant is to demonstrate the applicability of soil degradation models used in site-specific site response analysis for the site conditions.

COL 3.7(13): The COL applicant is to compare the site-specific strain compatible soil properties with generic soil properties in order to confirm the site meets the generic soil profile used in the standard design.

The staff finds that these two COL information items provide clear directions for a COL applicant to: (1) develop site-specific strain-compatible soil profiles based on soil degradation models suitable for the site, and (2) compare the COL strain-compatible soil profiles with the DCD Tier 2 generic soil profiles to determine whether the site meets the generic soil profiles used in the standard design and whether a site-specific SSI analysis is needed. Therefore, the staff finds these two COL information items acceptable. As stated in the previous subsection, RAI 182-8160, Question 03.07.01-4, is resolved and closed.

In its response to RAI 253-8300, Question 03.07.01-6, (ML15365A548), the applicant modified DCD Tier 2 Table 3.7-8 to include the foundation embedment, foundation size, and maximum height for the NI structures, EDGB, and DFOT. The embedment, maximum height, and maximum plan dimension are 16.4 m (53 ft. 8 in.), 87.9 m (288 ft. 6 in.), and 107.3 m (352 ft.), respectively, for the NI structures; 2.0 m (6 ft. 8 in.), 17.8 m (58 ft. 6 in.), and 39.9 m (131 ft.), respectively, for the EDGB; and 12.1 m (39 ft. 8 in.), 18.7 m (61 ft. 6 in.), and 20.3 m (66 ft. 6 in.), respectively, for the DFOT. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 253-8300, Question 03.07.01-6, is resolved and closed.

Section 5.1 of APR1400-E-S-NR-14001, Revision 0, identifies two ground water levels: (1) the design ground water level, 2 feet below the ground surface (at elevation 96 ft., 8 inches), and (2) the extreme ground water level, at the ground surface (at elevation 98 ft. 8 in.). However, the report does not explicitly identify how these water tables were used. Therefore, the staff issued RAI 253-8300, Question 03.07.01-8 (ML15293A567), to request clarification of the conditions under which the design ground water table and extreme ground water table were used. In its response to RAI 253-8300 Question 03.07.01-8, (ML16239A427), the applicant indicated that the design ground level was used for calculating the hydrostatic load and the hydrodynamic load in the structural analyses, and the buoyant force in stability check of the seismic Category I structures for the overturning and the sliding. The extreme ground water level was used in the seismic analysis, buoyancy load calculation in the structural analyses, and the buoyant force calculation in the stability check of the seismic Category I structures for flotation. The applicant further explained that the use of a higher ground water level in the seismic analysis produces conservative seismic responses, as shown by the vertical 5 percent damped in-structure response spectrum (ISRS) comparisons at various locations in RCB and AB as shown in Figures 1 through 12 of the RAI response. The staff found this justification acceptable because: (1) the aforementioned comparisons show that the use of extreme ground water level produced conservative response, and (2) the difference between the extreme ground water level and the design ground water level is only 0.61 m. Accordingly, the applicant also revised DCD Tier 2, Sections 3.7.1.3, 3.8.4.3.1, 3.8A.1.4.2.3.2, and APR1400-E-S-NR-14001,

APR1400-E-S-NR-14003, and APR1400-E-S-NR-14005. The staff found these proposed changes consistent with the RAI response and thus acceptable.

Based on the evaluation above, the staff finds that DCD Tier 2 Section 3.7.1.3 provides sufficient information concerning the supporting media and is consistent with SRP Acceptance Criterion 3.7.1.II.3.

Based on the review of the DCD, APR1400-E-S-NR-14001, Revision 1, APR1400-E-S-NR-14003, Revision 1, and APR1400-E-S-NR-14005, Revision 1, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 253-8300, Question 03.07.01-8, is resolved and closed.

3.7.1.5 Combined License Information Items

DCD Tier 2 Section 3.7.1, as modified by the applicant’s letter (ML15334A153) and in its response to RAI 182-8160, Question 03.07.01-4, (ML16221A559), contains two COL information items pertaining to seismic design parameters. The staff has evaluated the acceptability of these COL items in this SER section. The staff also determined that the original COL information items, COL 3.7(1) and COL 3.7(2), are not applicable because they are not considered part of the DC/COL interface and agreed with the applicant’s removal of these two COL information items from the DCD.

DCD Tier 2, Section 3.7.1, contains the following COL information items.

Table 3.7.1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.7(1)	The COL applicant is to demonstrate the applicability of soil degradation models used in site-specific site response analysis for the site conditions.	3.7.1.3
COL 3.7(2)	The COL applicant is to compare the site-specific strain-compatible soil properties with generic soil properties in order to confirm the site meets the generic soil profile used in the standard design.	3.7.1.3

3.7.1.6 Conclusion

The staff concludes that the applicant meets the regulatory requirements listed in Section 3.7.1.3 of this SER by adequately addressing seismic design parameters, in accordance with the acceptance criteria given in SRP Section 3.7.1, Revision 4. The applicant meets these requirements specifically by its use of (1) acceptable smooth broadband CSDRS, (2) synthetic acceleration time histories enveloping the CSDRS and with sufficient power in the frequency range of interest to the APR1400 standard design, (3) percentage of critical damping values that conforms to the RG 1.61 guidance, (4) eight generic soil profiles and one fixed base condition to cover a wide range of site conditions, and (5) HRHF response spectra and the associated synthetic acceleration time histories for the evaluation of the APR1400 seismic Category I SSCs against high frequency seismic motions. This ensures that the seismic design

parameters are adequate for use in the seismic analysis and design of the APR1400 seismic Category I SSCs to withstand design-level seismic loadings and HRHF seismic loadings.

3.7.2 Seismic System Analysis

3.7.2.1 Introduction

This section addresses the seismic analysis methods and acceptance criteria for seismic Category I structures. Seismic Category I structures are designed to withstand the effects of the SSE event and to maintain the specified design functions. SRP Section 3.7.2 provides guidelines and acceptance criteria for the staff to use in reviewing issues related to seismic analysis methods for seismic Category I structures. Non-seismic Category I structures are designed or physically arranged (or both) to prevent the SSE from causing unacceptable structural interactions with or the failure of seismic Category I SSCs.

3.7.2.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with seismic analysis of buildings and structures is found in Section 2.2, "Structural and System Engineering," which includes the design descriptions and ITAAC, for the Nuclear Island (NI) Structures, the EDGB, the TGB, and the Compound Building (CB); Table 2.1-1, "Site Parameters," Table 2.2.1-3, "Seismic Classification of the Building," Figure 2.1-1, "Horizontal Certified Seismic Design Response Spectra," Figure 2.1-2, "Vertical Certified Seismic Design Response Spectra (Vertical)," Figure 2.1-3, "Horizontal HRHF Response Spectra," and Figure 2.1-4, "Vertical HRHF Response Spectra."

DCD Tier 2: The applicant provided a Tier 2 description of the seismic system analysis in Section 3.7.2 summarized in part below.

The applicant defines three seismic categories APR1400 SSCs: (1) Seismic Category I SSCs are designed to withstand the effects of the earthquake event and to maintain their specified design functions; (2) Seismic Category II SSCs do not perform safety-related functions, but structural failure or interaction could degrade the function of a seismic Category I SSC to an unacceptable safety level; and (3) Seismic Category III SSCs do not perform safety-related functions, and structural failure or interaction could not degrade the function of a seismic Category I SSC to an unacceptable safety level.

The NI structures are categorized as seismic Category I structures. These include the Containment Structure (CS), the Containment Internal Structure (CIS), and the AB, all sharing a common basemat. Additionally, the EDGB and the DFOT room are categorized as seismic Category I structures. These structures are separated from the NI basemat and also from each other by a 3 ft. gap. The TGB and CB are categorized as seismic Category II structures. The minimum required separation between these structures and the NI basemat is also 3 ft.

The seismic responses of seismic Category I structures are obtained from site-independent analyses performed using three-dimensional soil-structure interaction (SSI) models with the program ACS SASSI, which performs time-history analysis in the frequency domain. These site-independent analyses consider a set of 8 generic layered soil profiles, a fixed-base case, and two concrete stiffness cases (i.e. cracked and uncracked concrete). In addition to the

design basis SSI analyses, the applicant performs structure-soil-structures interaction (SSSI) analyses to evaluate the interaction between adjacent structures.

The seismic analysis and design of the APR1400 standard plant are based on the CSDRS shown in Tier 1 Figures 2.1-1 and 2.1-2, for the horizontal and vertical directions, respectively. Additionally, the APR1400 standard plant is evaluated for the potential effects of hard rock high frequency (HRHF) spectra, shown in Figures 2.1-3 and 2.1-4, respectively.

ITAAC: The ITAAC associated with DCD Tier 2 Section 3.7.2 are given in DCD Tier 1 Section 2.2, "Structural and System Engineering."

Technical Specifications: There are no Technical Specifications for this area of review.

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

Technical Reports: The technical reports associated with DCD Tier 2, Section 3.7.2 are as follows:

- APR1400-E-S-NR-14002, "Finite Element Seismic Models for SSI Analyses of the NI Buildings," Revision 0, November 2014.
- APR1400-E-S-NR-14003, "SSI Analysis Methodology and Results of NI Buildings," Revision 0, December 2014.
- APR1400-E-S-NR-14004, "Evaluation of Effects of HRHF Response Spectra on SSCs," Revision 1, February 2015.
- APR1400-E-S-NR-14005, "Evaluation of Structure-Soil-Structure Interaction (SSSI) Effects," Revision 0, November 2014.

Cross Cutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): 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 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.

3.7.2.3 *Regulatory Basis*

The relevant requirements for this review and the associated acceptance criteria are found in SRP Section 3.7.2, Revision 4, issued September 2013, and summarized below. In addition, the review interfaces with other SRP sections are also found in SRP Section 3.7.2, Revision 4.

- Part 50 of 10 CFR, Appendix A, GDC 2, which requires that the design basis shall reflect appropriate consideration of the most severe earthquakes 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 historical data have been accumulated.
- Part 100 of 10 CFR, Subpart B, which is applicable to power reactor site applications on or after January 10, 1997, refers to 10 CFR 100.23 of this part for seismic criteria. Section 100.23 of 10 CFR describes the criteria and nature of investigations required to obtain the geologic and seismic data necessary to determine the suitability of the proposed site and the plant design bases. Section 100.23 of 10 CFR also refers to 10 CFR Part 50, Appendix S, for the definition of the minimum SSE ground motion for use in design.
- Part 50 of 10 CFR, Appendix S, is applicable to applications for a DC or COL to 10 CFR Part 52 or a construction permit or operating license pursuant to 10 CFR Part 50 on or after January 10, 1997. For SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account SSI effects and the expected duration of the vibratory motion. If the OBE is set at one third or less of the SSE, an explicit analysis or design is not required. If the OBE is set at a value greater than one third of the SSE, an analysis and design must be performed to demonstrate that the applicable stress, strain, and deformation limits are satisfied. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation level of the structures must be an appropriate response spectrum with a peak ground acceleration of at least 0.1g.
- Section 52.47(b)(1) of 10 CFR, which requires that a 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 DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act (AEA), and NRC regulations.

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

- SRP Section 3.7.2.II, including criteria for (1) seismic analysis methods, (2) natural frequencies and responses, (3) procedures used for analytical modeling, (4) soil-structure interaction, (5) development of in-structure response spectra (ISRS), (6) three components of design ground motion, (7) combination of modal responses, (8) interaction of non-seismic Category I structures with seismic Category I SSCs, (9) effects of parameter variations on floor responses, (10) use of equivalent vertical static factors, (11) methods used to account for torsional effects, (12) comparison of responses, (13) analysis procedure for damping, and (14) determination of seismic overturning moments and sliding forces for seismic Category I structures.
- RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, March 2007.

- RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Revision 3, September 2012.
- RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor Supported Equipment or Components," Revision 1, February 1978.
- DC/COL-ISG-1, "Interim Staff Guidance on Seismic Issues of High Frequency Ground Motion."

3.7.2.4 *Technical Evaluation*

In this section, the staff describes the review of the seismic analysis methods and results for the structures of the APR1400 standard plant. The staff performed its review in accordance with SRP Section 3.7.2 which describes acceptable methods for the seismic analysis and modeling of seismic Category I structures and major plant systems to assure that they accurately and/or conservatively represent the behavior of SSCs during postulated seismic events. Meeting the SRP Section 3.7.2 acceptance criteria provides assurance that seismic Category I systems will be adequately designed to withstand the effects of earthquakes, and thus, will be able to perform their intended safety function. Moreover, meeting these criteria will ensure that the seismic Category I systems will remain functional within applicable acceptance limits under the SSE demands.

DCD Tier 2 Section 3.7.2 describes the seismic analyses methods and models for the seismic Category I structures of the APR1400 standard plant design such as the RCB (which includes the CS and the CIS), the AB, EDGB, and DFOT room. The CS is a pre-stressed concrete structure and the CIS, AB, EDGB, and DFOT room are reinforced concrete structures. Three dimensional finite element models (FEMs) are developed to capture the global and local translational, rocking, and torsional responses of the structures. The NI model includes the RCB and the AB sharing a common basemat. The EDGB and the DFOT room are separated from the NI basemat and also from each other by a 3 ft. gap.

The applicant performed SSI analysis of the seismic Category I structures using the ACS SASSI computer program. Specifically, the direct method of the ACS SASSI analysis program is used. The applicant's site-independent SSI analysis considers a set of 8 generic layered soil profiles and a fixed-base case. For all 9 subgrade media cases, two concrete stiffness cases are analyzed (i.e., cracked and uncracked concrete), totaling 18 analysis cases.

In addition to the design basis SSI analyses, the applicant performed SSSI analyses to evaluate the interaction between adjacent structures. The APR1400 standard plant is also evaluated for hard rock high frequency (HRHF) spectra which have higher spectral acceleration content than the CSDRS for frequencies above approximately 10 Hz.

The staff has performed a detailed review of the DC application, including referenced technical reports relating to seismic analysis. The staff's review is described in the following sections.

3.7.2.4.1 *Seismic Analysis Methods*

DCD Tier 2 Section 3.7.2.1 describes the seismic analysis methods used for the standard plant seismic Category I structures. Specifically this section identified the following analysis methods:

- Response Spectrum Analysis (RSA): The RSA is used to compute the seismic design forces CS and CIS in the RCB using the (ISRS at the top of basemat generated from seismic SSI analysis.
- Time History Methods.
- Modal Superposition: The modal superposition method is used when the equations of motion can be decoupled as given in Subsection 3.7.2.1.1.
- Direct Integration Method: The direct integration method is used to validate the coarse mesh model to be used in the seismic analysis of the NI structures versus fine mesh model under the fixed-base condition.
- Complex Frequency Response Method: The complex frequency response method is used for the SSI and SSSI analyses of seismic Category I structures. This analyses are performed using the direct method of the ACS SASSI computer code.

The aforementioned analysis methods are acceptable for use in accordance with the acceptance criteria in SRP Section 3.7.2.II.1.

In addition to the above, DCD Tier 2, Sections 3.8A.2.3.1 and 3.8A.3.3.1, indicate that the equivalent static analysis method is used to obtain the design member forces for the AB and EDGB, respectively. As per SRP Section 3.7.2.II.1, this method of analysis is acceptable provided it can be demonstrated that the method produces conservative results in terms of responses. Therefore, to assist the staff in its evaluation of the conservatism of the equivalent static method implemented by the applicant, the staff issued RAI 252-8299, Question 03.07.02-12 (ML15293A566), requesting the applicant to provide comparisons of maximum member forces obtained from the equivalent static method to corresponding results from the time history analysis (THA) method (i.e. SASSI analysis), or to RSA results using foundation ISRS from the time history analysis. In its response to RAI 252-8299, Question 03.07.02-12 (ML16126A522), the applicant provided comparisons of maximum story shear forces obtained from the equivalent static and time history analyses for the AB, EDGB and DFOT room. The staff reviewed the analysis comparisons and found that the equivalent static results for these structures conservatively bound the results obtained from time history analysis. On this basis, the staff found the use of the equivalent static method to obtain the member forces for these structures to be acceptable. In its response, the applicant also proposed markups to DCD Tier 2 Table 3.7-22, "Maximum Member Forces of Auxiliary Building," to clarify the description of a number of locations in the AB for which maximum member forces are provided. The staff finds the proposed markups to be consistent with the information in APR1400-E-S-NR-14003 and therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 252-8299, Question 03.07.02-12, is resolved and closed.

3.7.2.4.2 *Natural Frequencies and Responses*

Natural Frequencies

The staff reviewed the natural frequencies and responses (including accelerations, displacements, and member forces) provided by the applicant in accordance with

SRP Section 3.7.2.II.2. DCD Tier 2 Section 3.7.2.2 states that 529, 2500, and 150 modes, and their frequencies were computed for the RCB (including the CS and CIS), AB, and EDGB respectively. DCD Tier 2, Tables 3.7-10 through 3.7-13, show the modal frequencies and participating mass ratios of the first major modes for the CS, CIS, AB, and EDGB respectively. The staff's review of these tables found that the lowest reported vibration mode numbers for the CS, CIS, and AB were 11, 18, and 75, respectively. Based on this information, the nature and mass participation of the modes lower than those reported in the aforementioned DCD Tier 2 tables were not clear to the staff. To address this issue, the staff issued RAI 252-8299, Question 03.07-02-10 (ML15293A566) requesting the applicant to clarify the frequencies and mass participation of the structural vibration modes lower than those reported in the DCD. In its response to RAI, Question (ML16050A273), the applicant provided the frequency and mass participation ratio of the RCB and the AB for 171 modes covering the frequency range of interest for structural design. The staff found the modes lower than those reported in the DCD tables to correspond to vibration modes with minimal mass participation. Further, the staff's review of the applicant's response confirmed that the modes reported in the DCD are the modes with significant mass participation. Additionally, the staff finds that the dominant frequencies are generally consistent with the dominant frequencies of other similar nuclear structures.

Responses

DCD Tier 2, Tables 3.7-14 through 3.7-25, show the seismic responses including maximum absolute nodal accelerations, maximum displacements relative to the top of foundation mat, and maximum member forces for the CS, CIS, AB, and EDGB. The staff found inconsistent information pertaining to the displacement results. Section 3 of APR1400-E-S-NR-14003, indicated a minimum 2 in. seismic gap between the RCB and AB and between the CS and CIS. However, the relative displacement results included in the DCD and Appendix E of APR1400-E-S-NR-14003 showed potential for combined RCB and AB relative displacement in excess of 2 in., which indicated a potential for physical interaction between the RCB and AB. Based on the relative displacement information, the staff issued RAI 183-8197, Question 03.07.02-3 (ML15244B272), requesting the applicant to describe the approach used for determining the adequacy of the seismic gaps between the aforementioned structures and to justify the appropriateness and sufficiency of the minimum 2 in. gap to preclude adverse interaction between these structures during an SSE event.

In its response dated December 31, 2015 (ML15365A580), the applicant provided maximum relative displacements between the RCB and AB and between the CS and CIS for the worst case condition of out-of-phase displacements. These results confirmed the staff's observation of relative displacements in excess of 2 in. between the RCB and AB. Additionally, the applicant clarified the minimum seismic gap of 6 in. between the RCB and AB. The staff review found that the maximum relative displacements for the worst case of out-plane displacements does not exceed the 6 in. seismic gap between the RCB and AB and therefore finds such seismic gap to be acceptable. Similarly, the maximum relative displacements between the CS and CIS do not exceed the 2 in. seismic gap between these structures and therefore, the staff found the seismic gap to be acceptable. Consistent with its response, the applicant proposed markups to the DCD and technical report to clarify the seismic gap of 6 in. between the RCB and AB, which the staff finds acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 183-8197, Question 03.07.02-3, is resolved and closed.

In addition to the responses discussed above, DCD Tier 2 Appendix 3.7A (Figures 3.7A-15 through 3.7A-93), provides ISRS at several locations (23 locations) in the RCB, AB, and EDGB. As stated in DCD Tier 2 Section 2.5.2.6 (e), site-specific ISRS (when site-specific analyses are performed) are to be compared with the corresponding ISRS in Appendix 3.7A. This comparison is COL 2.5(5). The staff's evaluation of the ISRS is found in Section 3.7.2.4.5 of this SER.

3.7.2.4.3 *Procedures Used for Analytical Modeling*

In this section, the staff reviewed the criteria and procedures used in the analytical modeling for seismic systems analysis in accordance with SRP Section 3.7.2.II.3. The staff reviewed modeling assumptions related to finite element type, stiffness, mass, and hydrodynamic effects. The staff also reviewed the applicant's process for model validation, and the decoupling criteria for subsystems. In addition, the staff reviewed the method used to address floor and wall flexibility and the method for transferring loads from the dynamic model to the structural design model.

Modeling of Structures

As stated in DCD Tier 2 Section 3.7.2.3, the safety-related structures that are analyzed in the main structural system are the CS, CIS, AB, and the EGDB (including the DFOT Room). The dynamic models of these structures are 3-D finite element models comprised of beam, shell, solid, and spring elements. Specifically, shell elements are used to model the CS cylindrical wall and hemispherical dome, a portion of the walls of the CIS, floor slabs in the RCB, and for the walls, floor slabs, and basemat in the AB. Beam elements are used to model the reactor coolant system (RCS), the polar crane, the vertical load resisting frames in the AB, and at the interface between shell elements and solid brick elements. Solid elements are used to model the RCB basemat, some of the walls in the CIS, and the structural fill granular (SFG) and lean concrete backfill models. Spring elements are used to connect the below grade walls and basemat with the SFG and lean concrete backfill. APR1400-E-S-NR-14002 provides the detailed procedure for the development of the models of the NI structures for dynamic response. DCD Tier 2 Section 3.7.2.3.3.2 states that the EDGB and DFOT room FEMs are individually developed following the procedure used in the development of the AB model. During the audit conducted on June 20-24, 2016, the staff reviewed calculations pertaining to the seismic analysis of EDGB and DFOT Room and confirmed that the procedure used in the development of these models is consistent with the procedure for the AB model.

As described in APR1400-E-S-NR-14002, the applicant developed fine mesh and coarse mesh models of each individual NI structure in ANSYS. To verify that the coarse mesh models adequately capture the dynamic properties of the NI Structures, the applicant compared modal properties (natural frequencies, mass participation, and cumulative modal mass), displacements from static analyses for 1g gravity loads, and ISRS between the coarse mesh models and the fine mesh models. Subsequent to this verification, the individual structure models were combined to create an ANSYS coupled 3D FEM of the NI structures and converted to ACS SASSI format for use in SSI analyses. To verify the ACS SASSI model, the applicant compared ISRS obtained from the ACS SASSI analysis with subgrade media simulating a fixed-base condition and the corresponding ISRS obtained from ANSYS fixed-base time history analysis. The staff reviewed the aforementioned comparisons of dynamic properties and analysis results

and found them to consistently show close agreement between the models with respect to the global response of such structures.

Pertaining to local structural response, such as that of individual floor panels or walls, as described in Section 4.2.6 of APR1400-E-S-NR-14002, the applicant conducted a study to identify any property adjustments that are needed in floor panels in the coarse model to obtain the same out-of-plane vertical flexibility of the respective floor panels in the fine model. Specifically, the applicant states that if the fundamental frequency of a fine mesh floor panel in the study is lower than 50 Hz and is 5 percent greater than that of the coarse mesh floor panel, the modulus of elasticity of the panel in the coarse model is adjusted to match that of the fine model. Based on staff experience, modulus of elasticity adjustments to match dynamic properties between coarse and fine models is a common practice for seismic analysis models. Additionally, the staff finds the selection of frequencies for adjustment based on a 5 percent variation in frequency value to be conservative. However, based on Table 4-8 in APR1400-E-S-NR-14002, which compares the floor panel frequencies for coarse and fine models it was not clear to the staff why the coarse model frequencies were consistently lower than the fine model frequencies.

The staff issued RAI 252-8299, Question 03.07.02-10 (ML15293A566), requesting the applicant to explain the reason for such a trend in coarse and fine model frequencies. In its response to RAI 252-8299, Question 03.07.02-10 (ML16050A273), the applicant provided the results of a parametric study of finite element mesh size to confirm the trend shown in the aforementioned Table 4-8. The applicant performed modal analysis of a square panel varying the mesh size and shell element type. The applicant reported the natural frequencies for several plate bending modes, which indicated that the vibration frequency convergence with mesh refinement can be from higher or lower frequency values, depending on the specific shell element type used for modeling. The study also showed consistent converged vibration frequency values for both types of shell elements. The staff reviewed the applicant's results and concluded that it confirmed the frequency trend shown in Table 4-8. Based on the above, the staff finds the adjustments made to the coarse floor panel dynamic properties in order to match those of the fine model acceptable.

APR1400-E-S-NR-14002 described the aforementioned coarse model adjustments pertaining to out-of-plane flexibility of floor panels. However, the report did not discuss out-of-plane flexibility of walls. During biweekly public conference calls, and the audit conducted on June 20-24, 2016, the staff discussed with the applicant pertinent aspects to fully verify the adequacy of the ANSYS coarse model mesh to accurately capture out-of-plane response of walls. In its supplemental response to RAI 252-8299, Question 03.07.02-10, (ML16222A410), the applicant identified AB walls with fundamental frequencies lower than 50 Hz using classical plate vibration formulas. For the identified walls, the applicant performed modal analyses of ANSYS fine and coarse mesh partial wall models. In its response the applicant summarized the fundamental frequencies, dimensions, and the mesh sizes for these walls. The staff verified that the fundamental frequencies of the coarse mesh wall models closely matched the fundamental frequencies of the fine mesh models. In addition, for those walls with relatively largest difference in fundamental frequencies (maximum difference of about 10 percent), the applicant compared the ISRS generated from the center nodes. The ISRS comparisons showed consistent response between the coarse and fine models and in some cases a conservative response obtained from the coarse model. In addition to these comparisons, the applicant compared ISRS from the ANSYS coarse model and the ACS SASSI model for a subset of the

identified walls with the coarser mesh sizes. These comparisons also showed a consistent response between both models with higher spectral peaks obtained from the ANSYS model in some cases. In its response, the applicant discussed that the differences in spectral peak amplitude are attributed to the different damping formulations for ACS SASSI and ANSYS, namely, constant hysteretic damping and Rayleigh (frequency dependent) viscous damping, respectively. The staff reviewed the applicant's discussion of the differences observed in spectral peak amplitude and finds that the different damping formulations for ACS SASSI and ANSYS adequately justify the differences in spectral peak amplitude because the Rayleigh damping in the ANSYS model is lower than the ACS SASSI hysteretic damping, thereby resulting in higher spectral peak amplitudes in ANSYS. Based on the above, the staff finds that the applicant's ANSYS and SASSI models adequately capture the local response of floor panels and walls. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 252-8299, Question 03.07.02-10, is resolved and closed.

APR1400-E-S-NR-14002 describes that at the transition between shell and solid elements, either massless shell elements are extended into the concrete volume or rigid beams are added at the transition of these elements, in order to maintain rotational compatibility and proper moment transfer. However, in its review of this technical report, the staff did not find a description of how this is accomplished between beam and solid elements. Such transitions take place for example at the connections between the RCS model and CIS model. Therefore, the staff issued RAI 252-8299, Question 03.07.02-7 (ML152923A566), requesting the applicant to provide a description in the technical report addressing the process to ensure rotational compatibility and proper moment transfer between beam elements and solid elements. In its response to RAI 252-8299, Question 03.07.02-7 (ML16050A273), the applicant described the use of rigid beam elements to connect the RCS beam element to the CIS solid element. The applicant also proposed markups to APR1400-E-S-NR-14002 addressing the connections between the RCS model and CIS model. The staff reviewed the applicant's approach for transition between shell elements and solid elements, as described in APR1400-E-S-NR-14002 and additional information in the above applicant response, related to the transition between beam elements and solid elements, and found them to be consistent with element transitions used in the analysis of other similar nuclear structures. On this basis, the staff concluded that the applicant's models adequately addressed the transition of beam and shell elements to solid elements.

Consideration of Concrete Cracking

SRP Section 3.7.2.II.3C.iv identifies that the effect of concrete cracking should be considered in the mathematical model, as appropriate. One approach for considering cracked concrete properties is to reduce the stiffness properties of the uncracked members by a reduction factor. Per SRP Section 3.7.2.II.3.iv, acceptable reduction factors are given in ASCE/SEI 43-05. In Sections 3.2.2 and 4.2.2 of APR1400-E-S-NR-14002 for the RCB and AB respectively, the applicant references ASCE/SEI 43-05 as the basis for their consideration of cracked concrete properties. Table 3-3 for the RCB, and Tables 4-3 and 4-4 for the AB, summarize the cracked concrete stiffness properties used in the models for seismic analysis. The staff reviewed these cracked concrete stiffness properties and found them to be consistent with the criteria in ASCE/SEI 43-05, and therefore acceptable. Additionally, in generating the standard design ISRS, the applicant enveloped the ISRS obtained from 9 site soil cases (including a fixed-base condition) for both cracked concrete with respective SSE damping and uncracked concrete with

respective OBE damping. The staff finds the applicant's consideration of concrete cracking in developing ISRS to be conservative and acceptable to satisfy the criteria in SRP Section 3.7.2.II.3.iv.

Decoupling Criteria for Subsystems

DCD Tier 2 Section 3.7.2.3.2 provides the criteria for decoupling subsystems from the main structural system. RCS and the polar crane are analyzed using a coupled model with the primary structure. The staff finds the inclusion of these subsystems as part of the main structural model to be consistent with common modeling practice for developing these subsystems. Further, the staff finds the applicant's decoupling criteria for subsystems to be in accordance with SRP Section 3.7.2.II.3.B and therefore, acceptable.

Modeling of Mass

SRP Section 3.7.2.II.3D provides the acceptance criteria regarding the representation of floor loads, live loads, and major equipment in a dynamic model. In addressing these SRP criteria, DCD Tier 2 Section 3.7.2.3.3 includes a description of masses that are assumed to contribute to the inertial forces in the seismic analyses. However, this DCD section did not specify the magnitude of such masses. For example, based on the description in DCD Tier 2 Section 3.7.2.3.3, it could be inferred that 100 percent of the live load is used in the seismic load case. The staff's review finds that Section 3.2.5 and Table 4-7 in APR1400-E-S-NR-14002, for the RCB and AB, respectively, provide additional information on the magnitude of the masses described in DCD Tier 2 Section 3.7.2.3.3. Section 3.2.5 in APR1400-E-S-NR-14002 states that 25 percent of floor live load or 75 percent of snow load are applied on the roof of the containment which appears to conflict with DCD Tier 2 Section 3.7.2.3.3. Based on these two statements it was not clear to the staff what floor live load has been considered on all floors of the RCB. The staff issued RAI 252-8299, Question 03.07.02-7 (ML15293A566), requesting the applicant to clarify in the DCD how the SRP Section 3.7.2.II.3D criteria regarding floor loads is addressed in the models used for seismic analysis. In its response to RAI 252-8299, Question 03.07.02-7 (ML16050A273), the applicant clarified that the floor masses for the RCB and AB are consistent with SRP Section 3.7.2.II.3D criteria with the exception of seismic live load not being considered for the floors in the seismic model of the RCB. Further, the applicant provided a qualitative basis for neglecting the seismic live load in the RCB. The staff reviewed the basis provided by the applicant and found that it contain insufficient details to justify the exclusion of seismic live load in the seismic model for the RCB. During biweekly public conference calls, and an audit conducted on June 20-24, 2016, the staff discussed with the applicant pertinent aspects to verify the effect of neglecting the seismic live load in the seismic model for the RCB. In addition to the consideration of seismic live loads, these discussions addressed floor slabs in the RCB that are not explicitly modeled in the seismic model of the RCB. These slabs, located between the secondary shield wall (SSW) and CS at EL 114'0", 136'-6", and 156', were indicated in DCD Tier 2 Section 3.8A.1.4.3.1.3 to be modeled as mass. The staff requested additional analysis and design information pertaining to these slabs in RAI 208-8245, Question 03.08.03-5, which is discussed in Section 3.8.3 of this SER.

Additionally, in its supplemental response to RAI 252-8299, Question 03.07.02-7 (ML16294A567), the applicant described the consideration of the floor masses related to these floor slabs in the seismic model of the RCB which the applicant indicated to be lumped onto the SSW. The applicant justified such distribution of mass based on the connection details at both

the SSW and CS, indicated by the applicant to be completely connected to the SSW and having a sliding connection at the CS. The sliding connection at the CS provides support in the vertical direction without restricting movement in the horizontal and radial directions. Based on the connection detail at the CS, part of the vertical slab mass could be lumped into the CS; however, the staff finds that distributing part of the vertical mass to the CS would have negligible effects on the CS and SSW fundamental frequencies, based on the mass ratios (slab/wall) provided in the response to RAI 208-8245, Question 03.08.03-5. On this basis, the staff found the applicant's distribution of all slab mass to the SSW to be acceptable.

In its response to the staff's concerns pertaining to the seismic live load discussed above, the applicant performed an analysis of the RCB with the inclusion of seismic live load and compared ISRS obtained from such analysis with the corresponding ISRS obtained from the original RCB analysis. In its supplemental response to RAI 252-8299, Question 03.07.02-7 (ML16294A567), the applicant described its analysis and ISRS comparisons. The staff's review of the ISRS comparisons agrees with the applicant's conclusion that the variation of ISRS due to the consideration of the seismic live load in the RCB seismic analysis model is negligibly small. On this basis, the staff found the results obtained from the design basis seismic model of the RCB without the seismic live load to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 252-8299, Question 03.07.02-7, resolved and closed.

Pertaining to the RCS and hydrodynamic masses of water tanks, in Section 3.2.5, Section 3.2.7, and Section 4.2.9 in APR1400-E-S-NR-14002, the applicant discusses that the weight of the RCS, the IRWST hydrodynamic masses (i.e. both impulsive and convective masses), and hydrodynamic masses for the auxiliary feed water (AFW) and fuel handling area (FHA) tanks are included in the FEMs for use in SSI analysis. However, Section 6.1 of APR1400-E-S-NR-14003, indicated that the RCS masses and the convective (sloshing) hydrodynamic masses for the first and second horizontal sloshing modes of IRWST were not included in the maximum building seismic response forces and moments from the SSI analysis. The consideration of these masses in the seismic analysis was unclear to the staff. To confirm adequate consideration of the above masses and related effects in the seismic analysis and design, the staff issued RAI 226-8235, Question 03.07.02-5, requesting the applicant to provide the basis associated with modeling of convective masses and a description of the process for developing design loads that correspond to the RCS and hydrodynamic masses and how these loads were combined with the seismic design loads. In its response to RAI 226-8235, Question 03.07.02-5 (ML15358A068), the applicant described that the RCS masses and the hydrodynamic masses for the IRWST, AFW, and FHA tanks are included in the FEMs used in the SSI analysis. The applicant stated that RCS masses are included in the models through modeling the major RCS components. The inclusion of the RCS in the seismic model is consistent with acceptance criteria in SRP Section 3.7.2.II.3.B, and therefore, the staff finds the response acceptable. Further, the applicant provided the basis for developing the hydrodynamic properties of equivalent mechanical models addressing the impulsive and convective parts of the water in the above mentioned tanks. The impulsive masses are attached rigidly to the lower portion of the tank walls and the convective masses are attached to the upper portion of tank walls with flexible beam/spring elements. In the vertical direction, the water mass is lumped at the bottom slabs of each tank. The staff's review of the applicant's response and information provided in APR1400-E-S-NR-14002 found the applicant's inclusion of hydrodynamic masses into the seismic model to be consistent with the acceptance criteria in SRP Section 3.7.3.II.14, and therefore, the staff finds the response acceptable. However, the

staff's review found the applicant's response to contain insufficient details pertaining to the seismic design loads for the above tanks.

The staff discussed the above issue with the applicant during a public meeting on January 27, 2016. Additionally, the staff reviewed detailed calculations pertaining to the modeling of hydrodynamic masses and development of seismic design loads for the above tanks during the audit conducted on June 20-24, 2016. During the audit, the staff confirmed that the seismic design forces and moments for the IRWST are obtained from RSA of the CIS using peak broadened in-structure responses spectra that envelop all the SSI analysis cases. The model used in this analysis includes the RCS model and the water mass conservatively considered as impulsive mass. Similarly the equivalent static analysis of the AB which includes the AFW and FHA tanks, conservatively considers the water mass in these tanks as impulsive mass. This analysis is performed using equivalent accelerations computed from the building story shears obtained from the SSI analyses. In addition, local structural analyses considering both the impulsive and convective pressures of water are carried out for the AFW and FHA tanks. The hydrodynamic pressures for impulsive and convective modes are calculated in accordance with TID-7024 and ACI 350.3. During the June 20-24, 2016 audit, the staff reviewed these local structural analyses and, because of the conservatism included, found them to be appropriate and acceptable.

In its supplemental response to RAI 226-8235, Question 03.07.02-5 (ML16215A188), the applicant described details pertaining to the consideration of hydrodynamic effects and development of seismic design loads for the aforementioned tanks, consistent with the above discussion, including proposed markups for Section 6.1 in APR1400-E-S-NR-14003. Based on the above discussion, the staff finds the applicant's consideration of hydrodynamic effects and development of seismic design loads for the aforementioned tanks to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 282-8238, Question 03.07.02-5, is resolved and closed.

Seismic loads for use in structural design model

DCD Section 3.7.2.1.1 states that RSA is used to compute the seismic design forces of the CS and CIS in the RCB using the ISRS at the top of basemat generated from seismic SSI analysis. DCD Sections 3.8A.2.3.1 and 3.8A.3.3.1, for the AB and EDGB respectively, indicate that an equivalent static method of analysis is performed to obtain the member forces for these structures. The staff issued RAI 183-8197, Question 03.07.02-2 (ML15244B272), and RAI 252-8299, Question 03.07.02-12 (ML15293A566), requesting the applicant to provide comparisons between RSA and SSI analysis results and between equivalent static analysis and SSI analysis results, respectively. In its responses to RAI 183-8197, Question 03.07.02-2 (ML16210A514) and RAI 252-8299, Question 03.07.02-12 (ML16126A522), the applicant provided these comparisons for RSA and equivalent static analysis results, respectively. The comparison of results showed that the seismic loads obtained from the RSA and equivalent static analysis conservatively bound the corresponding loads obtained from the SSI analysis. Based on the conservative response obtained from the RSA and equivalent static analysis, the staff concludes that the method employed to transfer the aforementioned seismic responses from the dynamic model to use as input to the structural design model is acceptable. The staff's review of the responses to the above RAIs is further discussed in Sections 3.7.2.4.1 and 3.7.2.4.12 of this report.

3.7.2.4.4 *Soil-Structure Interaction*

The staff reviewed the modeling methods used in the seismic system analysis to account for SSI effects in accordance with SRP Section 3.7.2.II.4. DCD Tier 2 Section 3.7.2.4 states that ACS SASSI program is used for the SSI analyses of seismic Category I structures. SASSI is a linear analysis code that performs time history analysis in the frequency domain using a substructuring technique. These analyses use the ACS SASSI flexible volume method (i.e. the direct method). The use of the direct method of analysis is acceptable to the staff per SRP Section 3.7.2.II.4, which states that the direct method should be used to the extent practical to perform the SSI analysis of embedded structures. The details of these analyses are summarized in DCD Appendix 3.7A and APR1400-E-S-NR-14003.

As stated on DCD Tier 2 Section 3.7A.1, the applicant performs 3D SSI analyses using as input a set of three statistically independent CSDRS compatible time histories (E-W, N-S, and Vertical). The characteristics of the time histories are evaluated in SER Section 3.7.1. These time histories, per DCD Tier 2 Section 3.7.2.6 and Section 6 of APR1400-E-S-NR-14003, are applied separately in the SASSI analyses. The applicant's SSI analyses considered eight generic site profiles ranging from soft soil site profile with an average shear wave velocity of 1,200 fps to hard rock profile with average shear wave velocity of 9,200 fps. A fixed-base analysis case was also considered by defining the shear and compression wave velocities of the foundation medium with high values, namely 20,000 fps and 50,000 fps for shear and compression wave velocities, respectively. The SSI analyses are performed considering the soil embedment of the seismic Category I structures. Table 3.7-8 provides the embedment depth for the seismic Category I structures. Additionally, these SSI analyses considered two levels of structural stiffness, based on cracked and un-cracked reinforced concrete properties. A total of 18 SSI cases were analyzed (i.e., 9 site profile cases times 2 levels of structural stiffness).

In addition to the design basis SSI analyses, the applicant performed SSSI analyses to evaluate the interaction between adjacent structures. These SSSI analyses are summarized in technical report APR1400-E-S-NR-14005 and are evaluated in this SER section and SER Section 3.7.2.4.8.

Using ACS SASSI, the applicant also performed analysis of hard rock high frequency (HRHF) spectra representative of the CEUS hard rock sites, with consideration of spatial incoherence of ground motion. The staff's evaluation of the applicant's HRHF analysis is included below in this SER section.

Separation of Soil from Sidewalls

Per SRP Section 3.7.2.II.4, to ensure proper implementation of SSI methodologies, the staff reviews sensitivity studies performed by the applicant to evaluate the effects of important parameters including potential foundation uplift, and separation and sliding of soil from sidewalls. The applicant's study of potential foundation uplift is documented in APR1400-E-S-NR-14006 and discussed below in this SER section. However, the staff's review did not find descriptions of other studies such as separation and sliding of soil from sidewalls. Therefore, the staff issued RAI 252-8299, Question 03.07.02-11 (ML15293A566), requesting the applicant to provide a description of its consideration of sensitivity studies.

In its response to RAI 252-8299, Question 03.07.02-11 (ML16222A403), the applicant described their sensitivity study for the potential separation of soil from sidewalls and provided pertinent results. In its study the applicant performed SSI analyses of the NI with S1 and S9 soil profiles (i.e. representing soft soil and hard rock cases). For the analysis, the rigid spring which connect the backfill nodes to the structure nodes were removed from the ACS SASSI NI model. The applicant determined the separation depth of the soil from sidewalls according to the criteria in ASCE 4-98, Section 3.3.1.9 "Embedment Effects." This is acceptable to the staff. In the SSI analyses performed for the sensitivity study, both cracked and uncracked concrete stiffness cases were analyzed, and the enveloped ISRS obtained from the sensitivity study were compared to the respective ISRS obtained from the original SSI analyses (which assume no soil separation). The staff's review of these comparisons found the original ISRS to generally bound the corresponding ISRS from the analyses that allow soil/wall separation, except for limited number of locations and frequencies. The more noteworthy exceedances are for the AB ISRS with S9 case. To address the limited number of higher spectral acceleration amplitudes, the applicant also compared the ISRS from the study for the S1 and S9 cases with the original envelop for all soil cases including the fixed-base case. As indicated by the applicant, the governing case for the AB included in the original ISRS envelop is the fixed-base case, which is not affected by the separation of soil from sidewalls. The comparisons with the original envelop including the fixed-base case showed that the original envelop bounds the ISRS for both the S1 and S9 case with soil separation. On this basis, the staff concluded that soil separation from below grade walls does not change the enveloped seismic response for the APR1400 standard design, and therefore finds the assumption of no soil separation in the design basis analyses to be acceptable. Therefore, RAI 252-8299, Question 03.07.02-11, is resolved and closed.

SSI Model Passing Frequency

As per DC/COL-ISG 1, SSI models should be sufficiently refined to provide accurate results up to at least 50 Hz. In DCD Table 3.7A-10 the applicant provided the wave-passing frequencies for the 8 soil cases and the fixed base case used for SSI analysis (i.e. the maximum frequencies that the soil media can transmit without loss of accuracy in the solution). The staff's review finds that for softer soil cases, the wave-passing frequencies are lower than 50 Hz. To verify the adequacy of SSI models with such passing frequencies, the staff reviewed the individual ISRS for both cracked and uncracked concrete cases, for all 8 soil cases and the fixed base case, provided in the applicant's response to RAI 252-8299, Question 03.07.02-9. The staff found that, in general, the ISRS envelop above about 9 Hz is governed by the stiffer soil cases or the fixed-base case, which have wave passing frequencies greater than 50 Hz; 9 Hz is about half the lowest wave passing frequency, which is associated with the softest soil profile (S1). Since the design basis consists of the envelope of all cases, and the stiffer soil cases or the fixed base case with wave passing frequencies greater than 50 Hz govern the response above 9 Hz, the staff concluded that, taken as a group, the passing frequencies in the SSI models are adequate and meet the criteria in DC/COL-ISG 1.

Ground Water Effects

As described in Section 4.3 of APR1400-E-S-NR-14003, for the APR1400 standard plant design, the design groundwater table elevation is 2 ft. below the ground surface at El. 96'-8" and the extreme groundwater table elevation considered in the design is at a ground surface of El. 98'-8". To simulate saturated soil conditions, a value of Poisson's ratio approaching 0.5 is used. Specifically, the applicant used values as high 0.47 and 0.48 as shown in

DCD Tier 2 Tables 3.7A-1 and 3.7A-2 for soil profiles S1 and S2, respectively. Based on staff experience, use of Poisson's ratio approaching these values may result in numerical instability of the SSI analysis results. This is a highly case-dependent issue. To address this issue, the staff issued RAI 252-8299, Question 03.07.02-7 (ML15293A566), requesting the applicant to provide a demonstration (e.g. sensitivity study) that the assumed Poisson's ratio values do not produce numerical instabilities in the SSI results based on these profiles. In its response to RAI 252-8299, Question 03.07.02-7 (ML16222A410), the applicant described its sensitivity study of Poisson's ratio effects for the NI model with S1 and S2 soil profiles and provided pertinent results. In its sensitivity study, the applicant modified the Poisson's ratio values for the S1 and S2 soil profiles (which have the maximum Poisson's ratio values of 0.47 and 0.48) to have maximum Poisson's ratio values of 0.45 and 0.42 (i.e. for each soil profile). The applicant performed SSI analyses of the NI models with the modified S1 and S2 soil cases for both cracked and uncracked concrete cases. Based on these analyses, the applicant obtained transfer function results at the bottom of the NI basemat and at plant grade elevation and compared such results with the respective results obtained from the original SSI analyses. The staff reviewed the comparisons and agrees with the applicant's conclusion that the transfer functions obtained with their sensitivity study are similar and comparable to the respective transfer functions obtained from the original SSI analyses. Moreover, the staff did not observe abrupt changes, spurious peaks or other indications of numerical instabilities in the original SSI transfer functions nor the transfer functions from the sensitivity study. On this basis, the staff concludes that the original Poisson's ratios used in the applicant's design basis analysis are adequate for the APR1400 standard design and therefore acceptable.

Basemat Uplift

The staff reviews the calculation of ground contact ratio to ensure that foundation uplift does not adversely affect the linear SSI analysis results, according to the guidance in SRP Section 3.7.2.II.4. As stated in this SRP section, the ground contact ratio is defined as the minimum area of the foundation in contact with the soil divided by the total area of the foundation, computed in each time step throughout the SSI analysis. The acceptance criterion is that linear SSI analysis methods are appropriate if the ground contact ratio is equal to or greater than 80 percent. The ground contact percent is calculated from the linear SSI analysis, using the minimum basemat area that remains in compression with the soil. If the ratio is less than 80 percent, then the effect of the nonlinearity due to the foundation uplift should be evaluated.

In Sections 4.1.1 and A.4.1.1 of APR1400-E-S-NR-14006, Revision 1, the applicant described the ground contact ratio calculation for the NI common basemat and EDGB/DFOT room basemats, respectively. Further, Tables 4-1 and A-2 of the report provide the calculated ground contact ratios for the NI common basemat and EDGB/DFOT room basemats, respectively. The applicant's initial ground contact ratio calculations appeared to be calculated by a method that deviates from the criteria in SRP Section 3.7.2.II.4. To assess the adequacy of the applicant's ground contact ratio calculation, the staff issued RAI 183-8197, Question 03.07.02-4 (ML15244B272), requesting the applicant to clarify whether the specified ground contact ratios represent the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation, computed in each time step throughout the SSI analysis time history. If this was not the case, the staff requested the applicant to provide the technical basis for the adequacy of the alternate method used to calculate the ground contact ratio, as applicable. In its response to RAI 183-8197, Question 03.07.02-4 (ML16029A048), the applicant indicated that

the original ground contact ratios were calculated using the structural analysis results instead of the seismic SSI analysis results. Further, the applicant described additional ground contact ratio calculations and pertinent results for the NI structures, which the staff found insufficient to justify the adequacy of the applicant's ground contact ratio calculation or consistency with the criteria in SRP Section 3.7.2.II.4. Further, the applicant's response pertaining to the additional ground contact ratio calculations did not address the EDGB and DFOT room. The staff and applicant discussed the applicant's ground contact ratio calculation during biweekly public conference calls and an audit conducted on June 20-24, 2016.

In its supplemental response to RAI 183-8197, Question 03.07.02-4 (ML16232A598), the applicant presented alternate ground contact ratio calculations for the NI, the EDGB, and DFOT room. These calculations were performed using SSI analysis results. The applicant evaluated the stresses at the bottom of the basemats for the NI, the EDGB, and DFOT room throughout the entire duration of the SSI analysis and combined them with stresses obtained from static load analysis. The static load analysis included dead load, 25 percent of design live loads, and buoyancy load due to groundwater. From the combination of stresses from the static analysis and those obtained from the SSI analysis, for each respective structure, the applicant obtained the minimum contact ratios of the area of the basemat in contact with the soil to the total area of the basemat. The staff found that the applicant's method for calculating the ground contact ratio as described in its supplemental response to RAI 183-8197, Question 03.07.02-4, is consistent with SRP Section 3.7.2.II.4, and therefore, the staff finds the response acceptable. Further, the resulting ground contact ratios for the NI, the EDGB, and DFOT room are greater than 80 percent which meets the criteria in SRP Section 3.7.2.II.4. Based on the above, the staff concludes that the applicant has adequately justified the use of linear SSI methods and demonstrated that foundation uplift does not adversely affect the linear SSI results. Based on the review of the DCD and APR14006-E-S-NR-14006, Revision 4, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 183-8197, Question 03.07.02-4, is resolved and closed.

SSSI Effects

APR1400-E-S-NR-14005 describes the applicant's evaluation of SSSI effects. The SSSI analyses used the same 3D finite element models used in the SSI analysis for the NI structures, the EDGB and DFOT room. In addition, these analyses include 3D models of the TGB and CB. The aforementioned structures are separated from each other by a gap of 3 ft. The analysis cases considered for the SSSI analyses included soil profiles S1 and S9, selected to represent the soft and hard soil cases, respectively. Given the size of the coupled SSSI model (i.e. 3D model including all the structures), the SSSI analyses were initially performed assuming no embedment (i.e. surface-supported structures). To validate the surface-supported assumption and enable assessment of SSSI effects based on this assumption, the applicant performed additional SSI analyses for the stand-alone structures using surface-supported SSI models. APR1400-E-S-NR-14005, Figures 4-7 through 4-9, show ISRS for the design basis embedded standalone structure case, and Figures 4-10 through 4-12 show ISRS for surface-supported standalone structure case, in order to validate the surface-supported assumption. These figures consistently show that the ISRS for the surface-supported structure bound the ISRS for the embedded structure.

The ISRS (SSI and SSSI based ISRS) comparisons to assess SSSI effects based on the surface-supported assumption are provided in Figures 5-1 through 5-96 of

APR1400-E-S-NR-14005. For the surface-supported assumption, the staff found that the ISRS from the SSI analysis of the NI structures largely envelop the corresponding ISRS from the SSSI analysis. However, the SSSI analysis for soft soil case S1 showed noticeable exceedances in the vertical ISRS for the EDGB. Such response was not observed for the hard soil case (i.e. S9 soil case). Therefore, to further assess the effects on the EDGB the applicant performed additional SSSI analyses using soil profiles S2, S3, and S4. The SSSI analysis results for the additional soil cases were evaluated in terms of both ISRS and maximum structural response forces.

In terms of ISRS, the applicant developed ISRS amplification factors based on the ratio of the enveloped ISRS for the EDGB obtained from the SSSI analyses to the enveloped ISRS obtained from the individual SSI analyses using the stand-alone EDGB model for soft soil cases, S1 through S4. These amplification factors are used to increment the design-basis ISRS for both the EDGB and DFOT room for soft soil cases, S1 through S4. Prior to the application of these factors, any ratio lesser than 1.0 were modified to 1.0 in order to prevent reduction of the design basis ISRS.

In terms of the structural response forces, the SSSI effects result in increased vertical forces for the EDGB and DFOT room for the envelop of the SSSI results for soil profiles S1 through S4, compared to the envelop of the SSI results for soil profiles S1 through S4. However, the applicant showed that the increased forces for these cases are bounded by the design-basis structural response forces corresponding to the fixed-base condition. Therefore, SSSI does not increase the design-basis structural response forces for the EDGB and DFOT room.

To further assess potential SSSI effects, the staff issued RAI 226-8235, Question 03.07.02-6 (ML15296A001), requesting the applicant to provide analysis results with consideration of embedment. The staff's concern was that additional coupling can occur through soil acting on the embedded sidewalls of the adjacent structures. Based on the staff's experience, neglecting such coupling, by analyzing the structures as surface-supported, could potentially underestimate the magnitude of the interaction effects and the pressure distributions on the embedded walls.

In its response to RAI 226-8235, Question 03.07.02-6 (ML16252A476), the applicant described its SSSI analyses and respective results, including ISRS, relative displacements, and soil pressures on below grade walls, based on the embedded foundation configuration for the combined model of the NI and EDGB/DFOT room. The staff's review of the ISRS comparisons for the NI structures found that the SSI ISRS are generally in very close agreement with or greater than the SSSI ISRS. Based on these ISRS comparisons and the aforementioned ISRS comparisons for the SSSI analysis with surface-supported assumption, the staff concludes that the seismic response of NI structures is not adversely affected by SSSI effects with adjacent structures.

In contrast, the ISRS comparisons for the EDGB and DFOT room showed significant increases of the SSSI based ISRS relative to the SSI based ISRS. To account for the SSSI effects (based on the embedded foundation condition) on the seismic response of the EDGB and DFOT room, the applicant developed a new set of amplification factors to amplify the design-basis ISRS of the EDGB and DFOT room for all soil cases. Consistent with the amplification factors for the surface-supported condition, ISRS ratios that were less than 1.0 were modified to 1.0 in order to prevent reduction of the design-basis ISRS. Additionally, the applicant compared the

amplification factors from the SSSI analyses considering the embedded foundation with those corresponding to the surface-supported condition, and used the larger one at each frequency point to amplify the enveloped (S01~S09 and cracked/uncracked) ISRS from the SSI analyses. The staff finds the use of the larger amplification factor between those corresponding to the surface-supported condition and those from the embedded foundation condition, to amplify the design-basis ISRS, to be conservative and acceptable. However, given the increase response based on the SSSI analysis, including increases in ZPA, it was not clear to the staff whether changes in design-basis seismic forces are necessary according to the increases in ZPA of the EDGB and DFOT room.

To address this concern, in its supplemental response to RAI 226-8235, Question 03.07.02-6 (ML17095B030), the applicant provided ratios of seismic equivalent accelerations obtained from the SSSI and SSI analysis. The seismic equivalent accelerations are those used in the structural design equivalent static analysis of the EDGB and DFOT room. The equivalent acceleration ratios showed that in general, the equivalent acceleration ratios from the SSI analysis bound those from the SSSI analysis. Some of the results showed minimal exceedances of the SSSI equivalent acceleration over the SSI equivalent accelerations. The staff found these exceedances to be negligible on the basis that the ratios of the resulting story shear forces between the equivalent static analysis and the SSI analysis, provided in the applicant's response to RAI 252-8299, Question 03.07.02-12 (ML16126A522), largely bound the equivalent acceleration ratios between the SSSI and SSI analyses. Therefore, the staff concluded that no changes in design-basis seismic forces due to SSSI effect were necessary.

In its response to RAI 226-8235, Question 03.07.02-6, the applicant also addressed the relative displacements and lateral earth pressures on below grade walls calculated from the SSSI and SSI analyses. In terms of the relative displacements, the applicant described that the maximum relative displacement is less than 0.2 ft. The staff notes that such displacement is significantly lower than the 3 ft. seismic gap between the NI and adjacent structures. On this basis, the staff concludes that the 3 ft. seismic gap is adequate to preclude adverse impact between these structures. In term of the lateral earth pressures on below grade walls, the applicant provided comparisons of lateral pressures generated from the SSSI and SSI analyses. The applicant calculated the lateral earth pressures along the embedded walls at each time history step. These pressures are calculated from the co-directional forces (i.e. absolute value of the forces) obtained from the three orthogonal components of seismic input motion. Further, the applicant conservatively selected the maximum pressure throughout the entire time history as the lateral earth pressures for different elevations along the embedment. This is conservative because the maximum pressures at different elevations along the embedment depth do not occur at the same time step. The staff finds the lateral earth pressures to be acceptable because they are calculated from SSI and SSSI analyses with adequate consideration of three components of input motion and are conservatively developed as described above. In its response, the applicant also discussed that the lateral soil pressures computed from the SSSI and SSI analyses are higher than the dynamic earth pressure calculated in accordance with ASCE 4 which was used in the design of below grade exterior walls. Based on these results, the applicant reevaluated the structural design of exterior embedded walls to consider the calculated maximum lateral soil pressures from the SSSI and SSI analyses. As indicated in the applicant's response to RAI 226-8235, Question 03.07.02-6, the details of structural design of the exterior embedded walls with consideration of the calculated maximum lateral soil pressures are described in the response to RAI 227-8274, Question 03.08.04-7. The staff's evaluation is found in SER Section 3.8.4.

As described above, the staff reviewed the applicant's SSSI analyses including surface-supported and embedded foundation cases and respective results in terms of ISRS, design forces, relative displacements, and lateral earth pressures on exterior embedded walls. As described above, the staff concludes that the applicant has adequately addressed SSSI effects on the design basis seismic response of the NI and adjacent seismic category I structures obtained from SSI analysis, including modifications as necessary of the design basis SSI seismic response to account for the SSSI effects. Based on the review of the DCD and APR14006-E-S-NR-14005, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, RAI 226-8235, Question 03.07.02-6, is resolved and closed.

Evaluation of Effects of Hard Rock High Frequency Response Spectra on SSCs

The seismic analysis and design of the APR1400 standard plant are based on the CSDRS described in DCD Tier 2 Section 3.7.1.1.1. Additionally, the APR1400 standard plant is evaluated for the effects of HRHF spectra. The HRHF spectra for the APR1400 is based on EPRI TR-1023389 and is defined as a 0.8-fractile, 5 percent-damped, horizontal composite envelope GMRS for CEUS hard rock sites. The HRHF spectra exceed the CSDRS for frequencies above approximately 10 Hz. DCD Tier 2 Appendix 3.7B and APR1400-E-S-NR-14004, Revision 1, summarize the methodology and results of the evaluation of the effects of HRHF input ground motion on SSCs of the APR1400 standard plant. The following paragraphs describe the staff's safety evaluation of the applicant's SSI analyses of the APR1400 standard plant seismic Category I structures. The staff's evaluation of the effects of the HRHF spectra on Primary components, equipment, and piping is included in SER Sections 3.9.3, 3.10, and 3.12.

The applicant performed SSI analysis of the APR1400 NI, EDGB, and DFOT structures based on the HRHF input and taking into account the effects of spatial incoherence of seismic ground motion. This analysis is based on the SASSI flexible volume method (i.e. the direct method) and as stated in Section 4 of APR1400-E-S-NR-14004, Revision 1, the analysis used Abrahamson's hard-rock coherency function that is based on the recorded Pinyon Flat array data. The applicant used site profile S9. The applicant stated that while both site profiles S8 and S9 could be classified as hard-rock sites based on having shear wave velocities in the same order or higher than the Pinyon Flat site, the site profile S9 was determined to be more critical for this evaluation based on a comparison of site response transfer functions for both sites.

To show the significance of the HRHF spectra, the applicant provided comparisons of ISRS resulting from CSDRS and HRHF input motions in Figures 5-5 through 5-23 in APR1400-E-S-NR-14004, Revision 1. To show the significance of the coherency function used in this analysis, these comparisons included HRHF-based ISRS with and without consideration of spatial incoherence of seismic ground motion (i.e. incoherent ISRS and coherent ISRS respectively). The staff reviewed these ISRS comparisons and found that while the HRHF-based incoherent ISRS generally showed the expected outcome of reduced spectral accelerations in high frequencies, the magnitude of the reductions exceeded the reduction limits set forth in SRP Section 3.7.2.II.4.

Further, DCD Tier 2 Section 3.7B.4, and Section 5.4 in APR1400-E-S-NR-14004, Revision 1, describe the use of 7 spatial coherency modes for capturing the incoherent-motion SSI response of the NI structures based on comparisons with the response obtained by

using 12 modes. The staff reviewed these comparisons, as provided in Appendix B of APR1400-E-S-NR-14004, Revision 1, and found that both the use of 7 modes and 12 modes resulted in greater reductions in the ISRS (above 10 Hz) than the reductions presented in SRP Section 3.7.2.II.4, and that the reductions associated with the 7 mode solution were greater than those associated with the 12 mode solution. Based on the reductions observed in the 7 mode solution and the differences between the 7 mode solution and the 12 mode solution, the staff found the 7 mode solution to provide non-converged results and therefore determined that it was not adequate for capturing the incoherent motion and structural responses for the APR1400 standard plant.

As discussed in Section 5.5 of APR1400-E-S-NR-14004, Revision 1, the aforementioned ISRS comparisons showed that the HRHF-based ISRS (both the coherent and incoherent ISRS) exceed the CSDRS-based ISRS generally in the frequency range above 10 Hz. The applicant stated that these exceedances are addressed as part of the sampling evaluation of representative SSCs also provided in the HRHF report. DCD Tier 2 Section 3.7B.6 describes the general screening criteria used to identify the representative SSCs included in the applicant's evaluation. Consistent with these criteria, the applicant selected areas of the CS, CIS, AB, EDGB, and DFOT room with the potential to experience high seismic shear and moment loads in a seismic event. The evaluation of these representative areas consisted of a comparison of seismic loads and equivalent acceleration from the HRHF spectra to those obtained from the APR1400 design-basis CSDRS. Specifically, in DCD Tier 2 Section 3.7B.7.1 and Section 6.1 of APR1400-E-S-NR-14004, Revision 1, the applicant stated that the NI structures are considered qualified for the high frequency input if the seismic loads and equivalent acceleration from the CSDRS envelope those from the HRHF spectra.

The staff's review of the results provided in Tables 6-1 through 6-3, and Table 6-6 of APR1400-E-S-NR-14004, Revision 1, for the CIS, and EDGB/DFOT room, respectively, found that generally the HRHF-based results exceeded the CSDRS-based results. Furthermore, the staff notes that while the applicant documented these exceedances in Section 6.1 of APR1400-E-S-NR-14004, Revision 1, the report lacked justification for their acceptance. Based on the results provided and lack of justification, the staff did not have sufficient basis to conclude that the APR1400 standard plant structures are qualified for the applicant's HRHF input motions.

To address the aforementioned issues, the staff issued RAI 183-8197, Question 03.07.02-1 (ML15244B272), requesting the applicant to: (a) provide justifications for implementing ISRS reduction levels in excess of those stipulated in SRP Section 3.7.2.II.4; (b) provide justification for the selection of the appropriate number of modes to capture the incoherent-motion and structural responses for the APR1400 standard plant; and to (c) provide additional information, that demonstrate that the APR1400 standard plant is qualified for the HRHF input motions. Additionally, the issues pertaining to the applicant's HRHF evaluation were discussed during the public meeting dated, October 5-6, 2015, biweekly public conference calls, and an audit conducted on June-20-24, 2016. During these meetings and audit, the staff held detailed discussions with the applicant pertaining to the path forward for the applicant's HRHF evaluation.

In contrast to the analyses performed for the NI structures, as described in Section 2.3 of APR1400-E-S-NR-14004, Revision 1, the analysis for the EDGB and DFOT room were based on 50 spatial coherency modes. During the June 20 - 24, 2016, audit (ML17132A286), the staff

reviewed the applicant's calculation report documenting the EDGB and DFOT room evaluation to HRHF input motion, taking into account the effects of spatial incoherence of seismic ground motion. The staff confirmed the adequacy of the 50 mode solution based on the applicant's demonstration of a converged solution observed in ISRS comparisons for responses based on reduced number of spatial coherency modes (including ten, fifteen, and twenty mode responses). On this basis, the staff found the ISRS and respective reduction levels based on the 50 mode solution to be acceptable for the EDGB and DFOT room of the APR1400 standard plant. The adequacy of the HRHF-based ISRS for the NI structures as well as the evaluations of the high frequency range exceedance of the HRHF-based ISRS over the CSDRS-base ISRS for both the NI and EDGB/DFOT structures are described in the following paragraphs.

In its response to RAI 183-8197, Question 03.07.02-1 (ML16291A569), the applicant described additional SSI analyses with consideration of spatial incoherence, HRHF input motion, and additional spatial coherency modes performed to demonstrate that a converged solution has been achieved; to justify the ISRS reduction levels and the selection of the appropriate number of modes to capture the incoherent-motion and structural responses for the APR1400 standard plant. For these analyses, the applicant used two sets of models namely the SSI NI full model and a standalone basemat model extracted from the SSI NI full model, the latter used for a supplementary study as described below.

The applicant included up to 16 and up to 50 spatial coherency modes in their analyses performed with the SSI NI full model and the analyses performed with the standalone basemat model, respectively. As described by the applicant, the analyses with the standalone basemat model, which include up to 50 spatial coherency modes, were performed in advance to confirm that the cumulative effect of spatial coherency modes higher than the 16 modes is insignificant. Figures 5 through 33 in the RAI response show ISRS comparisons corresponding to analyses based on up to 7, 16, and 50 spatial coherency modes. The staff's review of these comparisons found instances of lower response from the 7 mode solution as compared with the 16 and 50 mode solution but no appreciable differences between the 16 mode and 50 mode solutions.

Further, Figures 52 through 81 in the RAI response, related to the analyses performed with the SSI NI full model, provided ISRS comparisons corresponding to analyses based on up to 7, 12, and 16 spatial coherency modes. The staff's review of these comparisons found them to continue to show that the 7 mode response resulted in a considerably lower response relative to the responses that include contribution from additional coherency modes, namely the 12 and 16 mode response. In contrast, the staff found the responses based on 12 and 16 spatial coherency modes to be in very close agreement (i.e. results being within approximately 5 percent difference), therefore confirming the convergence of the 16 mode response, except at 3 outlier locations in below grade AB walls. At these 3 locations, the consideration of analysis results based on uncracked and cracked concrete properties resulted in a total 5 outlier ISRS comparisons. While the applicant provided a brief discussion of the differences at those locations, staff review found such discussion to contain insufficient details to justify the non-negligible differences at those locations. Additionally, in regards to the applicant's evaluation of the effects of the HRHF-based structural demand exceedance over the CSDRS-based structural demands (i.e., applicant's response to item (c) in RAI 183-8197, Question 03.07.02-1), the staff's review found such evaluation to be based on the 7 mode response and therefore, consistent with the above findings, insufficient to demonstrate that the

APR1400 standard plant structures are qualified for the applicant's HRHF input motions. These issues were discussed with the applicant during bi-weekly public calls.

In its supplemental response to RAI 183-8197, Question 03.07.02-1 (ML17242A319), the applicant replaced the 7 mode response by the 16 mode response for both ISRS and HRHF-based structural demands for the evaluation of structures. With respect to the ISRS comparisons, and especially those at the aforementioned outlier locations, the applicant performed sensitivity analyses by implementing alternative approaches to model the backfill soils. In its response, the applicant provided comparisons which showed the ISRS at the affected locations (comprised of a group of nodes at each particular location) to be controlled by the nodes on the exterior below grade walls.

In addition, the applicant provided ISRS comparisons, based on the alternative modeling approaches for the backfill soil (i.e. original and modified models), at the outlier locations as well as other locations including interior AB walls and locations in the RCB. These ISRS comparisons demonstrated that the ISRS including the nodes at the exterior below grade walls were more sensitive to the modeling of backfill (i.e. showing relatively larger difference) than the ISRS at other locations internal to the AB structure as well as locations in the RCB which showed close agreement in the ISRS obtained from both alternative backfill modeling approaches. Nevertheless, the ISRS comparison based on the modified backfill modeling showed better agreement between the 12 and 16 mode response relative to the respective comparison based on the original backfill modeling approach. The staff's review found the ISRS comparison based on the modified backfill modeling to reasonably demonstrate convergence of the solution at the outlier locations. However, while in general the results obtained from the original model produced conservative results as compared to the corresponding results from the modified model, there were a number of cases for the outlier locations where the modified model produced conservative results as compared to the original model results. As such, for the outlier AB below grade wall locations/cases the applicant enveloped the ISRS results obtained from both the original and modified models. The staff found the enveloping of results at the outlier location to be conservative and therefore acceptable. Based on the above, the staff concluded that the applicant reasonably demonstrated that they had achieved a converged solution based on their analysis with up to 16 spatial coherency modes. On this basis, the staff found the ISRS and respective reduction levels based on the 16 mode solution to be acceptable for the APR1400 standard plant.

As mentioned above, to assess the effects of the high frequency range exceedance of the HRHF-based ISRS over the CSDRS-based ISRS, in its response, the applicant also provided HRHF-based structural demands for the evaluation of structures as follows. For the CIS, the applicant performed a response spectrum analysis (RSA) using the 16-mode basemat ISRS. From this analysis, the applicant calculated rebar stresses. The rebar stresses calculated from the RSA slightly exceeded the allowable rebar stresses at some locations in the CIS; however, the stresses remained below the rebar yield stress (i.e. within the elastic range of the rebar) at all locations therefore not requiring changes to the rebar arrangement based on CSDRS-based structural demands. Furthermore, the applicant described conservatism associated with the RSA such as the use of an input ISRS for the RSA consisting of the envelope of ISRS corresponding to uncracked and cracked concrete cases. Additionally, based on the conservative seismic demands obtained from the RSA relative to seismic demands obtained from time-history analysis (i.e. SASSI analysis), the applicant described that rebar stresses calculated from SASSI analysis with HRHF input are not expected to exceed the rebar allowable

stresses. The staff's review found the aforementioned conservative response from the RSA to be consistent with the comparisons between the RSA and time history analysis provided in the applicant's response to RAI 183-8197, Question 03.07.02-2 (ML16210A514). Based on the applicant's use of a conservative demand for calculation of rebar stresses and respective demonstration that such stresses remain within the elastic range for the rebar, the staff concludes that the applicant has reasonably demonstrated that the CIS design based on the CSDRS input is qualified for the HRHF input.

For the EDGB/DFOT room, as indicated above, in APR1400-E-S-NR-14004, Revision 1, the applicant compared equivalent accelerations from HRHF input motion with equivalent accelerations from CSDRS input motion. At some locations the equivalent accelerations from HRHF input motion exceeded the equivalent accelerations from CSDRS input motion. In its response dated August 30, 2017, the applicant verified that the provided reinforcement based on the CSDRS input bounded the required reinforcement for the HRHF input. The staff's review found the applicant's verification regarding the sufficiency of the provided reinforcement to reasonably demonstrate that the EDGB/DFOT design based on the CSDRS is qualified for the HRHF input.

For the AB, the applicant also compared equivalent accelerations from HRHF input motion with equivalent accelerations from CSDRS input motion. In its supplemental response to RAI 183-8197, Question 03.07.02-1 (ML16210A514), the applicant showed the comparisons which demonstrate that the CSDRS-based equivalent accelerations largely bound the HRHF-based equivalent accelerations, except at two locations showing minor exceedance of equivalent vertical accelerations, in Table 2. The staff found these exceedances to be negligible on the basis that the ratios of the resulting story shear forces between the equivalent static analysis and the SSI analysis, provided in the applicant's response to RAI 252-8299, Question 03.07.02-12 (ML16126A522), bound the ratios between the HRHF-based equivalent acceleration and CSDRS-based equivalent acceleration at the aforementioned two locations. Based on the above, the staff found that the applicant has reasonably demonstrated that the AB design based on the CSDRS input is qualified for the HRHF input.

For the CS, Figure 272 in the supplemental response to RAI 183-8197, Question 03.07.02-1, dated August 30, 2017, compares CSDRS-based ISRS at EL 78' (used in the RSA of the CS to compute seismic design forces), with the corresponding 7-mode HRHF-based ISRS, and 16-mode HRHF-based ISRS. As shown in Figure 272, both the 7-mode HRHF-based ISRS and the 16-mode HRHF-based ISRS are higher than the CSDRS-based above approximately 10 Hz. Further, below approximately 10 Hz the spectral amplitude of the CSDRS-based ISRS is significantly higher than the spectral amplitude for both the 7-mode HRHF-based and the 16-mode HRHF-based ISRS. Figure 272, also shows that both the 7-mode HRHF-based and the 16-mode HRHF-based ISRS have consistent shapes, and shows an increase of the spectral amplitude for the 16-mode ISRS relative to the 7-mode ISRS. The applicant described that since the governing natural frequencies for the CS lie below about 10 Hz, the higher spectral amplitude of the HRHF-based ISRS over the CSDRS-based ISRS, in the high frequency range, will not adversely affect the CS. In this regard, the staff notes that Table 6-4 in APR1400-E-S-NR-14004, Revision 1, showed that the seismic demands based on CSDRS input largely bounded the corresponding demands based on the HRHF input. Furthermore, the staff evaluated the level of increased spectral amplitude of the 16-mode ISRS over the 7-mode ISRS at the dominant peaks in the high frequency range and found such increase to be bounded by the ratios of CSDRS to HRHF demands in the aforementioned Table

6-4. Based on the above, the staff found the applicant's ISRS assessment for the CS to reasonably demonstrate that the CS design based on the CSDRS input is qualified for the HRHF input.

As described above, the staff's review concluded that the applicant adequately assessed the effects of the high frequency range exceedance of the HRHF-based ISRS over the CSDRS-based ISRS, on the design of the NI structures and EDGB/DFOT room. On this basis, the staff found the applicant's seismic evaluation to HRHF input to reasonably demonstrate that the APR1400 standard plant seismic category I structures are qualified for the applicant's HRHF input motions. In addition, the applicant provided markups for the DCD and APR1400-E-S-NR-14004. The staff review found the markups to be consistent with the applicant's response and therefore acceptable. Based on the review of the DCD and APR14006-E-S-NR-14004, Revision 3, the staff has confirmed incorporation of the changes described above; therefore, RAI 183-8197, Question 03.07.02-1, is resolved and closed.

3.7.2.4.5 *Development of In-Structure Response Spectra*

The staff reviewed the procedures and methods for developing ISRS in accordance with SRP Section 3.7.2.II.5. The SRP references RG 1.122, and provides augmented guidance for methods acceptable to the staff for developing two horizontal and the vertical ISRS from time history motions.

The staff reviewed the information provided in DCD Tier 2, Sections 3.7.2.5 and 3.7A.3.3, and Section 6.2 in APR1400-E-S-NR-14003 for the procedures used for developing the ISRS for seismic Category I structures. In these sections the applicant states that the ISRS are generated according to the procedure given in RG 1.122. As described in these sections, the applicant developed ISRS from time histories at selected locations computed from separate SSI analyses of the three directions of input motion (i.e. x, y, and z). The ISRS are computed at damping values of 2-, 3-, 4-, 5, 7-, and 10-percent, and at frequencies exceeding the SRP guidelines, as stated in DCD Section 3.7A.3.3. Further the applicant computed the total ISRS at each location using the square-root-of-the-sum-of-the-squares (SRSS) method. The peaks in the total ISRS were then widened by 15 percent. Lastly, the ISRS are enveloped for all eighteen SSI analysis cases. The staff's review finds that the procedure used by the applicant including development of ISRS from time histories, computation of ISRS at minimum number of frequencies, combining the ISRS at each location using the SRSS method, and the 15 percent widening of the peaks in the total ISRS, conform to the guidance of RG 1.122 and SRP Section 3.7.2. Therefore, the staff considers the response acceptable.

While the staff finds the aforementioned procedures pertaining to the development of ISRS to be acceptable, the staff found ISRS results that need clarification. For example, DCD Tier 2 Figures 3.7A-24 and 3.7A-25, show the ISRS in the E-W and N-S directions, respectively, at EL 191'-0" for the PSW. The staff notes that the N-S ISRS in Figure 3.7A-25 corresponds to the out-of-plane direction for the primary shield wall (PSW), and shows a very large difference in the amplitude of the response (e.g. at the ZPA and PSA) compared to the E-W ISRS in Figure 3.7A-24, which is the in-plane direction. The staff also observes a similar response in Figures 3.7A-42 and 3.7A-43 which show the ISRS in the E-W and N-S directions respectively at EL 191'-0" for the SSW. To address these results, the staff issued RAI 252-8299, Question 03.07.02-9 (ML15293A566), requesting the applicant to provide an expanded presentation of ISRS at the aforementioned locations to show the individual ISRS for

each soil case, including the fixed-base case, and the cracked and uncracked concrete cases. Additionally, to assist the staff in reviewing the adequacy of the analysis methods, the staff requested the applicant to provide the individual ISRS at foundation and top level of each major seismic Category I structures.

In its response to RAI 252-8299, Question 03.07.02-9 (ML16012A540), the applicant provided the individual ISRS as requested by the staff. For the PSW and SSW ISRS at the locations addressed in the aforementioned figures, the staff found that the peaks of the ISRS envelopes were governed by the fixed-base case response. Further, the staff confirmed that the dominant peaks in the ISRS envelopes were consistent with the major modes identified for the CIS in DCD Tier 2 Table 3.7-11. On this basis, the staff found the ISRS results at these locations in the PSW and SSW acceptable.

In addition to the above, in its response, the applicant identified abnormal ISRS results obtained from the SSI analysis of the EDGB and DFOT with the S5 soil profile, relative to the results obtained for these structures and the rest of the soil profiles. The applicant indicated that these ISRS results are not incorporated in the envelope ISRS for these structures and consequently S05 soil profile is deleted from the generic soil profile. Further, the applicant provided DCD and technical report markups addressing the deletion of soil profile S05. The staff's review finds the markups to adequately address the deletion of S05 profile and are therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 252-8299, Question 03.07.02-9, is resolved and closed.

3.7.2.4.6 Three Components of Earthquake Motion

The staff reviewed the methods for combining the responses due to three components of earthquake motion, for both the response spectrum method and the time history method, in accordance with SRP Section 3.7.2.II.6. The SRP references RG 1.92 for methods acceptable to the staff for combining seismic responses.

In DCD Tier 2 Section 3.7.2.6, the applicant stated that three statistically independent orthogonal components of earthquake motion are applied to the structural models as separate loading cases. The applicant stated that the total response of the structure due to the three input seismic motion is obtained by algebraic summation and SRSS method for time-history and response spectrum analysis, respectively. Additionally, the applicant used the 100-40-40 percent combination rule as alternative for combining seismic responses from response spectrum analysis. The staff's review finds the applicant's use of algebraic summation, SRSS, and 100-40-40 percent combination acceptable because it conforms to the guidance in RG 1.92.

3.7.2.4.7 Combination of Modal Responses

The staff reviewed the applicant's modal responses, including consideration of closely-spaced modes and high frequency modes, in accordance with SRP Section 3.7.2.II.7. The SRP references RG 1.92 for methods acceptable to the staff for combining seismic responses.

DCD Tier 2 Section 3.7.2.7 describes the methods used for combination of modal responses when using the response spectrum method of analysis. The applicant stated, and staff verified, that the combination of modal responses is performed in accordance with RG 1.92. Specifically,

in order to obtain the complete solution for response spectrum analysis, the applicant implemented Combination Method A in RG 1.92, including consideration of periodic and rigid modal response components and the residual rigid response of the missing mass modes. The staff finds the approach described in DCD Tier 2 Section 3.7.2.7, acceptable because it conforms to the guidance in RG 1.92.

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

The staff reviewed the methods for assessing all non-seismic Category I structures to determine whether their failure under SSE conditions could impair the integrity of seismic Category I SSCs, or result in incapacitating injury to control room occupants. The staff reviewed the interaction of non-seismic Category I structures with seismic Category I structures in accordance with the guidance in SRP Section 3.7.2.II.8.

DCD Tier 2 Section 3.7.2.8 describes the criteria used to provide reasonable assurance that the failure of non-seismic Category I structure under the effect of a seismic event does not impair the integrity of an adjacent seismic Category I structure. In addition, the applicant refers to APR1400-E-S-NR-14005, for the details of its evaluation of SSSI effects on the NI structures. The SSSI analyses used the same 3D finite element models used in the SSI analysis for the NI structures, the EDGB, and DFOT room. In addition these analyses include 3D models of the TGB and the CB. Also, in DCD Tier 1, Sections 2.2.3 and 2.2.4, the applicant provided ITAAC for the TGB and CB, respectively, addressing whether these seismic Category II structures impair the ability of the safety-related SSCs to perform their safety-related functions. Therefore, the staff issued RAI 252-8299, Question 03.07.02-14 (ML15293A566), requesting the applicant to address the scope of the information presented in the DCD pertaining to these structures.

In its response to RAI 252-8299, Question 03.07.02-14 (ML16126A323), the applicant clarified that the seismic analysis and design of the TGB and CB are to be addressed by the COL applicant. The applicant proposed markups to DCD Tier 2 Section 3.7.2.8, specifying the acceptance criteria, seismic analysis and design procedures, and the corresponding COL information items, to ensure that these structures do not impair the integrity of the adjacent seismic Category I structures. The staff reviewed the RAI response and proposed DCD markups, and found them to be consistent with SRP Section 3.7.2.II.8. On this basis, the staff finds the response acceptable. Therefore, the staff concludes there is reasonable assurance that the criteria, seismic analysis and design approach, COL information items, and ITAAC are adequate to ensure that the TGB and CB response during a seismic event do not impair the integrity of the adjacent seismic Category I structures.

In addition to the above, DCD Tier 1, Section 1.2.14 and Figure 1.2-1, identified the seismic Category II alternate alternating current (AAC) gas turbine generator building TGB as being within the scope of the DC for APR1400. However, the staff did not find information in DCD Tier 2 Section 3.7.2.8, concerning the seismic analysis and design methods for this building, or the treatment of seismic Category I and non-seismic Category I interaction considerations. Therefore, the staff issued RAI 252-8299, Question 03.07.02-15, requesting the applicant to address applicable seismic interaction aspects for the (AAC) gas turbine generator building in DCD Tier 2 Section 3.7.2.8.

In its response dated March 29, 2016 (ML16089A159), the applicant clarified that the seismic analysis and structural design for the AAC gas turbine generator building are to be addressed

by the COL applicant. The applicant also proposed markups to the following DCD Tier 2 information: Sections 1.2 and 1.2.14, Figure 1.2-1, and Table 1.8-1. Further, the applicant referenced the response to RAI 252-8299, Question 03.07.02-14, to address seismic interaction. The staff reviewed the seismic interaction aspects described in response to RAI 252-8299, Question 03.07.02-14, and finds the response acceptable because it is consistent with SRP Section 3.7.2.8. SER Section 3.7.2.5 addresses additional aspects of the applicant's response to RAI 252-8299, Question 03.07.02-14 and Question 03.07.02-15.

3.7.2.4.9 Effects of Parameter Variation on Floor Response Spectra

The staff reviewed the procedures and methods for consideration of the effects of parameter variations on floor response spectra in accordance with SRP Section 3.7.2.II.9.

SRP Section 3.7.2.II.9 refers to the acceptance criteria in SRP Section 3.7.2.II.5 for the consideration of effects of parameter variations and to SRP Section 3.7.2.II.3.C.iv for addressing the effect of potential concrete cracking on the structural stiffness of concrete structures. SRP Section 3.7.2.II.3.C.iv states that acceptable stiffness reduction factors for cracked concrete members are given in American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 43-05 (e.g., 0.5 for cracked walls for flexure and shear).

The staff reviewed the information in DCD Tier 2, Sections 3.7.2.9 and 3.7A.3.3, and Section 6.2 of APR1400-E-S-NR-14003, pertaining to the consideration of the effects of parameter variation on floor response spectra. For each seismic Category I structures and each analysis case, the ISRS at selected nodal locations on each designated floor elevation are enveloped and then broadened by +/- 15 percent in frequency. As stated in DCD Tier 2 Section 3.7.2.9, the response spectra broadening and smoothing is performed in accordance with RG 1.122. Further, the broadened ISRS are enveloped for all 18 analyses cases which include 8 soil profiles, 1 fixed-base condition, and 2 concrete stiffness conditions (i.e. uncracked and cracked concrete stiffness). For consideration of concrete cracking, the applicant used reductions factors consistent with the criteria in ASCE/SEI 43-05.

As described above, the staff finds the applicant's consideration of the effects of parameter variation on floor response spectra acceptable because it is consistent with the guidance in RG 1.122, and SRP Section 3.7.2 II.3.C.

3.7.2.4.10 Use of Constant Vertical Factors

DCD Tier 2 Section 3.7.2.10 states that the seismic design of seismic Category I structures does not utilize constant vertical static factors. Hence, the staff's review in accordance with SRP Section 3.7.2.II.10, is not required.

3.7.2.4.11 Methods Used to Account for Torsional Effects

The staff reviewed the applicant's method to account for torsional effects in accordance with SRP Section 3.7.2.II.11. This SRP section states that an acceptable method to account for torsional effects in the seismic analysis of seismic Category I structures is to perform a dynamic analysis that incorporates the torsional degrees of freedom. The SRP also states that to account for accidental torsion, an additional eccentricity of ± 5 percent of the maximum building dimension shall be assumed for both horizontal directions.

In DCD Tier 2 Section 3.7.2.11, the applicant stated that the structural models used for seismic Category I structures are constructed with finite elements containing 6 degrees of freedom per node, incorporating torsional effects into the model. Regarding the consideration of accidental torsion, this DCD section states that additional eccentricity of 5 percent of the maximum building dimension, perpendicular to load direction that results in an accidental torque, is applied to the static finite element structural model to calculate element forces due to accidental torsion. This accidental torsion is considered in both the E-W and N-S directions. Based on this information, it was not clear to the staff how the accidental torsion effects are combined with the computed seismic response. To address this issue, the staff issued RAI 252-8299, Question 03.07.02-8 (ML15293A566), requesting the applicant to clarify how the accidental torsion effects are combined with the computed seismic response. In its response to RAI 252-8299, Question 03.07.02-8 (ML16223A972), the applicant described that accidental torsional moments are calculated by multiplying the maximum seismic story shear forces of each floor by 5 percent of the maximum building dimension at that floor elevation and applied at the mass center of each floor with the SSE loads in the static finite element structural model. Further, the applicant provided analysis results of the SSE and the accidental torsion loading cases for several shear wall elements. The staff reviewed the applicant's method for addressing accidental torsional effects and found it to be consistent with the criteria in SRP Section 3.7.2.II.11, and therefore acceptable. Accordingly, RAI 252-8299, Question 03.07.02-8, is resolved and closed.

3.7.2.4.12 *Comparison of Responses*

The staff reviewed the comparison of responses between time history analysis and responses spectrum analysis in accordance with SRP Section 3.7.2.II.12. Per the guidance in SRP Section 3.7.2.II.12, if both the THA method and the response spectrum analysis (RSA) method are used to analyze an SSC, the peak responses obtained from these two methods should be compared, to demonstrate approximately equivalency between the two methods. The comparison of the RSA and the THA methods is also important since the RSA method only utilizes the translational response spectra at the basemat of the NI as input to the containment and containment internal structures without consideration of the rotational input at the basemat.

The staff found that while DCD Tier 2, Sections 3.7.2.1.1 and 3.7.2.1.2, identify the RSA and THA methods as methods used in the analysis/design of APR1400 standard plant structures, a comparison between the peak responses obtained from these methods was not provided. Therefore, the staff issued RAI 183-8197, Question 03.07.02-2 (ML15244B272), requesting the applicant to provide the comparison of analysis results obtained from RSA and THA. In its response to RAI 183-8197, Question 03.07.02-2 (ML16210A514), the applicant provided a comparison of story shear forces for the containment structure and the containment internal structure. This comparison showed that the results obtained from the RSA bound those obtained from the THA. On this basis, the staff concluded that the seismic response obtained from the RSA of the containment structure and the containment internal structure is conservative and therefore, acceptable for used in the design of these structures. The applicant proposed markups to DCD Tier 2 Section 3.7.2.12, and APR1400-E-S-NR-14003, describing the comparison of results. The staff finds the proposed markups and associated comparison of responses acceptable because it is consistent with the criteria in SRP Section 3.7.2.II.12. Based on the review of the DCD and APR1400-E-S-NR-14003, the staff has confirmed the incorporation of the changes described above; therefore, RAI 183-8197, Question 03.07.02-2, is resolved and closed.

3.7.2.4.13 *Methods for Seismic Analysis of Dams*

DCD Tier 2 Section 3.7.2.13 addresses COL 3.7(5), which is also discussed in DCD Tier 2 Section 3.7.3.8. This COL item states that the COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if necessary. The staff's evaluation of this COL item is included in SER Section 3.7.3.

3.7.2.4.14 *Determination of Dynamic Stability of Seismic Category I Structures*

In accordance with SRP Section 3.7.2, the staff reviewed the applicant's determination of seismic overturning moments and base shears for use in the stability evaluation of seismic Category I Structures.

In DCD Tier 2 Section 3.7.2.14, the applicant stated that design overturning moments and base shears for seismic Category I structures are determined by time-history analysis based on the complex frequency response method. The seismic motion is input separately to the structural models in three independent orthogonal directions. To check overturning and sliding, the simultaneous action of horizontal and vertical seismic forces is considered using methods described in DCD Tier 2 Section 3.7.2.6. The staff finds the applicant's determination of seismic overturning moments and base shears based on time-history analysis using three components of input motion and considering the simultaneous action based on the methods acceptable. The staff's conclusion is based on the applicant's determination described in DCD Tier 2 Section 3.7.2.6, which conforms to the criteria in SRP Section 3.7.2.

In addition, the applicant referred to DCD Tier 2 Section 3.8.5, for the procedures to check the stability of seismic Category I structures. The details of the applicant's stability evaluation of seismic Category I structures are described in APR1400-E-S-NR-14006. The staff's evaluation of the dynamic stability of seismic Category I structures is in SER Section 3.8.5.

3.7.2.4.15 *Analysis Procedures for Damping*

The staff reviewed the applicant's analysis procedures for damping in accordance with SRP Section 3.7.2.II.13. In DCD Tier 2 Section 3.7.2.14, the applicant addressed the composite modal formulation used for modal superposition analysis method. This section addressed the formulation for viscous damping proportional to the mass and stiffness matrix which is used for the direct integration analysis method. The staff reviewed these formulations and found them acceptable because it conforms to the criteria in SRP Section 3.7.2. The staff also evaluated the specific percentage of critical damping values used in the analyses of seismic Category I structures. This evaluation is found in SER Section 3.7.1.

3.7.2.5 *Combined License Information Items*

DCD Tier 2, Section 3.7.2, contains the following COL information items. These COL items include updates from markups provided in RAI responses as discussed below.

Table 3.7.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.7(3)	<p>The COL applicant is to provide the seismic design of the seismic Category I SSCs and seismic Category II structures that are not part of the APR1400 standard plant design. The seismic Category I and II structures are as follows:</p> <ul style="list-style-type: none"> a. Seismic Category I ESWB b. Seismic Category I component cooling water heat exchanger building c. Seismic Category II turbine generator building d. Seismic Category II compound building e. Seismic Category II alternate alternating current gas turbine generator building 	3.7.2
COL 3.7(4)	<p>The COL applicant is to confirm that any site-specific non-seismic Category I structures are designed not to degrade the function of a seismic Category I SSC to an unacceptable safety level due to their structural failure or interaction. The COL applicant is to confirm that the calculated relative displacements do not exceed the gaps between seismic Category I and non-seismic Category I structures. The COL applicant is to apply the site-specific FIRS as seismic input motions and to establish a site-specific soil profile as a supporting media for the seismic analysis of the seismic Category II structures. The COL applicant is to apply the same seismic analysis procedure as the seismic Category I structures to the seismic Category II structures. The COL applicant is to perform the structural design of the seismic Category II structures using the design codes described in Subsection 3.7.2.8 and Table 3.2-1. The COL applicant is to check the potential effects of sliding and uplift for the seismic Category II structures using the same approach applied in the stability check for the seismic Category I structures. The COL applicant is to address the evaluation of pressures on the below grade walls of the NI, resulting from site-specific SSSI effects between the NI and adjacent seismic Category II structures.</p>	3.7.2.8

The staff found that COL 3.7(3) and COL 3.8(1) in DCD Tier 2 Section 3.8.4, identified the seismic Category I ESWB and the seismic Category I component cooling water heat exchanger building as site-specific structures. However, DCD Tier 1, Section 1.2.14 and Figure 1.2-1, identified these structures as being within the scope of the DC for APR1400. The staff found the information in DCD Tier 1, Section 1.2.14 and Figure 1.2-1, to be inconsistent with the aforementioned COL items. Therefore, the staff issued RAI 249-8299, Question 03.07.02-15 (ML15293A566), requesting the applicant to clarify whether the aforementioned structures are site-specific and correct any related inconsistencies presented the DCD, as necessary.

In its response to RAI 249-8299, Question 03.07.02-15 (ML16089A159), the applicant clarified that for seismic analysis and structural design, the certified design scope is limited to the RCB,

the AB, and the EDBG including the DFOT room, which are seismic Category I buildings. The applicant also stated that the other seismic Category I buildings, including the component cooling water heat exchanger building and the ESWB, and the seismic Category II buildings, such as the turbine generator building, the compound building, and the AAC gas turbine generator building, are designed by the COL applicant. In its response, the applicant proposed markups to DCD Tier 2, Sections 1.2 and 1.2.14, Figure 1.2-1, and Table 1.8-1, consistent with the clarifications discussed above. The staff's review concluded that the proposed markups adequately clarify the scope of the DCD with respect to the seismic analysis and the design of structures, and therefore, are acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 252-8299, Question 03.07.02-15, is resolved and closed.

Consistent with the discussion above, and in its response to RAI 252-8299, Question 03.07.02-14, the applicant proposed markups to COL 3.7(3) to describe both the site-specific seismic Category I and seismic Category II structures. The markups are acceptable to the staff because it is consistent with the scope of the certified design pertaining to seismic analysis and design of structures. Further, in its response, the applicant proposed markups for COL 3.7(4) to augment the details pertaining to the site-specific evaluation criteria for the interaction of non-seismic Category I structures with seismic Category I SSCs. As described above in SER Section 3.7.2.4.8, the markups are acceptable because the criteria addressed by the markups are consistent with SRP Section 3.7.2.II.8, to ensure no adverse interaction between non-seismic Category I and seismic Category I structures. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 252-8299, Question 03.07.02-14, is resolved and closed.

The staff finds the above COL information item listing to be complete. Further, the staff finds that the list adequately describes actions necessary for the COL applicant pertaining to seismic system analysis.

3.7.2.6 Conclusion

The staff concludes that the seismic system analysis procedures used in the APR1400 standard plant meet the applicable requirements described in SER Section 3.7.2.3. This conclusion is based on the applicant meeting the acceptance criteria in SRP Section 3.7.2 as described below.

The scope of review of the seismic system analyses included review of seismic analyses methods, natural frequencies, and responses, procedures for modeling, seismic SSI, development ISRS, use of three components of design ground motion, combination of modal responses, design criteria and procedures for evaluation of the interaction of non-seismic Category I structures with seismic Category I structures, consideration of the effects of parameter variations on floor response spectra, inclusion of torsional effects, determination of seismic overturning moments and sliding forces for seismic Category I structures, and analysis procedures for damping.

The applicant used suitable dynamic analyses to demonstrate that SSCs can withstand the seismic loads. The system analyses were performed by the applicant on an elastic and linear basis with conservative consideration of uncracked and cracked concrete conditions. Time history methods form the bases for the analyses of all standard plant seismic Category I SSCs.

ISRS inputs to be used for design and test verifications of SSCs are generated from the time history method. The seismic system dynamic analyses were performed for the three orthogonal components of ground motion (two horizontal and one vertical components). Coupled structure and soil models (eight soil cases and a fixed-base case) were used to evaluate SSI effects upon seismic responses. The applicant adequately assessed the effects of effects of parameter variations on the in-structure seismic responses. The applicant adequately considered the effects of SSSI on the seismic analysis and design of seismic Category I structures. Further, the applicant adequately assessed the effects of the HRHF input spectra on the APR1400 standard plant seismic category I structures and demonstrated the qualification of these structures to the HRHF input.

3.7.3 Seismic Subsystem Analysis

3.7.3.1 Introduction

DCD Tier 2, Revision 0, Section 3.7.3, "Seismic Subsystem Analysis," covers seismic analysis of seismic Category I subsystems that are not included in the main structural systems, such as miscellaneous concrete and steel structures; buried piping, tunnels, and conduits; concrete dams; and atmospheric tanks. For distribution systems (e.g., cable trays, conduit, heating, ventilation, air conditioning, piping) and equipment, including their supports, the staff reviews supplementary seismic analysis criteria under SRP Section 3.7.3 while the review of the actual distribution systems and their supports falls under SRP Section 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," and SRP Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, and Component Supports, and Core Support Structures." The staff also reviews intervening structural elements between these distribution systems and equipment supports and the building structural steel/concrete under this SRP section. The staff's review of DCD Section 3.7.3 follows SRP Section 3.7.3, Revision 4, issued September 2013.

The main areas of review include the following:

- seismic analysis methods
- determination of the number of earthquake cycles
- procedures used for analytical modeling
- basis for selection of frequencies
- analysis procedure for damping
- three components of design ground motion
- combination of modal responses
- interaction of non-seismic Category I subsystems with seismic Category I SSCs
- multiply supported equipment and components with distinct inputs
- use of equivalent vertical static factors

- torsional effects of eccentric masses
- seismic Category I buried piping, conduits, and tunnels
- methods for seismic analysis of seismic Category I concrete dams
- methods for seismic analysis of aboveground tanks

3.7.3.2 *Summary of Application*

DCD Tier 1: There is no DCD Tier 1 information associated with this section.

DCD Tier 2: DCD Tier 2, Revision 0, Section 3.7.3 describes the seismic analysis methods for APR1400 seismic Category I subsystems that are not included in the main structural systems described in DCD Tier 2, Section 3.7.2. The subsystems described in this section include miscellaneous concrete and steel structures, buried piping, conduits, tunnels, dams, and aboveground tanks.

As applicable, DCD Tier 2 Section 3.7.3 references DCD Tier 2 Section 3.7.2, and, to a limited extent, DCD Tier 2 Section 3.7.1 for the seismic analysis methods for the subsystems, such as response spectrum analysis, time history analysis, procedure used for analytical modeling, analysis procedures for damping, and modal and spatial response combination methods.

Several subsections of DCD Tier 2 Section 3.7.3, Revision 0, reference DCD Tier 2, Section 3.9.2, and Section 3.12.3.7, “Non-Seismic/Seismic Interaction (II/I),” for the seismic analysis methods applicable to mechanical subsystems (e.g., piping and equipment, and their supports).

DCD Tier 2, removes these references by including necessary descriptions.

DCD Tier 2 Section 3.7.3 has generic descriptions of the methodologies used for the seismic analysis of the subsystems. This DCD section also covers some subsystems which are treated as COL information items.

ITAAC: There are no ITAAC for this area of review.

Technical Specifications: There are no Technical Specifications for this area of review.

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

Technical Reports: There are no Technical Reports for this area of review.

Cross Cutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): 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 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.

3.7.3.3 *Regulatory Basis*

SRP Section 3.7.3 describes the relevant requirements for seismic subsystem analysis, and the associated acceptance criteria. The specific requirements include the following:

- GDC 2 of Appendix A to 10 CFR Part 50 requires that the design basis shall reflect appropriate consideration of the most severe earthquakes reported to have affected the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated.
- Appendix S to 10 CFR Part 50 is applicable to applications for a DC or COL under 10 CFR Part 52 or a construction permit or operating license under 10 CFR Part 50 on or after January 10, 1997. Appendix S requires that for SSE ground motions, certain SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of these SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motion. If the operating basis earthquake (OBE) is set at one third or less of the SSE, an explicit analysis or design is not required. If the OBE is set at a value greater than one third of the SSE, an analysis and design must be performed to demonstrate that when subjected to the effects of the OBE in combination with normal operating loads, all SSCs of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public must remain functional and within applicable stress, strain, and deformation limits.
- Section 52.47(b)(1) of 10 CFR, requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria that are necessary and sufficient to give reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act of 1954, as amended, and the Commission's rules and regulations.

In addition, the acceptance criteria and regulatory guidance associated with the review of DCD Tier 2 Section 3.7.3 include the following:

- SRP Section 3.7.3, Revision 4, for reviewing seismic subsystem analysis to ensure that it is appropriate and contains a sufficient margin so that seismic analyses accurately and/or conservatively represent the behavior of SSCs during postulated seismic events.
- SRP Section 3.7.2, Revision 4, for acceptance criteria referenced in SRP Section 3.7.3.
- RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants," issued March 2007, to determine the acceptability of damping values used in the dynamic seismic analyses of seismic Category I subsystems.

- RG 1.92, Revision 3, “Combining Modal Responses and Spatial Components in Seismic Response Analysis,” issued October 2012, to determine the acceptability of modal and spatial combination methods used in the dynamic seismic analyses of seismic Category I subsystems

3.7.3.4 *Technical Evaluation*

Consistent with the guidance in SRP Section 3.7.3, Revision 4, the staff reviewed the 14 main areas of review described in Section 3.7.3.1 of this SER. The staff also reviewed other sections of the DCD as referenced in DCD Tier 2 Section 3.7.3.

3.7.3.4.1 *Seismic Analysis Methods*

DCD Tier 2, Section 3.7.3.1, “Seismic Analysis Methods,” indicates that the APR1400 seismic Category I subsystems may be analyzed using the response spectrum analysis method, time history analysis method, or equivalent static method. The first two methods are the same as those described in DCD Tier 2 Section 3.7.2, and are evaluated in SER Section 3.7.2.

The equivalent static method for seismic analysis of subsystems is evaluated below.

DCD Tier 2, Section 3.7.3.1.1, “Use of Equivalent Static Load Method of Analysis,” indicates that the equivalent static method would be used for the seismic analysis of components if a dynamic analysis is not performed. Therefore, the staff issued RAI 267-8301, Question 03.07.03-3, requesting that the applicant explain how seismic Category I subsystems are analyzed. In its response to RAI 267-8301, Question 03.07.03-3 (ML16135A007), the applicant modified the seismic static load to specify it as the product of the equipment or component mass times the constant static factor. The constant static factor is 1.5 times the peak spectral acceleration of the applicable required response spectra (a smaller factor can be used if adequately justified). Because the peak spectral acceleration is used regardless of the natural frequency of the components, and the conservative factor of 1.5 is consistent with the guidance in SRP Section 3.7.2 (which SRP Section 3.7.3 references for this area of review), the staff finds that the method is conservative and consistent with SRP Acceptance Criterion 3.7.2.II.1.B.iii. However, the SRP Section 3.7.2 guidance also states that the use of the equivalent static method needs to be technically justified to ensure that: (1) the system can be realistically represented by a simple model and the method produces conservative results in terms of responses (SRP Acceptance Criterion 3.7.2.II.1.B.i), and (2) the simplified static analysis method accounts for the relative motion between all points of support (SRP Acceptance Criterion 3.7.2.II.1.B.ii). Therefore, the staff issued RAI 267-8301, Question 03.07.03-4 (ML15295A261), requesting the applicant to augment the description of this DCD section to address these issues. In its response to RAI 267-8301, Question 03.07.03-4 (ML16012A547), the applicant revised the DCD to capture all three acceptance criteria in SRP Section 3.7.2.II.1.B. Therefore, the staff finds the RAI response and the DCD markup acceptable.

The committed changes also include other issues as discussed latter in this SER. Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 182-8160, Questions 03.07.03-3 and 03.07.03-4, are resolved and closed.

3.7.3.4.2 *Determination of Number of Earthquake Cycles*

DCD Tier 2, Section 3.7.3.1.2, "Determination of Number of Earthquake Cycles," indicates that the fatigue design of seismic Category I subsystems, components, and equipment considers two SSE events with 10 maximum stress cycles (20 full cycles of maximum SSE stress range in total). It also allows an alternative method in which the number of fractional vibratory cycles equivalent to 20 full SSE vibratory cycles may be used (but with an amplitude not less than one third of the maximum SSE amplitude) when derived in accordance with Appendix D to Institute of Electrical and Electronics Engineers (IEEE) Standard 344 2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Plants," dated June 8, 2005. The staff found that the DCD specification of these two methods, with the exception about the versions of this IEEE standard as evaluated below in this subsection, is consistent with SRP Acceptance Criterion 3.7.3.II.2 for the case in which the OBE is defined as less than or equal to one third the SSE. The OBE for the APR1400 standard design is specified as one third of the CSDRS, as evaluated in SER Section 3.7.1.

During the review, the staff found that the applicant referenced a more recent version of IEEE Standard 344-2004 than the 1987 version referenced in SRP Section 3.7.3, Revision 4. The staff compared these two versions of IEEE Standard 344 and determined that the standards were technically equivalent. Therefore, the staff finds the methods for determining the number of earthquake cycles acceptable.

3.7.3.4.3 *Procedures Used for Analytical Modeling*

DCD Tier 2, Section 3.7.3.2, "Procedure Used for Analytical Modeling," indicates that the criteria and bases described in DCD Tier 2, Section 3.7.2.3, "Procedures Used for Analytical Modeling," are used to determine whether a component or structure will be analyzed as a subsystem. This approach is consistent with SRP Acceptance Criterion 3.7.3.II.3, which directly references SRP Acceptance Criterion 3.7.2.II.3. In addition, the damping coefficients are consistent with DCD Tier 2 Table 3.7-7, which is included in DCD Tier 2 Section 3.7.1. These areas of review are separately addressed in SER Sections 3.7.2 and 3.7.1.

DCD Tier 2, Section 3.7.3.2 also generically indicates that (1) the modeling techniques incorporate either a single- or a multi- degree of freedom subsystem consisting of discrete masses connected by spring elements, and (2) the degree of model complexity is sufficient to accurately evaluate the dynamic behavior of the component. Because there are no specific components discussed and the stated techniques reflect the common practice, the staff finds the generic description of the modeling techniques acceptable.

3.7.3.4.4 *Basis for Selection of Frequencies*

DCD Tier 2, Section 3.7.3.10, "Basis for Selection of Frequencies," describes the basis for selection of frequencies by directly referencing DCD Tier 2, Section 3.9.2.2.4, "Basis for Selection of Frequencies." However, because the scope of subsystems covered by DCD Tier 2 Section 3.7.3 is generally broader than that covered in DCD Tier 2 Section 3.9.2, , the staff issued RAI 267-8301, Question 03.07.03-2 (ML15295A261), requesting that the applicant resolve scope inconsistencies. In its response (ML16147A628) to RAI 267-8301, Question 03.07.03-2 (ML15295A261), the applicant revised DCD Tier 2 Section 3.7.3.10 to indicate that the fundamental frequencies of components and equipment are selected to be less than one

half or more than twice the dominant frequencies of the support structure to avoid resonance. In addition, the applicant indicated that if the equipment frequencies are within this range (from one-half to twice), the equipment must be adequately designed for the applicable loads. The staff finds the description in the DCD acceptable because it is consistent with SRP Acceptance Criterion 3.7.3.II.4. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 182-8160, Question 03.07.03-2, is resolved and closed.

3.7.3.4.5 *Analysis Procedure for Damping*

DCD Tier 2, Section 3.7.3.3, "Analysis Procedures for Damping," indicates that the analysis procedure used to account for the damping in subsystems conforms to DCD Tier 2, Sections 3.7.1.2, "Percentage of Critical Damping Values," and 3.7.2.15, "Analysis Procedure for Damping." The staff finds this approach acceptable because it is consistent with SRP Acceptance Criterion 3.7.3.II.5, which references SRP Acceptance Criterion 3.7.2.II.13. The evaluations of DCD Tier 2, Sections 3.7.1.2 and 3.7.2.15, are presented in SER Sections 3.7.1 and 3.7.2.

3.7.3.4.6 *Three Components of Design Ground Motion*

DCD Tier 2, Section 3.7.3.4, "Three Components of Earthquake Motion," indicates that seismic responses resulting from the analysis of subsystems due to three components of earthquake motions are combined in the same manner as the seismic response resulting from the analysis of building structures, as specified in DCD Tier 2, Section 3.7.2.6, "Three Components of Earthquake Motion." The staff finds this approach acceptable because it is consistent with SRP Acceptance Criterion 3.7.3.II.6, which directly references SRP Acceptance Criterion 3.7.2.II.6. The evaluation of DCD Tier 2 Section 3.7.2.6 is in SER Section 3.7.2.

3.7.3.4.7 *Combination of Modal Responses*

DCD Revision 0, Section 3.7.3.5, "Combination of Modal Responses," indicates that in response spectrum analysis of subsystems, the square root of the sum of the squares (SRSS) method is used to combine the modal responses when the modal frequencies are well separated; otherwise, the modal response are combined in accordance with RG 1.92, Revision 3. However, DCD Tier 2 Section 3.7.3.5 does not provide the criteria required to determine whether the modal frequencies are well separated. The description in DCD Tier 2 Section 3.7.3.5 also appears to indicate that a method specific to the APR1400 would be used for combining the modal responses of the APR1400 subsystems. Therefore, the staff issued RAI 267-8301, Question 03.07.03-5 (ML15295A261), requesting the applicant to specify and justify the criteria to be used for determining whether modal frequencies are well separated.

In its response to RAI 267-8301, Question 03.07.03-5 (ML16147A628), the applicant augmented DCD Tier 2 Section 3.7.3.5 by indicating that for combination of modal responses of subsystems, DCD Tier 2, Section 3.7.2.7 "Combination of Modal Responses," should be referred to for details. This approach is consistent with SRP Acceptance Criterion 3.7.3.II.7 that references SRP Acceptance Criterion 3.7.2.II.7. The evaluation of DCD Tier 2 Section 3.7.2.7 is in SER Section 3.7.2.

In addition, the applicant added to DCD Tier 2, Section 3.7.3.5 the criteria for determining whether modal frequencies are well separated, following the NRC damping-dependent criteria in RG 1.92, Revision 3, for the definition of modes with closely spaced frequencies:

1. For critical damping ratios less than or equal to 2 percent, modes are considered closely spaced if the frequencies are within 10 percent of each other.
2. For critical damping ratios greater than 2 percent, modes are considered closely spaced if the frequencies are within five times the critical damping ratio of each other.

Therefore, the staff finds the augmented DCD Tier 2 Section 3.7.3.5 acceptable because it is consistent with SRP Acceptance Criterion 3.7.3.II.7 and follows RG 1.92, Revision 3, for determining whether modal frequencies are well separated.

Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 267-8301, Question 03.07.03-5, is resolved and closed.

3.7.3.4.8 Interaction of Non-Seismic Category I Subsystems with Seismic Category I SSCs

DCD Tier 2 Section 3.7.3.11, "Interaction of Other Systems with Seismic Category I Systems," references DCD Tier 2 Section 3.12.3.7, to address the interaction of non-seismic Category I subsystems with seismic Category I SSCs. The staff's review of DCD Tier 2 Section 3.12.3.7 found that, in addition to the inconsistency between the titles of DCD Tier 2, Section 3.7.3.11 and Section 3.12.3.7, the scope of DCD Tier 2 Section 3.12.3.7 covers only the Category II/Category I interaction of piping systems. DCD Tier 2 Section 3.7.3.11 should cover the interaction of all non-seismic Category I subsystems with seismic Category I SSCs. Therefore, the staff issued RAI 267-8301, Question 03.07.03-2 (ML15295A261), requesting that the applicant resolve scope inconsistencies. In its response to RAI 267-8301, Question 03.07.03-2 (ML16147A628), the applicant indicated that DCD Tier 2 Section 3.7.3.11 will no longer reference DCD Tier 2 Section 3.12.3.7, but instead will indicate that the non-seismic Category I subsystems are designed to be isolated by either a constraint or barrier or are remotely located from any seismic Category I SSC. Otherwise, adjacent non seismic Category I subsystems are analyzed according to the same seismic criteria as applicable to seismic Category I SSCs. For non-seismic Category I subsystems attached to seismic Category I SSCs, the dynamic effects of the non-seismic Category I subsystems should be simulated in the modeling of the seismic Category I SSCs. The attached non seismic Category I subsystems, up to the first anchor beyond the interface, should also be designed in such a manner that, during an earthquake of SSE intensity, they will not cause a failure of the seismic Category I SSC. The above description reflects common design approaches and is consistent with SRP Acceptance Criterion 3.7.3.II.8, therefore the staff finds this section acceptable.

As stated in Section 3.7.3.4.1 of this SER, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 267-8301, Question 03.07.03-2, is resolved and closed.

3.7.3.4.9 Multiply-Supported Equipment and Components with Distinct Inputs

DCD Tier 2 Section 3.7.3.12, "Multiply-Supported Equipment and Components with Distinct Inputs," as modified by the applicant's response (ML16147A628) to RAI 267 8301, Question 03.07.03-2 (ML15295A261), indicates that the seismic response of multiply supported equipment and components with distinct inputs are obtained by one of the three methods:

1. The uniform support motion method can be applied with a uniform response spectrum (URS) that envelops all of the individual response spectra at the various support locations. In addition, the maximum relative support displacements are imposed on the supports in the most unfavorable combination. The final responses are obtained by the absolute summation of responses due to inertial effects and relative displacements.
2. The independent support motion (ISM) method can be employed such that all of the criteria presented in NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee," issued December 1984, related to the ISM method are satisfied.
3. The time history method can be applied with the time histories of support motions used as input excitations to the subsystems.

These three methods are consistent with the three acceptable approaches in SRP Acceptance Criterion 3.7.3.II.9; therefore, the staff finds the methods for analysis of multiply supported equipment and components with distinct inputs to be acceptable.

3.7.3.4.10 *Use of Equivalent Vertical Static Factors*

DCD Tier 2 Section 3.7.3.6, "Use of Constant Vertical Static Factors," indicates that no constant vertical static factors are used for subsystems. However, when describing how the vertical seismic responses are determined, the DCD states, "In general, seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Subsection 3.7.3.1." The phrase "in general" suggests that methods other than those in Section 3.7.3.1 may be used. Therefore, the staff issued RAI 267-8301, Question 03.07.03-3 (ML15295A261), requesting the applicant to explain whether methods other than those in DCD Tier 2 Section 3.7.3.1 are used for the APR1400 standard design and, if so, to describe these methods in the DCD.

In its response to RAI 267-8301, Question 03.07.03-3 (ML16135A007), the applicant revised DCD Tier 2 Section 3.7.3.6 to enable the COL applicant to use a constant vertical static factor. DCD Tier 2 Section 3.7.3.6 indicates that the seismic analysis of seismic Category I subsystems can be performed using the response spectrum analysis method, the THA method, or the equivalent static load method, as specified in DCD Tier 2 Section 3.7.3.1. More specifically, when the equivalent static load method is employed, a constant vertical static factor can be used to calculate the vertical response loads only if it can be demonstrated that the subsystem is rigid in the vertical direction or SRP Acceptance Criterion 3.7.2.II.1.B is satisfied. The staff finds the above description consistent with SRP Acceptance Criterion 3.7.2.II.10, which SRP Acceptance Criterion 3.7.3.II.10 references. Therefore, the staff finds the revised description for the use of constant vertical static factors acceptable.

As stated in Section 3.7.3.4.1 of this SER, the staff has confirmed incorporation of the changes described above; therefore, RAI 267-8301, Question 03.07.03-3, is resolved and closed.

3.7.3.4.11 *Torsional Effects of Eccentric Masses*

DCD Tier 2 Section 3.7.3.13, "Torsional Effects of Eccentric Masses," as modified by the applicant's May 26, 2016, response (ML16147A628) to RAI 267-8301, Question 03.07.03-2, indicates that to consider the torsional effects of eccentric masses in seismic Category I subsystems, the eccentric masses are included in the mathematical model as masses located

at their center of gravity and coupled by, as applicable, either rigid members or elastic members with their own properties. The staff finds the above description acceptable because it is consistent with SRP Acceptance Criterion 3.7.3.II.11.

As stated in Section 3.7.3.4.4 of this SER, the staff has confirmed incorporation of the changes described above; therefore, RAI 267-8301, Question 03.07.03-2, is resolved and closed.

3.7.3.4.12 *Seismic Category I Buried Piping, Conduits, and Tunnels*

DCD Tier 2 Section 3.7.3.7, "Buried Seismic Category I Piping, Conduits, and Tunnels," indicates that the seismic analysis of buried seismic Category I piping, conduits, and tunnels is to be performed by the COL applicant in accordance with the following COL information item:

COL 3.7(6): The COL applicant is to perform seismic analysis of buried seismic Category I conduits and tunnels.

This DCD section gives a generic description of the methodologies; however, based on COL 3.7(6), the detailed review and evaluation of these items will be performed at the COL stage following SRP Acceptance Criterion 3.7.3.II.12.

DCD Tier 2 Section 3.7.3.7 describes the general methodologies for the seismic analysis of seismic Category I buried piping, conduits, and tunnels. It recognizes that various seismic waves propagating through the surrounding soil and the dynamic differential movements of the buildings create a very complex seismic loading condition for the buried SSCs. ASCE 4-98, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," is referenced for the calculation of the seismic induced upper bound strains and stresses. This DCD section indicates that the strain of the buried structure is assumed to be the same as that of the surrounding soil, and the relative deformation between anchor points and the adjacent soil is considered in the design using the SRSS method for the three orthogonal stresses associated with the relative displacements. The resistance effect of the surrounding soil, the differential movement of the anchors, the shape or curvature changes of the bent parts, underground water effect, and lateral dynamic soil pressure are considered following various ASCE 4-98 procedures. The DCD also indicates that the buried structure can be modeled as beam elements supported by an elastic foundation representing soil stiffness. The generic description in DCD Tier 2 Section 3.7.3.7 is consistent with SRP Acceptance Criterion 3.7.3.II.12. In particular, SRP Acceptance Criterion 3.7.3.II.12 states that the actual methods used to determine the design parameters associated with seismically induced transient relative deformations are reviewed and accepted on a case by case basis. Consistent with this guidance, the detailed staff evaluation of seismic Category I buried piping, conduits, and tunnels will be performed in the review of COL applications.

3.7.3.4.13 *Methods for Seismic Analysis of Seismic Category I Concrete Dams*

DCD Tier 2 Section 3.7.3.8, "Methods for Seismic Analysis of Category I Concrete Dams," indicates that the seismic analysis of any site specific seismic Category I concrete dams will be performed by the COL applicant in accordance with the following COL information item:

COL 3.7(5): The COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if necessary.

Therefore, the review and evaluation of the methods for seismic analysis of seismic Category I concrete dams will be performed in the review of COL applications using SRP Acceptance Criterion 3.7.3.II.13.

3.7.3.4.14 *Methods for Seismic Analysis of Aboveground Tanks*

DCD Tier 2 Section 3.7.3.9, "Methods for Seismic Analysis of Above-ground Tanks," indicates that the seismic analysis of aboveground seismic Category I tanks will be performed by the COL applicant in accordance with the following COL information item:

COL 3.7(7): The COL applicant is to perform seismic analysis for the seismic Category I above-ground tanks.

This DCD section gives a generic description of the methodologies; however, based on COL 3.7(7), the detailed review and evaluation of the methods for seismic analysis of seismic Category I aboveground tanks will be performed at the COL stage using SRP Acceptance Criterion 3.7.3.II.14.

DCD Section 3.7.3.9, Revision 0, generically describes the methods for seismic analysis of aboveground tanks. The DCD indicates that the aboveground tanks are generally large, flat-bottomed, single-shell, cylindrical tanks that can be anchored either to reinforced concrete pads or directly on a building structure. The DCD also indicates that seismic analysis procedures for aboveground tanks are based primarily on the Haroun and Housner methods, and that the hydrodynamic mass effects are considered following ASCE 4-98. The DCD also describes the method to combine the seismic effects due to three components of the seismic motion, verification of tank stability against buckling effect, consideration of tank shell flexibility, modeling of hydrodynamic loads to include impulsive and convective modes, fluid damping (0.5 percent for the convective mode and structural damping of the tank wall for impulsive mode), and structural adequacy of the anchorage. Consistent with COL 3.7(7), the DCD indicates that site specific foundation input response spectra developed at the base of the tank will be used to determine the spectral accelerations for each mode at the appropriate damping and frequency. These spectral accelerations will then be used to calculate the appropriate effective masses. The DCD generic description does not include (1) the soil-structure interaction analysis of the tanks if they were founded on a soil site, and (2) the consideration of tank-pipe connections. However, because the actual analysis of tanks will be performed by the COL applicant and will be evaluated in detail at the time of the COL application and because the DCD description is consistent with SRP Acceptance Criterion 3.7.3.II.14, the staff finds the generic description of methods for seismic analysis of aboveground tanks acceptable, with the exception discussed in the following paragraphs.

DCD Tier 2 Section 3.7.3.9 states that, "because of the symmetry of these vertical tanks, the larger of the two horizontal earthquake components, if they are not equal in magnitude, is combined by the SRSS method with the vertical earthquake component." Neglecting the input component in the other horizontal direction, which is smaller but generally close to the larger direction, can be non-conservative because of the vector (combination) effect of two horizontal components of the input motion. The vector effect may not be an issue for a cylindrical tank mounted on the ground surface if the input motion is truly statistically independent in the two horizontal directions, but it can be significant for tanks that are not cylindrical or tanks mounted in a structure that can yield highly correlated input motions at the base of the tanks. Therefore,

the staff issued RAI 267-8301, Question 03.07.03-1 (ML15295A261), asking the applicant to provide a technical basis for considering only the larger of the two horizontal input motions in the seismic analysis of tanks.

In its response to RAI 267-8301, Question 03.07.03-1 (ML15295A261), the applicant revised DCD Tier 2 Section 3.7.3.9 to restrict the scope of this DCD section to only cylindrical tanks that are anchored to reinforced concrete pads. With this revision, the staff finds that the use of the larger of the two horizontal earthquake components is acceptable because the vector effect is not considered to be significant for the cylindrical tanks mounted on the ground surface when they are subjected to statistically independent ground motion. The statistical independence of ground motions for CSDRS or HRHF response spectra has been confirmed in SER Section 3.7.1.4.1.

The applicant also revised DCD Tier 2, Section 3.7.3.9, to indicate that the seismic Category I tanks constructed as part of buildings are included in the seismic analysis finite element models. Therefore, the potentially correlated building responses imposed on these tanks as input motions, are directly considered in the seismic analysis. The seismic analysis of seismic Category I structures is described in DCD Tier 2 Section 3.7.2.3, and is evaluated in SER Section 3.7.2.

For seismic Category I tanks installed in the buildings, such as firewater tanks, fuel tanks for the emergency diesel generator, and other mechanical tanks, the applicant included in DCD Tier 2, Section 3.7.3.9, a reference to DCD Tier 2, Section 3.9.2.2.14, "Seismic Analysis for Mechanical Tanks," which is a new DCD section as a result of RAI 267-8301, Question 03.07.03-1. The staff's evaluation of DCD Tier 2 Section 3.9.2.2.14 is found in SER Section 3.9.2.

Based on the review of the DCD, the staff has confirmed incorporation of the changes discussed above; therefore, RAI 267-8301, Question 03.07.031-1, is resolved and closed.

3.7.3.5 Combined License Information Items

DCD Tier 2, Section 3.7.3, contains three COL information items pertaining to seismic subsystem analysis. Based on the discussion above, the staff concludes that these three COL information items are acceptable.

Table 3.7.3 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.7(5)	The COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if necessary.	3.7.2.13
COL 3.7(6)	The COL applicant is to perform seismic analysis of buried seismic Category I conduits and tunnels.	3.7.3.7
COL 3.7(7)	The COL applicant is to perform seismic analysis for the seismic Category I above-ground tanks.	3.7.3.9

3.7.3.6 Conclusion

The staff finds that the applicant has adequately addressed seismic subsystem analysis, in accordance with the acceptance criteria in SRP Section 3.7.3. For each of the 14 review areas identified in SRP Section 3.7.3, the applicant provided an adequate description of the methodology to be used for the seismic analysis of the subsystem and/or created an acceptable COL information item to address the subsystem at the COL stage. On this basis, the staff concludes that the regulatory criteria in SER Section 3.7.3.4 are satisfied.

3.7.4 Seismic Instrumentation

3.7.4.1 Introduction

Installation of instrumentation that is capable of adequately measuring the effects of an earthquake at a plant site is addressed. The criteria for the seismic instrumentation include the following:

1. Comparison with RG 1.12, "Nuclear Power Plant Instrumentation for Earthquakes," Revision 2, March 1996.
2. Location and description of instrumentation.
3. Control room operator notification.
4. Comparison of measured and predicted responses.
5. Tests and inspections.

3.7.4.2 Summary of Application

DCD Tier 1: There is no DCD Tier 1 information associated with this section.

DCD Tier 2: The applicant has provided a DCD Tier 2 system description in Section 3.7.4, "Seismic Instrumentation," summarized in part below.

DCD Tier 2 Section 3.7.4, describes the seismic instrumentation and procedures necessary to evaluate the seismic response of nuclear power plant features important to safety after an earthquake promptly and to determine if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) has occurred. DCD Tier 2 Section 3.7.4, also provides a list of relevant regulations and RGs.

The seismic instrumentation program described in DCD Tier 2 Section 3.7.4, specifies the location and description of instrumentation, the type of accelerograph, recording and playback equipment, control room operator notification, comparison of measured and predicted responses, and in-service surveillance.

ITAAC: There are not ITAAC items associated with DCD Tier 2, Section 3.7.4.

Technical Specifications: There are no Technical Specifications for this area of review.

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

Technical Reports: There are no Technical Reports for this area of review.

Cross-cutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): There are no cross cutting requirements for this area of review.

APR1400 Interface Issues Identified in the DCD: See DCD Tier 2, Table 1.8-2.

Site Interface Issues Identified in the DCD: See DCD Tier 2, Table 1.8-2.

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

3.7.4.3 *Regulatory Basis*

The relevant requirements of the NRC's regulations for this area of review, and the associated acceptance criteria are given in SRP Section 3.7.4, and are summarized below. Review interfaces with other SRP sections are also found in SRP Section 3.7.4.

- Part 20 of 10 CFR, and 10 CFR Part 50, Appendix S, as they relate to meeting the capabilities and performance of the instrumentation system to adequately measure the effects of earthquakes.
- Part 20 of 10 CFR, requires licensees to make every reasonable effort to maintain radiation exposure as low as reasonably achievable (ALARA).
- Part 50, Appendix S, requires that suitable instrumentation be provided to promptly evaluate the seismic response of nuclear power plant SSCs important to safety after an earthquake. Appendix S also requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the OBE occurs.
- Section 52.47(b)(1) of 10 CFR, requires that a DCD 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 is built and will operate in accordance with the design.

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

- SRP Section 3.7.4.II, including criteria: (1) comparison with RG 1.12, and (2) comparison with RG 1.166, and (3) comparison with the requirements of 10 CFR 20.1101 (ALARA).
- RG 1.12, Revision 2.
- RG 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions," December 1997.

3.7.4.4 *Technical Evaluation*

The staff reviewed the list of RGs and the descriptions provided in DCD Tier 2 Section 3.7.4, of the seismic instrumentation program and procedures to ensure that the relevant requirements of Appendix S to 10 CFR Part 50, can be met by potential COL applicants. Paragraph IV(a)(4) of Appendix S to 10 CFR Part 50, requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50, requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the OBE occurs.

The staff reviewed the seismic instrumentation program described in DCD Tier 2 Section 3.7.4, to ensure that the instrumentation program provides an adequate number of instruments in suitable locations capable of recording a suitable range of earthquake strong ground motions.

The applicant specified in DCD Tier 2 Section 3.7.4.2 that COL applicants are required to determine whether seismic response at a multi-unit site is expected to be essentially the same at each unit and determine if the units are should be instrumented separately as part of COL 3.7(8). This information item ensures that, for multi-unit sites, the variations in seismic response across units are considered in seismic instrumentation placement.

The applicant specified in DCD Tier 2 Section 3.7.4.2 that COL applicants are required to confirm details of the locations of the seismic recorders as part of COL 3.7(9). This information item ensures that the placement of accelerographs considers site-specific conditions within the plant and in the free-field.

The staff issued RAI 4-7830, Question 03.07.04-1 (ML15103A455), requesting the applicant to propose a criterion for determining the exceedance of the OBE by earthquake ground motions and procedures for determining the exceedance of the cumulative absolute velocity (CAV) limit.

In its response to RAI 4-7830, Question 03.07.04-1 (ML15132A595), the applicant provided the following additional information:

1. Specific provisions for determining the exceedance of the OBE including specific acceleration values between 2 and 10 Hz and spectral velocity levels between 1 and 2 Hz, in accordance with guidance in RG 1.66.
2. The procedure for determining if the CAV limit is exceeded and the CAV limit, in accordance with RG 1.66 and EPRI TR-100082 will be developed by the COL applicant.

The applicant also proposed modifications to the DCD Tier 2 Section 3.7.4.4 to incorporate the RAI response into the DCD. Because the RAI response and proposed DCD modification address the need for procedures for determining if the OBE has been exceeded and for determining the CAV and following applicable NRC guidance, the staff finds the response acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 4-7830, Question 03.07.04-1, is resolved and closed.

The applicant specified in DCD Section 3.7.4.6 that the COL applicant is to develop implementation milestones for the seismic instrumentation program as part of COL 3.7(10).

This information item ensures that COL applicants have a seismic instrumentation program developed and implemented at the time of startup.

The staff issued RAI 4-7830, Question 03.07.04-2 (ML15103A455), requesting the applicant to discuss what DCD provisions are applicable to plant restart in the event of a seismic event.

In its response to RAI 4-7830, Question 03.07.04-2, (ML15132A595), the applicant stated that COL applicants are to prepare a procedure for post-shutdown inspection and plant restart due to a seismic event in accordance with RG 1.167 as part of COL 3.7(11).

The applicant also proposed modifications to DCD Tier 2, Section 3.7.4.6, Section 3.7.5, and Table 1.8-2. The staff reviewed the RAI response and the proposed changes to the DCD. The applicant cites applicable regulatory guidance and requires that COL applicants develop procedures for post-earthquake actions in accordance with that guidance. Therefore, the staff finds the applicant's response acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 4-7830, Question 03.07.04-2, is resolved and closed.

The staff notes that there are no ITAAC Items associated with DCD Tier 2 Section 3.7.4.

3.7.4.5 Combined License Information Items

DCD Tier 2, Section 3.7.4, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.7.4 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.7(8)	The COL applicant is to determine whether essentially the same seismic response from a given earthquake is expected at each unit in a multi-unit site or if each unit is to be provided with a separate set of seismic instruments.	3.7.4.2
COL 3.7(9)	The COL applicant is to confirm details of the locations of the triaxial time- history accelerographs.	3.7.4.2
COL 3.7(10)	The COL applicant is to identify implementation milestones for the seismic instrumentation implementation program as discussed in DCD Subsections 3.7.4.1-3.7.4.5.	3.7.4.6
COL 3.7(11)	The COL applicant is to prepare a post-shutdown inspection and plant restart procedure in accordance with guidance in RG 1.167.	3.7.4.6

3.7.4.6 Conclusion

Based on its review of DCD Tier 2 Section 3.7.4, the staff concludes that the applicant provided an adequate description of the seismic instrumentation program and procedures to ensure that

the relevant requirements of Appendix S to 10 CFR Part 50, can be met by potential COL applicants. The applicant also adequately followed the applicable RGs.

3.8 Seismic Category I Structures

3.8.1 Concrete Containment

3.8.1.1 Introduction

As described in DCD Tier 2 Section 3.8.1, “Concrete Containment,” the RCB is a posttensioned concrete containment structure located on the nuclear island and surrounded by the AB. The RCB houses the containment internal structures, controls the release of airborne radioactivity following design-basis accidents, and provides radiation shielding for the reactor core and the reactor coolant system. This section of the APR1400 DCD provides the following information on the RCB:

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

3.8.1.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section appears in DCD Tier 1 Section 2.2.1.

DCD Tier 2: The applicant provided a system description in DCD Tier 2 Section 3.8.1, including information on the physical layout, design, construction, and inspection of the concrete containment.

ITAAC: The ITAAC associated with DCD Tier 2 Section 3.8.1, appear in DCD Tier 1 Section 2.2.1.2, “Inspections, Tests, Analyses, and Acceptance Criteria.”

Technical Specifications: The applicant provided the technical specifications in DCD Tier 2, Chapter 16, “Technical Specifications,” Section 3.6, “Containment Systems,” and Section 3.9.3, “Containment Penetrations.”

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

Technical Reports: The technical report associated with DCD Tier 2 Section 3.8.1, is APR1400-E-S-NR-14006, Revision 1, "APR1400 Stability Check for NI [Nuclear Island] Common Basemat," issued February 2015.

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, 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.

3.8.1.3 Regulatory Basis

The relevant requirements and associated acceptance criteria for this review are found in SRP Section 3.8.1, "Concrete Containment," Revision 4, issued September 2013, and are summarized below.

- Section 50.55a of 10 CFR and GDC 1, "Quality Standards and Records," of Appendix A, to 10 CFR Part 50, as these relate to the concrete containment being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.
- GDC 2, as it relates to the ability of the concrete containment design to withstand the most severe natural phenomena, such as winds, tornadoes, floods, and earthquakes, and the appropriate combination of all loads.
- GDC 4, as it relates to the concrete containment being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.
- GDC 16, "Containment Design," as it relates to the ability of the concrete containment to act as a leaktight membrane to prevent the uncontrolled release of radioactive effluents to the environment.
- GDC 50, "Containment Design Basis," as it relates to the concrete containment being designed with a sufficient margin of safety to accommodate appropriate design loads.
- GDC 53, "Provisions for Containment Testing and Inspection," as it relates to periodic testing of the concrete containment penetrations.
- Appendix B to 10 CFR Part 50 as it relates to the QA criteria for nuclear power plants.
- Section 50.44 of 10 CFR, "Combustible Gas Control for Nuclear Power Reactors," as it relates to demonstrating the structural integrity of boiling water reactors with Mark III

type containments, all pressurized water reactors with ice condenser containments, and all containments used in future water cooled reactors for loads associated with combustible gas generation.

- Section 52.47(b)(1) of 10 CFR, which requires that a DCA 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 NRC's regulations.

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

- SRP Section 3.8.1, Section II, includes acceptance criteria for (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and loading combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs.
- RG 1.7, "Control of Combustible Gas Concentrations in Containment," Revision 3, issued March 2007.
- RG 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," issued July 1990.
- RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," issued April 2013.
- RG 1.136, "Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments," Revision 3, March 2007.
- RG 1.206, "Combined License Applications for Nuclear Power Plants," issued June 2007.
- RG 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design-Basis Pressure," issued August 2010.
- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," issued October 2011.

SRP Section 3.8.1 lists the review interfaces with other SRP sections.

3.8.1.4 Technical Evaluation

The staff reviewed DCD Tier 2 Section 3.8.1 to ensure that it represents the complete scope of information relating to this review topic. SRP Section 3.8.1 identifies seven specific SRP acceptance criteria that are acceptable for meeting the relevant requirements listed in SRP Section 3.8.1.II and included in SER Section 3.8.1.3. This section evaluates DCD Tier 2 Section 3.8.1, with regard to each of these seven SRP acceptance criteria.

SRP Section 3.8.1 provides guidelines for the staff to use in reviewing the technical areas related to the design of a concrete containment vessel based on the requirements of 10 CFR 50.55a and GDC 1, 2, 4, 16, and 50; 10 CFR Part 50, Appendix B; 10 CFR 50.44; and 10 CFR 52.47(b)(1). Using the guidance described in SRP Section 3.8.1, the staff reviewed DCD Tier 2 Section 3.8.1, and the associated Section 3.8A containing the structural design summary, as well as technical report APR1400-E-S-NR-14006, Revision 1, which is associated with the stability and design of the basemat of the NI. In particular, the review described in this section focused on (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and load combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs. The staff also reviewed applicable COL action items.

3.8.1.4.1 *Description of the Containment*

DCD Tier 2 Section 3.8.1.1, "Description of the Containment," and Section 3.8A.1.1, "Structural Description and Geometry," describe the physical characteristics of the concrete containment building for the APR1400 plant. The RCB is a prestressed concrete shell structure that is designed in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, "Rules for Construction of Nuclear Facility Components," Division 2, "Code for Concrete Containments." The geometric shape of the RCB structure is a vertically oriented cylinder topped by a hemispherical dome with no ring girder at the dome and cylinder interface. The containment structure includes a reinforced concrete basemat that it shares with the AB, which wraps around the RCB with a seismic isolation gap of 50 millimeters (mm) (2 inches (in.)). The containment structure has an inside diameter of 45.72 meters (m), (150 feet (ft.)) and an inside height of 76.66 m (251 ft., 6 in.). The thickness is 1.37 m (4 ft., 6 in.) for the cylinder and 1.22 m (4 ft.) for the dome. Areas around the large openings are thickened to provide additional strength and space for the prestressing tendons that are deflected around the openings. The RCB provides biological shielding during normal operation and following a loss of coolant accident (LOCA). In addition, it functions as a leaktight barrier following an accident inside the containment.

The RCB consists of a prestressed concrete shell containing horizontal (hoop) and vertical high strength steel unbonded tendons (i.e., ungrouted) and reinforcement steel. Prestressing force for the cylindrical portion of the containment is obtained through a posttensioning system—a method of prestressing in which prestressing tendons are tensioned after concrete has hardened—consisting of horizontal and inverted U-shaped vertical tendons. The unbonded tendons are placed in steel sheaths embedded in the concrete. The dome is prestressed by horizontal tendons and inverted U-shaped tendons. The horizontal tendons are anchored at three buttresses, equally spaced at 240 degrees apart around the containment wall, bypassing the intermediate buttress. The inverted U shaped tendons run vertically up the RCB cylinder and over the dome, then down to the circular tendon gallery in the basemat slab. The tendon gallery allows for installing and servicing the vertical tendons.

The concrete containment wall, dome, and basemat inner surfaces are lined with 6.0 mm (1/4 in.) carbon steel and stainless steel plates that are anchored to the concrete to provide the required pressure boundary leaktightness. The other items integrally welded to the liner that form part of the overall pressure boundary include but are not limited to the equipment hatch, two personnel airlocks, various piping and electrical penetrations, and miscellaneous supports

that are embedded in the concrete shell, such as the polar crane brackets and the main steam; feedwater; and heating, ventilation, and air conditioning lines. The liner plate system is not designed nor considered as a structural member but rather serves as a leaktight membrane and provides an inside formwork for the cylindrical wall and dome during concrete placement.

The staff reviewed the description of the RCB to ensure that it contains sufficient information that defines the primary structural aspects and elements that are relied upon to perform the RCB's safety related functions. To assess the acceptability of the RCB description in the DCD Tier 2 document, the staff followed the guidelines in SRP Section 3.8.1 and Section C.I.3.8.1.1, "Description of the Containment," of RG 1.206.

DCD Tier 2 Section 3.8.1.1 contains information on the general arrangement and physical features of the prestressed concrete containment, including the penetrations and attachments structurally connected to the containment. The description contains information on the 6.0 mm (0.25 in.) thick carbon steel and stainless steel liners that are anchored to the concrete shell, dome, and basemat essentially to provide the required pressure boundary leaktight barrier in the containment. It also provides information about the prestressing system used in the containment, including descriptions of the steel prestressing tendons, such as location, type of tendons, spacing, use of vertical buttresses, and other information.

The staff compared the design of the RCB for the APR1400 to those for similar design centers and previously licensed plants that use prestressed concrete for the containment structure to identify new and unique features in the APR1400 design. The staff noticed that there are two notable differences between the RCB designs of the previous licensed plants and the APR1400. First, the thickness of the common concrete basemat under the APR1400 RCB and AB ranges from 3.05 m to 10.06 m (10 ft. to 33 ft.). This concrete basemat thickness is much greater than those used for the previously licensed plants, whose basemats are approximately 2.90 m (9 ft., 6 in.) thick on average. The use of a much thicker concrete basemat is not significant; it is related to the design of the RCB walls and dome, and also because the tendon gallery is located within the basemat, unlike other prestressed concrete containments where the tendon gallery is either not integrally connected or is not within the basemat region. The thicker concrete foundation slab does require some special construction techniques and measures, which are discussed in SER Section 3.8.5.

The APR1400 RCB does not use a ring girder at the spring line joint between the cylinder and the dome used on the RCBs for some of the existing plants. This ring girder in the prestressed concrete containment provides anchorages for the vertical tendons in the cylinder and for the tendons in the dome; as well as added structural capability to resist discontinuity stresses at the spring line. The APR1400 RCB employs continuous inverted U shaped vertical tendons in which one end of the tendon is anchored at the base of the tendon gallery. The tendon then runs up inside of the cylindrical wall and dome and comes down through the other side of the wall, where it is anchored to the base at the other side of the tendon gallery of the RCB. Therefore, it is not necessary to use a ring girder. These differences between the existing prestressed containments and the APR1400 RCB do not materially affect the overall structural characteristics of the RCB.

When compared to the RCB used for previously licensed plants, the APR1400 RCB appears to have a reasonable overall design, considering geometry, wall and basemat thicknesses, the general arrangement of prestressing steel tendons and other reinforcement in the RCB wall and

dome, prestressing tendons, layouts at large openings and penetrations, and descriptions of major penetrations and attachments. The design of the APR1400 RCB exhibits structural characteristics similar to those of existing U.S. plants using RCB containment structures, including those characteristics that provide desirable seismic design margins.

In DCD Tier 2 Section 3.8.1.1.3, the applicant discussed the physical characteristics of the containment shell, including the attachment of the polar crane into the cylindrical wall. The staff determined that additional information was needed to better understand how equipment (e.g., the electrical conduit, cable tray, spray piping) is attached to the inside and outside surface of the concrete containment. Therefore, the staff issued RAI 199-8223, Question 03.08.01-07 (ML15251A052), requesting the applicant to describe the design of the attachments to the inside and outside of the concrete containment. In its response to RAI 199-8223, Question 03.08.01-07 (ML16008A913), the applicant stated that the structural steel supports are provided for the electrical conduit, cable tray, and the spray system piping and that the supports are welded to the embedment plates on the inside and outside of the containment wall and dome.

The staff reviewed the applicant's response and considered the applicant's approach for attaching equipment such as the electrical conduit, cable tray, and spray system piping to be acceptable because it is consistent with industry practices and the applicant is committed to using Section III of the ASME Code in its design of the structural steel supports. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-07, is resolved and closed.

In DCD Tier 2 Section 3.8.1.1.4.4, "Liner Plate Details and Anchorage," the applicant discussed the physical characteristics of the liner plate details and anchorage system. The applicant stated that "radial and hoop stiffeners are provided for attaching the 6.0 mm (1/4 in.) liner plate to the concrete dome." DCD Tier 2, Figure 3.8 5, "Liner Plate and Anchorage System," shows the use of the meridional and hoop stiffeners but not radial stiffeners. The staff found that without a figure or further description, it was difficult to understand the configuration and to find the exact location of the radial stiffeners used in the dome. Therefore, the staff issued RAI 129-8085, Question 03.08.01-03 (ML15218A040), requesting the applicant to provide a description or a figure that depicts all of the stiffeners used to attach the liner plate to the concrete dome. In its response to RAI, Question (ML15260B252), the applicant provided a marked-up figure that depicts the stiffeners used to attach the liner plate to the concrete dome. The staff reviewed the marked up figure and considered it to be acceptable because it clarifies the use of radial stiffeners to attach the liner plate to the concrete dome. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-03, is resolved and closed.

The descriptive information and referenced figures in DCD Tier 2, Sections 3.8.1.1 and 3.8A, contain sufficient detail to define the primary structural aspects and elements relied upon for the prestressed containment structure to perform its safety related function. The staff finds the description of the containment in DCD Tier 2 Section 3.8.1.1, acceptable on the basis that it is consistent with the acceptance criteria in 10 CFR Part 52, SRP Section 3.8.1, and RG 1.206.

3.8.1.4.2 *Applicable Codes, Standards, and Specifications*

DCD Tier 2, Section 3.8.1.2, "Applicable Codes, Standards, and Specifications," and Table 3.8-1, "Codes, Standards, Specifications, and Regulations," identifies the following

industry codes, standards, and specifications that are applicable for the design, fabrication, construction, materials, testing, and inspections of the RCB for the APR1400 plant:

- ASME Code, Section III, Division 2, 2001 Edition through 2003 Addenda
- ASME Code, Section III, Division 1, 2007 Edition through 2008 Addenda
- ASME Code, Section XI, Subsection IWL, 2007 Edition through 2008 Addenda
- RG 1.136, "Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments," Revision 3, issued March 2007.
- RG 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," issued July 1990.
- RG 1.7, "Control of Combustible Gas Concentrations in Containment," Revision 3, issued March 2007.
- RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Revision 3, issued April 2013.
- RG 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design-Basis Pressure," issued August 2010.
- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," issued October 2011.

The staff reviewed the applicable codes and standards given in DCD Tier 2, Section 3.8.1.2 and Table 3.8-1, for the prestressed RCB and determined that the application did not describe certain codes and standards in sufficient detail to determine whether they conform with the regulatory requirements in 10 CFR 50.55a; 10 CFR 50.44; GDC 1, 2, 4, 16, 50 and 53; and the guidance in SRP Section 3.8.1.II.2.

DCD Tier 2 Section 3.8.1.2 presents Table 3.8-1, which lists the codes, standards, specifications, and regulations used in the design of the concrete containment. However, the staff did not find the identification of the codes, standards, and specifications applicable to the individual DCD sections or applicable to the different types of structures (i.e., concrete containment, containment internal structures, other Category I structures such as the AB, and the foundation) to be clear. Generally, the individual DCD sections reference Table 3.8-1 without indicating which codes, standards, and specifications are applicable to the particular DCD sections or structures. The acceptance criteria in SRP Section 3.8.1.II.2 states that the design, materials, fabrication, erection, inspection, testing, and inservice surveillance of the concrete containment are covered by codes, standards, specifications, and RGs that are applicable either in their entirety or in part. It then lists the various applicable codes that are acceptable. The staff reviewed DCD Tier 2 Section 3.8.1.2, and noticed that additional information was needed to complete the safety review. Therefore, the staff issued RAI 129-8085, Question 03.08.01-04 (ML15218A040), requesting the applicant to provide information in the applicable sections of the DCD about the relevant codes, standards, specifications, and regulations. Specifically, in part (a) of the RAI, the staff asked the applicant to identify the

version and edition of the various codes, standards, specifications, and regulations, including the ASME Code. The version and edition of some of the codes provided in the DCD were not consistent (e.g., ASME Code, Section III, Subsection CC, "Code for Concrete Containment," 2001 Edition with 2003 Addenda, and ASME Code, Section III, Subsection NE, 2007 Edition with 2008 Addenda). The staff also noted that Table 3.8-1 did not provide the editions; however, the list of references identified some of the editions.

In its response to RAI 129-8085, Question 03.08.01-04 (ML16203A303), the applicant provided marked up copies of the DCD that show the inclusion of the appropriate codes for each section of the DCD. The applicant stated in its response that the prestressed concrete containment vessel will be designed in accordance with ASME Code, Section III, Division 2, "Code for Concrete Containments," Subsection CC, 2001 Edition with 2003 Addenda; and RG 1.136, Revision 3. The metal containment (MC) components will be designed in accordance with ASME Code, Section III, Division I, Subsection NE, "Class MC Components," 2007 Edition and 2008 Addenda; and RG 1.57, Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components," Revision 2, issued May 2013. The applicant also provided a comparison between the Subsection NE 2001 Edition including 2003 Addenda and the later Subsection NE 2007 Edition including 2008 Addenda to verify the appropriateness of using the later edition of Subsection NE instead of the same edition of Subsection CC of the ASME Code used for the concrete portion of the containment. The comparison demonstrates that the changes that were made in the later edition of Subsection CC do not affect the safety of the Class MC Component design of containment, and thus this item is acceptable.

In part (b) of RAI 129-8085, Question 03.08.01-04, the staff asked the applicant to provide complete titles and editions of the codes, standards, and specifications listed in DCD Table 3.8-1. Table 3.8-1 lists some specifications and standards without the full title and edition (e.g., American Institute of Steel Construction (AISC), and American Concrete Institute, ACI-301, "Specifications for Structural Concrete"). Because DCD Tier 2, Sections 3.8.2, "Steel Containment," through 3.8.5, "Foundation," reference Table 3.8-1, the information requested should be applicable to the other DCD sections. It should be clear from the text within each section of DCD Tier 2, Sections 3.8.1 through 3.8.5 or from Table 3.8-1 which codes, standards, and specifications are applicable to the particular DCD sections.

The applicant's response to part (b) of the RAI provided a revised table that shows the inclusion of the appropriate version and edition of the codes used in the design of the APR1400. The applicant stated that it will revise Table 3.8-1 to clearly identify the version and edition of the codes used in its design of the APR1400. The response also included markups in the various DCD sections to identify the primary design codes for the particular DCD section in addition to referencing Table 3.8-1.

In part (c) of RAI 129-8085, Question 03.08.01-04, the staff asked the applicant to include, in DCD Tier 2 Section 3.8.7, "References," all the codes, standards, specifications, and regulations, as well as other references, cited in DCD Tier 2 Section 3.8, "Design of Category I Structures." DCD Tier 2 Section 3.8.7 does not list some of the codes and standards used in the individual DCD Tier 2, Sections 3.8.1 through 3.8.5 (e.g., AISC N690-1994, "Specification for the Design, Fabrication and Erection of Safety-Related Steel Structures for Nuclear Facilities," Supplement No. 2).

The applicant's response to part (c) of the RAI stated that it will revise DCD Tier 2 Section 3.8.7 to identify the version and edition along with the complete title of the various codes, standards and specifications used in the design of the APR1400.

The staff reviewed the applicant's response and concluded that the information provided by the applicant is acceptable because the appropriate ASME Code is used for the design of the concrete containment in accordance with 10 CFR 50.55a and RG 1.136 and RG 1.57. The applicant compared the two editions of the ASME Code in relation to the design of the MC components and demonstrated that the design safety of the MC components would not change if the 2001 edition were followed instead of the 2007 Edition with 2008 Addenda. The applicant also provided marked-up copies of the DCD that include the appropriate version and edition of the codes, standards, and specifications for its design of the concrete containment. Because the applicant has complied with the regulatory requirements in 10 CFR 50.55a and GDC 1, and applicable RGs, by providing the details requested in response to RAI 129-8085, Question 03.08.01-04, the staff considers the RAI to be resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 129-8085, Question 03.08.01-04, is resolved and closed.

In summary, the staff reviewed the codes, standards, and specifications given in DCD Tier 2 Section 3.8.1.2, for applicability to the design of the APR1400 RCB. The applicant provided a list of the industry codes, standards and specifications; RG; and SRP guidance that are applicable for the design, construction, materials, testing, and inspections of the APR1400 RCB design. The staff found the use of these codes, standards, and specifications in the design and construction of the APR1400 RCB to be in accordance with the guidance given in SRP Section 3.8.1.II.2 and that the codes provided comply with requirements in 10 CFR 50.55a. On this basis, the staff concludes that the information provided in DCD Tier 2 Section 3.8.1.2, on applicable codes, standards, and specifications, is acceptable.

3.8.1.4.3 *Loads and Load Combinations*

DCD Tier 2, Sections 3.8.1.3.1, "Load Category," through 3.8.1.3.4, "Liner Plate Loads and Load Combinations," and Section 3.8A.1.4.1.2, "Load Combination Considered," specify all credible conditions of loading, including service loads (i.e., normal loads, construction loads, and preoperational testing loads) and factored loads (i.e., loads during severe environmental, extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme conditions), for which the RCB is designed. The applicant indicated that the load combinations specified are consistent with ASME Code, Section III; Article CC 3200, "Load Criteria," Table CC-3230-1, "Load Combinations and Load Factors," and RG 1.136, with the clarification to Regulatory Position 5, "CC-3000 Design," of the RG as given below:

- The post-LOCA flooding, combined with the operating-basis earthquake, set at one third or less of the plant SSE, is eliminated, since the load combination is less severe than the post-LOCA flooding combined with an SSE.
- ASME Code, Section III, Division 2, Subarticle CC 3720, "Liner," is satisfied by addressing an accident that releases hydrogen generated from a 100 percent fuel cladding coolant reaction accompanied by hydrogen burning, including the effects of temperature and prestress.

The staff reviewed DCD Tier 2 Section 3.8.1.3, "Load and Load Combinations," and noted that it includes the hydrogen generation pressure load as a result of fuel cladding and water interaction. However, DCD Tier 2, Sections 3.8.1.4, "Design and Analysis Procedures," and 3.8.1.5, "Structural Acceptance Criteria," do not describe the design and analysis procedures and the acceptance criteria for this loading condition. RG 1.216, Regulatory Position 2, "Combustible Gas Control Inside Containment," states that containment should be evaluated for the pressure arising from the fuel cladding-water reaction, hydrogen burning, and postaccident inserting (if applicable).

The staff issued RAI 199-8223, Question 03.08.01-08 (ML15251A052), requesting the applicant to describe the design and analysis approach and the acceptance criteria for the hydrogen generation pressure load. The staff noted that if the applicant's approach is different from the criteria presented in SRP Section 3.8.1 and RG 1.216, then the applicant should provide the technical basis for this difference.

In its response to RAI 199-8223, Question 03.08.01-08(ML16207A127), the applicant stated that the safety of the concrete containment under the combustible gas load (P_s) condition, which includes the hydrogen generation pressure load as a result of 100 percent fuel cladding and water interaction (P_{g1}) accompanied by hydrogen burning (P_{g2}), is assessed and demonstrated to comply with the allowable values in ASME Code, Section III, Division 2, Subarticle CC-3720. The pressure from the hydrogen generation event including P_{g1} and P_{g2} is determined by using the adiabatic, isochoric, complete combustion (AICC) pressure evaluation. Based on the results of the AICC evaluation, the upper-bound value for the pressure load as a result of slow deflagrations of hydrogen produced from 100 percent metal-water reaction is 109 pounds per square inch gauge (psig) (123.7 pounds per square inch absolute (psia)), which is greater than the minimum requirement of 45 psig (59.7 psia) described in RG 1.216. The pressure (P_{g3}) resulting from postaccident inerting does not exist in the APR1400 and thus the applicant's analysis did not include it. The applicant further stated that under these loading conditions, the loading produces strains in the containment liner plate below the limits established in ASME Code, Section III, Division 2, Subarticle CC-3720.

The staff reviewed the applicant's response to ensure that the method for determining the hydrogen pressure load is adequate. The applicant demonstrated that the structural integrity of the containment will be maintained when subject to hydrogen generation caused by the reaction between the fuel cladding and the water coolant. The applicant performed a three-dimensional FEA for the safety evaluation during the combustible gas load conditions. The FEA model includes the prestressed concrete containment structure, which consists of the concrete wall and dome, liner plate, rebar, and tendons. The results of the FEA demonstrated that the tendons and rebar are still in the elastic range and at the maximum pressure loading level of the combustible gas load condition, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions are less than the allowable limit for strain values in ASME Code, Section III, Division 2, Subarticle CC-3720. Based on the information presented by the applicant, the staff considered the response to be acceptable because the applicant's method for demonstrating the structural integrity of the containment subject to hydrogen generation caused by the reaction between the fuel cladding and the water coolant is consistent with the guidance in RG 1.216 the regulatory requirement in 10 CFR 50.44. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-08, is resolved and closed.

Based on the above discussion, the staff found the loads and load combinations provided by the applicant to be in accordance with Section III of the ASME Code, which is the specified code governing the RCB design, and in accordance with the guidance given in SRP Section 3.8.1.II.3 and RG 1.136.

Design and Analysis Procedures

DCD Tier 2, Sections 3.8.1.4, and 3.8A.1.4.1.3, "Analysis and Design Procedures," describe the design and analysis procedures for the RCB. The applicant indicated that the design and analysis of the prestressed concrete containment, including the steel liner, comply with the requirements of ASME Code, Section III, Division 2, Article CC 3000, "Design," and RG 1.136.

Acceptance criterion 4 in SRP Section 3.8.1 states that ASME Code, Section III, Division 2, Article CC-3300, covers the design and analysis procedures for concrete containments. The procedures given in the ASME Code, as augmented by the applicable provisions of RG 1.136, constitute an acceptable basis for the design analysis of the APR1400 concrete containment. SRP Section 3.8.1, acceptance criterion 4, also provides acceptance criteria for assumptions on boundary conditions, treatment of axisymmetric and nonaxisymmetric loads, transient and localized loads, creep, shrinkage and cracking of concrete, dynamic soil pressure, computer programs, tangential shear, variations in physical material properties, thickened penetrations, steel liner plate and anchors, ultimate capacity of concrete containment, structural audit, and design report.

DCD Tier 2, Section 3.8.1.4.5.2, "Thermal Stress Analysis," discusses the thermal analysis of the containment and Section 3.8A.1.4.1.3.2, "Analysis Model," discusses the effects of temperature variations during normal operating and accident conditions. However, these sections did not provide the design temperatures used for normal and accident conditions.

The staff issued RAI 199-8223, Question 03.08.01-14 (ML15251A052), requesting the applicant to include, in the applicable sections of the DCD, the ambient temperatures inside and outside containment considered for the design during normal and accident conditions. In addition, for the variation of temperature through the containment thickness, the applicant should provide the results of the thermal analysis showing the gradient for the various cases (normal loading and accident loading over time) and identify which ones were used in the design of the containment.

In its response to RAI 199-8223, Question 03.08.01-14 (ML16008A913), the applicant provided a marked up copy of the DCD that shows the temperature values both inside and outside of the containment during normal and accident conditions. The operating temperature inside containment is 48.9 °C (120 °F), outside containment is 46.1 °C (115 °F) during the summer and -40.0 °C (40 °F) during the winter. For accident temperature, the maximum temperature inside containment is expected to be 143.3 °C (290 °F) and the outside accident temperature is expected to be the same as the operating temperature during the summer and winter. Additionally, the applicant provided figures that show the variation of both operating and accident temperatures through the containment thickness. The applicant stated that the most critical case among all of the temperature load cases is the accident condition combined with winter ambient temperature. The applicant considered all the cases in its thermal analysis of the containment.

The staff reviewed the applicant's response and concluded that the information on the effects of temperature variations during normal operating and accident conditions on the containment is acceptable because the applicant provided: (1) design temperatures inside and outside of containment used for normal and accident conditions for winter and summer, (2) temperature gradients through the containment thickness for accident conditions for winter and summer as a function of time, and (3) deformation and stress contours for the different cases. The response also indicates that all of the temperature cases (i.e., design and accident temperatures, inside and outside of containment, under normal and accident conditions) are evaluated. Because the applicant provided the details requested in response to RAI 199-8223, Question 03.08.01-14, the staff considers the RAI to be resolved and the regulatory requirements in 10 CFR Part 50 and GDC 1, 2, 4, 16, and 50, met in accordance with SRP Section 3.8.1.II. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-14, is resolved and closed.

DCD Tier 2, Section 3.8.1.4.6, "Creep and Shrinkage Analysis," states that the effects of concrete creep, concrete shrinkage, concrete elastic shortening, and tendon steel relaxation are included in the computations for prestress losses in the tendons. The applicant also provided values for these items. DCD Tier 2 Section 3.8.1.4.8, "Variation in Physical Properties," also indicated that the values are based on engineering experience. Based on the information provided by the applicant, it was not clear to the staff how the values were obtained. SRP Section 3.8.1, Section II.4.D, states that creep and shrinkage values should be established by tests performed on the concrete to be used or from data obtained from completed containments with the same kind of concrete.

The staff issued RAI 129-8085, Question 03.08.01-02 (ML15218A040), requesting the applicant to describe: (1) how it obtained the values provided in DCD Tier 2 Section 3.8.1.4.6, (2) the various parameters for prestress tendon losses, including frictional losses because of the curvature of the tendons and slip at the anchorage because these are additional items identified in the ASME Code, and (3) how all of the parameters affect the prestress losses over the life of the plant. In addition, the staff asked the applicant to describe the effects of concrete cracking in DCD Tier 2, Section 3.8.1 or provide a technical basis for not considering the effects of concrete cracking.

In its response to 129-8085, Question 03.08.01-02 (ML16250A863), the applicant stated that concrete creep, shrinkage, and tendon relaxation values for the prestress losses are obtained from engineering experience gained through the construction of Shin-Kori Units 3 and 4 that are currently operating in South Korea. The values are to be evaluated and confirmed by certified material test reports and concrete long term material testing. The applicant added COL 3.8(14), which requires the COL applicant to perform concrete long-term material testing in a way that verifies the physical properties of the materials used during the design stage and the characteristics of long term concrete deformation. The elastic shortening coefficients of concrete are to be computed using the static modulus of elasticity when calculating the losses of prestress. The static modulus of elasticity is also to be evaluated by concrete long-term material testing. The applicant provided markups for DCD Tier 2, Sections 3.8.1.4.8 and 3.8.6, "Combined License Information," and Table 1.8-2 that show the revised changes.

The applicant further stated that there are two types of friction losses—wobble friction loss from unintended curvature and curvature friction loss from intended curvature. The two kinds of curvature in tendons induce friction loss of tensile stress. Friction losses are calculated in

accordance with ASME Code, Section III, Division 2, Subarticle CC-3542, "Loss of Prestress," and they are taken into account in the design of prestressing tendons. The wobble and curvature friction coefficients are determined experimentally and verified by testing while stressing tendons. The design of the containment posttensioning also considers slip at anchorage. Because of slipping at the anchorage, 5 percent of the maximum stress is lost at the anchor point. Thus, 95 percent of the maximum stress at the anchor point is applied to calculate the tendon stress. The supplier provides the value of 5 percent. The applicant provided a markup of DCD Tier 2 Section 3.8.1.4.6 that shows the revised changes.

The applicant provided two tables, Table 1, "Stress Profiles of Typical Prestressing Tendons-Vertical," and Table 2, "Stress Profiles of Typical Prestressing Tendons-Horizontal," which show the stress results for each type of tendon (hoop and vertical) at the start of prestressing and at the end of plant life. The tables included the results of the stress losses in the tendons with regard to elastic shortening, creep, shrinkage, relaxation, and total losses. The applicant stated that the stresses at each design stress point—the anchor point, spring line, dome apex in the vertical direction, and the anchor point, tangent point, and midpoint of tendon in the horizontal direction—are calculated in accordance with ASME Code, Section III, Division 2, Subarticle CC-3433, "Tendon System Stresses," and Subarticle CC-3542, "Loss of Prestress." The stress losses in the tendons are computed in conformance with the tolerance bands in RG 1.35.1.

The staff reviewed the applicant's response and concluded that the information presented on the approach for obtaining the values for the prestress losses in tendons is acceptable because the applicant (1) added a COL item to ensure that the tendon properties are evaluated and confirmed by certified material test reports and concrete long-term material testing, (2) provided stress profiles of typical prestressing tendons in the vertical and horizontal directions at the initial and at the end of life of the plant, (3) computed the tendon stresses in accordance with ASME Code, Subarticle CC-3433, to consider the stress limits and Subarticle CC-3542 to consider the friction loss, and (4) computed the tendon stress losses in conformance with RG 1.35.1. Because the applicant has complied with the regulatory guidance in SRP Section 3.8.1.II, RG 1.136, and RG 1.35.1, in the response to RAI 129-8085, Question 03.08.01-02, the staff considers the RAI to be resolved and finds the regulatory requirements in 10 CFR Part 50 and GDC 1, 2, 4, 16, and 50 are met. Based on the review of the DCD, the staff has incorporated the changes described above; therefore, RAI 129-8085, Question 03.08.01-02, is resolved and closed.

DCD Tier 2, Section 3.8.1.4.11, "Ultimate Pressure Capacity," states that the ultimate pressure capacity (UPC) of the containment is evaluated based on the design results of the structure. The applicant further stated that the analysis for the UPC is performed with consideration for the material nonlinear behaviors for the reinforced concrete containment.

In reviewing DCD Tier 2 Section 3.8.1.4.11, the staff noted that the applicant did not provide adequate information about its approach to determining the UPC of the containment. SRP Section 3.8.1.II.4.K, discusses the acceptance criteria for determining the internal pressure capacity of the containment. SRP Section 3.8.1 states that the design and analysis procedure for the UPC of the containment is acceptable if it is performed in accordance with RG 1.216.

The staff issued RAI 129-8085, Question 03.08.01-05 (ML15218A040), requesting the applicant to provide a detailed description of the approach used to calculate the UPC of the containment

identified in DCD Tier 2, Section 3.8.1.4.11, and explain how this approach compares to that described in Regulatory Position 1, "Prediction of Containment Internal Pressure Capacity Above Design Pressure," of RG 1.216.

In its response to RAI 129-8085, Question 03.08.01-05 (ML17103A629), the applicant provided a detailed description of the approach for determining the UPC of the prestressed concrete containment, which is the assessment of the safety margin beyond the design-basis accident pressure. The UPC of the prestressed concrete containment is evaluated based on the design results of the tendon and rebar arrangements within the structure. The applicant developed a full three-dimensional finite element model for the analysis of the concrete containment. Material properties of the nonlinear models for steel and concrete are constructed in accordance with an applicable design code. For simulating the cracking behavior of concrete, the smeared crack model is adopted and the tension stiffening effect and interaction are also taken into consideration. Rebar provides the reinforcement in concrete structures; with this modeling approach, concrete behavior is considered independently of the rebar. Therefore, the smeared crack model requires use of the tension stiffening effect to simulate load transfer across cracks through the rebar. This approach takes into account the effects of the reinforcement interaction with concrete.

The steel is assumed to be consistent with a linear elasto-plastic model. The stress strain curves for the reinforcing steel and tendons are based on the minimum yield strengths specified in the ASME Code. An elastic-plastic and a piece-wise linear stress strain relationship above yield stress is used for the reinforcing steel and tendons. In the initial state of the nonlinear analysis, the containment structure is subject to dead and prestressing loads. During the UPC analysis, the internal pressure is monotonically increased until a specified failure criterion is reached. The pressure corresponding to the failure criterion of the liner, rebar, and tendons is recorded. The pressure at which the first failure criterion is reached is determined to be the UPC of the prestressed concrete containment.

The design and analysis procedures for determining the UPC are performed in accordance with RG 1.216. The UPC is estimated based on satisfying both of the following strain limits:

1. A total tensile average strain in tendons away from discontinuities of 0.8 percent, which includes the strains in the tendons before pressurization (typically about 0.4 percent) and the additional straining from pressurization, and
2. A global free-field strain for the other materials that contribute to resist the internal pressure (i.e., liner, if considered, and rebar) of 0.4 percent.

The UPC of the containment is calculated to be a pressure of 1.089 mPa (158 psi), at which the maximum strain of the liner plate is approximately 0.4 percent. This UPC pressure is the lowest pressure given in the acceptance criteria in RG 1.216 and is determined to occur near the upper portion of the equipment hatch. At this ultimate pressure level, the maximum strains of the rebar and tendons do not reach the allowable limit strain values. In addition, with regard to the punching shear (local failure of concrete) near discontinuities such as the equipment hatch, the shear capacity of shear rebar exceeds the shear force corresponding to the ultimate pressure level. However, the concrete shear strength is conservatively neglected.

The applicant also included COL 3.8(2) which requires the COL applicant to provide the detailed design results and evaluation of the UPC of penetrations, including the equipment hatch, personnel airlocks, and electrical and pipe penetrations in accordance with RG 1.216.

The staff considers the applicant's approach for determining the UPC of the prestressed concrete containment beyond the design pressure to be acceptable because the approach is consistent with the criteria prescribed in Regulatory Position 1 of RG 1.216. In accordance with RG 1.216, the applicant determined the pressure capacity of the containment at which the structural integrity is retained, and a failure leading to a significant release of fission products does not occur. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 129-8085, Question 03.08.01-05, is resolved and closed.

DCD Tier 2 Section 3.8.1.4.12, states that the safety of the containment under severe accident conditions is assessed and demonstrated to conform to the allowable values in ASME Code, Section III, Division 2, Subarticle CC-3720. The DCD further states that, at the maximum pressure loading level of the critical severe accident scenario, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the limit strain of the allowable values.

The staff reviewed DCD Tier 2 Section 3.8.1.4.12, and noted that the application did not include information such as a description of the severe accidents that are being evaluated, the loads that are selected, the mathematical models that are being used, and the analysis approach and results. RG 1.216, Regulatory Position 3, "Commission's Severe Accident Performance Goal," describes the methods acceptable for demonstrating that the containment can maintain its role as a reliable, leaktight barrier for approximately 24 hours following the onset of core damage, and following this initial 24-hour period, the containment can continue to provide a barrier against the uncontrolled release of fission products. The staff issued RAI 199-8223, Question 03.08.01-10 (ML15251A052), requesting the applicant to describe its severe accident analysis approach which is described in DCD Tier 2, Section 3.8.1.4.12, and explain how it compares to the approach described in RG 1.216, Regulatory Position 3.

In its response to RAI 199-8223, Question 03.08.01-10, (ML16279A547), the applicant described its severe accident approach with regard to RG 1.216, Regulatory Position 3. It stated that the selection of accident sequences is based on a Level 1 probabilistic risk assessment study using a combination of deterministic and probabilistic approaches for the more likely severe accident sequences to analyze the performance of the containment. The top 10 dominant sequences contributing to the core damage frequency are selected from the Level 1 probabilistic risk assessment results. The accident initiators for these sequences include the station blackout, large break loss of coolant accident (LBLOCA), small break loss of coolant accident, loss of feedwater, and steam generator tube rupture. These 10 sequences account for more than 87 percent of the cumulative core damage frequency.

The applicant identified the pressure and temperature transient loadings for the more likely severe accident challenges and determined that the peak pressure buildup inside the containment is 112 pounds per square inch absolute (psia) following an LBLOCA event with a temperature of 166.7 °C (332 °F). The applicant conservatively assumed a constant temperature of 176.7 °C (350 °F), which bounds the transient response to an LBLOCA as the temperature loading, and a peak pressure of 112 psia as the maximum pressure after the

initial 24 hours of the onset of core damage. For the period after the initial 24 hours of the onset of core damage, the applicant indicated that the pressures and temperatures are enveloped by the values which occur during the initial 24 hour period.

In its response to RAI 199-8223, Question 03.08.01-10 (ML1620727), the applicant also summarized the finite element model and the analysis approach used for this evaluation. The model and analysis approach followed the analytical guidance provided in RG 1.216. Markups were provided for DCD Tier 2 Section 19.2.4.2.2, to incorporate the summary of the containment evaluation for severe accident challenges, rather than including this information in DCD Tier 2 Section 3.8.1.4.12.

The staff considers the applicant's approach for identifying the more like severe accident challenges to be acceptable because the approach is consistent with the criteria prescribed in Regulatory Position 3 of RG 1.216. In accordance with RG 1.216, the applicant demonstrated that the containment can maintain its role as a reliable, leaktight barrier for approximately 24 hours following the onset of core damage, and following this initial 24-hour period, the containment can continue to provide a barrier against the uncontrolled release of fission products for the more likely severe accident challenges. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-10, is resolved and closed.

The containment structure, including the basemat directly beneath the containment, is integral with the AB basemat. The staff noted that DCD Tier 2 Section 3.8.1, did not describe the jurisdictional boundary for the design of the containment in accordance with ASME Code, Section III, Division 2, Subsection CC.

The staff issued RAI 199-8223, Question 03.08.01-11 (ML15251A052), requesting the applicant to identify the jurisdictional boundary of the containment for the design in accordance with ASME Code Section III, Division 2, and describe what aspects of the design incorporate additional design requirements beyond the portion of the containment foundation directly beneath the containment shell. In addition, the staff asked the applicant to update DCD Tier 2 Section 3.8.1, accordingly.

In its response to RAI 199-8223, Question 03.08.01-11 (ML16130A771), the applicant stated that the design basis of the RCB and the AB foundations conforms to the requirements of ASME Code, Section III, Division 2, Subsection CC, and ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures." The applicant provided a figure that depicts the boundary of jurisdiction between the ASME Code and ACI 349 for the design of the common basemat. At the boundary between RCB and AB, which is the interface between the two codes, the applicant has chosen to follow the code that calls for the greater amount of reinforcement that is required by both codes, and the reinforcement of the RCB foundation is developed into the AB foundation. The provisions of both codes are used to select a conservative development length.

The outside portion of the RCB foundation (i.e., the entire AB foundation area) was conservatively designed using the larger member forces from the analysis results of the ASME Code and ACI-349. For the effect of the ACI load combination on the RCB foundation, the applicant compared the load combinations in the ASME Code and ACI- 349. It was determined that the loads in the AB, which do not exist in the RCB load combinations (e.g., soil pressures), were negligible and/or would not have an effect on the global behavior of the RCB foundation.

The staff reviewed the applicant's design and analysis procedures for the RCB. The applicant stated that the design and analysis procedures are in accordance with the requirements of ASME Code, Section III, Division 2, and in accordance with ASME code interpretation III-2-83-01, "Load Criteria Used for Containment Vessel and Auxiliary Building," which relates to the code jurisdictional boundary and design. The staff found the use of the ASME Code in the design and construction of the RCB for the APR1400 to be in accordance with the acceptance criteria given in SRP Section 3.8.1.II.4. On this basis, the staff concluded that the information provided in DCD Tier 2, Section 3.8.1.4, is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-11, is resolved and closed.

3.8.1.4.4 *Structural Acceptance Criteria*

In DCD Tier 2 Section 3.8.1.5, "Structural Acceptance Criteria," the applicant stated that the RCB, including its liner, is designed with consideration for the loads and load combinations to meet the structural acceptance criteria based on the allowable stresses, strains, forces, displacements, and temperature requirements given in ASME Code Section III, Division 2, Subarticle CC-3000. DCD Tier 2, Table 3.8-2, lists the load combinations for the service and factored load conditions that determine which acceptance criteria in the ASME Code are applicable. The applicant further stated that, in accordance with those requirements, the RCB structure is designed to remain elastic under service load conditions. General yielding of reinforcing steel does not develop under factored primary load conditions, and the leaktight integrity of the liner is maintained.

DCD Tier 2 Section 3.8.1.5, specifies the criteria and requirements for acceptance of the RCB design, including criteria for the concrete, prestressing system, and steel reinforcement. The following summarizes these criteria:

- Concrete design stresses follow the requirements of ASME Code Section III, Division 2, Subarticle CC-3421.1, "Compression," and Table CC-3421.1, "Allowable Compression Stresses for Factored Loads," and Subarticle CC-3431.1, "Compression," and Table CC-3431.1, "Allowable Compression Stresses for Service Loads." These define the allowable concrete stresses for membrane and membrane plus bending, under primary and primary plus secondary stresses. Requirements for concrete in radial shear, tangential shear, peripheral shear, and torsional shear are discussed and are in accordance with ASME Code, Section III, Division 2, Subarticles CC-3420, "Allowable Stress for Factored Loads," and CC-3430, "Allowable Stresses for Service Loads."
- Prestressing system design stresses follow the requirements of ASME Code, Section III, Division 2, Subarticle CC-3423, "Tendon System Stresses," for tendons; Subarticle CC-3431.1, for end anchors; and Subarticle CC-3542, for prestressing losses.
- Division 2, Subarticles CC-3422, "Reinforcing Steel," and CC-3432, "Reinforcing Steel and Strains." Requirements for reinforcement steel in tension, compression, radial shear, tangential shear, peripheral shear, torsional shear, radial tension reinforcement, and end anchor reinforcement are discussed.

In DCD Tier 2 Section 3.8.1.5, the applicant indicated that the allowable stresses, strains, forces, displacements, and temperatures for the containment structure, including the liner, are

defined based on the requirements given in ASME Code, Section III, Division 2, Article CC-3000. The staff reviewed the information provided by the applicant and noted that the applicant's approach for the structural acceptance criteria did not seem to be in accordance with SRP Section 3.8.1.II, which indicates that the specified allowable limits are acceptable if they are in accordance with ASME Code, Section III, Division 2, Subsection CC-3000 and additional guidance provided by RG 1.136 and RG 1.216. Also, the staff noted that the specific acceptance criteria for the service level load conditions and factored load conditions listed in DCD Tier 2, Section 3.8.1.5.1, "Acceptance Criteria for Service Load Conditions," and Section 3.8.1.5.2, "Acceptance Criteria for Factored Load Conditions," respectively, were not complete.

The staff issued RAI 199-8223, Question 03.08.01-12 (ML15251A052), requesting the applicant to clarify, in DCD Tier 2, Sections 3.8.1.5.1 and 3.8.1.5.2, whether the acceptance criteria identified in these two sections are supplemented by other provisions in ASME Code, Section III, Division 2, Subsection CC-3000 and additional guidance provided by RG 1.136 and RG 1.216. In its response to RAI 199-8223, Question 03.08.01-12 (ML16008A913), the applicant stated that the structural acceptance criteria for the allowable stresses, strains, forces, displacements and temperature are determined in accordance with the criteria prescribed in ASME Code, Section III, Division 2, Subsection CC-3000 and additional guidance provided in RG 1.136 and RG 1.216. The applicant further stated that the allowable stress and strain of the liner plate under severe accident conditions follow the requirements in ASME Code, Section III, Division 2, Subarticle CC-3720, and the guidance in RG 1.136 and RG 1.216.

The staff reviewed the applicant's response and found it to be acceptable because the approach to the structural acceptance criteria is in accordance with the ASME Code and the guidance in RG 1.136 and RG 1.216. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-12, is resolved and closed.

DCD Tier 2 Section 3.8.1.5.1.2, "Prestressing System," describes the criteria for not exceeding the tendon tensile stress limits during stressing and anchoring of the tendons. The applicant stated that the tendon stresses during stressing and anchoring and the tendon stresses used for the design do not exceed $0.96 f_{py}$ (tendon minimum yield strength) and $0.80 f_{pu}$ (tendon ultimate strength). The applicant further stated that, "Immediately after anchoring, the tensile stress at the anchor point does not exceed $0.81 f_{py}$ or $0.73 f_{pu}$, and the average tensile stress at the anchorage point of the tendon group after anchoring does not exceed $0.70 f_{pu}$."

The staff reviewed ASME Code, Section III, Division 2, Subsection CC-3433 (2001 Edition with 2003 Addenda), which is referenced in the DCD, and noticed that the allowable minimum yield strength provided by the applicant during stressing of the tendons exceeded the allowable of $0.94 f_{py}$ in the 2001 Edition of the ASME Code. In addition, the values for the tension stress immediately after anchoring are not consistent with the values presented in the 2001 Edition of the ASME Code. The staff issued RAI 129-8085, Question 03.08.01-06 (ML15218A040), requesting the applicant to explain why the allowable limits for the tendon stresses are not in accordance with the ASME Code, 2001 Edition, and provide a technical justification for this difference.

In its response to RAI 129-8085, Question 03.08.01-06 (ML15260B252), the applicant provided a marked-up copy of DCD Tier 2 Section 3.8.1.5.1.2, that included the criteria for the stressing

and anchoring of the tendon. The applicant stated that the stressing and anchoring of the tendon will be in accordance with ASME Code, Section III, Division 2, Subsection CC-3433 (2001 Edition with 2003 Addenda).

The staff reviewed the applicant's response and considered the DCD Tier 2 markup to be in accordance with ASME Code, Section III, Division 2, Subarticle CC-3433 (2001 Edition with 2003 Addenda). The staff concluded that the structural acceptance criteria in DCD Tier 2 Section 3.8.1.5, are acceptable on the basis that the applicant follows the acceptance criteria in ASME Code, Section III, Division 2, and that the applicant's structural acceptance criteria are consistent with those in SRP Section 3.8.1.II.5. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 129-8085, Question 03.08.01-06, is resolved and closed.

3.8.1.4.5 *Materials, Quality Control, and Special Construction Techniques*

In DCD Tier 2 Section 3.8.1.6, "Materials, Quality Control, and Special Construction Techniques," the applicant provided information relating to the materials, quality control program, and special construction techniques used in the fabrication and design of the RCB. The applicant stated that the materials and quality control satisfy the requirements specified in ASME Code, Section III, Division 2, Articles CC-2000, "Material," CC-4000, "Fabrication and Installation," CC-5000, "Examination," and CC-6000, "Testing," and the guidance in RG 1.136.

In DCD Tier 2 Section 3.8.1.6, the applicant described the materials used for the construction of the containment, including the concrete and concrete ingredients, reinforcing bars and splices, prestressing system, and liner plate within containment backed by concrete. The applicant further identified the material for the prestressing elements and, in the case of the anchorage components, referred to the tendon manufacturer's respective material specifications. However, the staff could not find the manufacturer's specifications for the bearing plates, anchor head assemblies, and wedges that are part of the anchorage system.

The staff issued RAI 199-8223, Question 03.08.01-13 (ML15251A052), requesting the applicant to identify the manufactured tendon system used for the design of APR1400 and, if the information is not publicly available, to provide the manufacturer's technical literature on this type of tendon system, including its anchorage system.

In its response to RAI 199-8223, Question 03.08.01-13 (ML16162A798), the applicant stated that the design of the concrete containment will use a VSL International LTD, VSL E6-42 multi-strand posttensioning system using a wedge block with wedge type anchors. The anchorage system of the VSL E6-42 multi-strand system is equivalent to that of the VSL E6-43, which is identified in the VSL international brochure. The applicant provided a brochure that shows the dimension, spacing, and reinforcement of the VSL E6 42 anchorage system. The VSL E6-42 multi-strand system consists of 0.6 in. diameter, seven wire, low relaxation strands that are manufactured in accordance with American Society of Testing and Materials (ASTM) A416, "Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete," Grade 270. Materials such as the bearing plates, anchor head assemblies, and wedges that are integral parts of the anchorage system conform to the requirements described in ASME Code, Section III, Division 2, Subarticle CC-2430, and the guidance in RG 1.136.

The applicant will add information of the type of prestressing system, including the manufacturer and product designation, and description of the duct material to DCD Tier 2 Section 3.8.1.6.3. The specified materials, quality control, and special construction techniques for the prestressing system satisfy the requirements given in ASME Code, Section III, Division 2, Articles CC-2000, CC-4000, CC-5000, and CC-6000, and the guidance in RG 1.136. Therefore, staff concludes that the information presented with regard to the material, quality control, and special construction techniques used in the design and construction of the prestressed concrete containment for the APR1400 is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 199-8223, Question 03.08.01-13, is resolved and closed.

3.8.1.4.6 *Testing and Inservice Surveillance Requirements*

DCD Tier 2 Section 3.8.1.7, "Testing and Inservice Inspection Requirements," describes the structural integrity test (SIT) and the inservice surveillance requirements for the RCB. The SIT of the RCB is performed in accordance with ASME Code, Section III, Division 2, Article CC-6000. The applicant stated that the test will be performed after the containment is complete, including the liner, concrete structures, all electrical and piping penetrations, equipment hatch, personnel airlocks, and posttensioning. The inservice inspection (ISI) of the RCB is performed in accordance with ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Subsection IWL, "Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Plants."

The staff reviewed DCD Tier 2 Section 3.8.1.7, and found the requirements presented by the applicant for SIT and ISI of the containment and components to be acceptable for the prestressed concrete containment. The testing and inservice surveillance requirements for the APR1400 conform to the criteria in ASME Code, Section XI, and the guidance in SRP Section 3.8.1.II.7, RG 1.136, and RG 1.216.

3.8.1.5 *Combined License Information Items*

DCD Tier 2, Section 3.8.1, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.8.1 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.8(1)	The COL applicant is to perform concrete long term material testing in a way that verifies the physical properties of the materials used during the design stage and the characteristics of long term deformation of concrete.	3.8.4.1.8
COL 3.8(2)	The COL applicant to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, and electrical and piping penetrations, in accordance with RG 1.216.	3.8.1.4.11

Item No.	Description	Section
COL 3.8(6)	The COL applicant is to evaluate any applicable site-specific loads, such as explosive hazards in proximity to the site, projectiles and missiles generated from activities of nearby military installations, potential non-terrorism-related aircraft crashes, and the effects of seiches, surges, waves, and tsunamis.	3.8.4.3
COL 3.8(8)	The COL applicant is to determine the environmental condition associated with the durability of concrete structures and provide the concrete mix design that prevents concrete degradation including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.	3.8.4.6.1.1
COL 3.8(9)	The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.	3.8.4.6.3
COL 3.8(12)	The COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1 are met or exceeded.	3.8.5.5

Markups for COL 3.8(1) and COL 3.8(2) were provided in the responses to RAI 129-8085, Question 03.08.01-05, and RAI 129-8085, Question 03.08.01-02. The staff found the list of COL items complete because it adequately describes actions necessary for the COL applicant to perform. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 129-8085, Questions 03.08.01-02, and RAI 129-8085, Question 03.08.01-05, are resolved and closed.

3.8.1.6 Conclusion

The staff concludes that the design of the concrete containment is acceptable and meets the relevant requirements of 10 CFR 50.44, 10 CFR 50.55a, and GDC 1, 2, 4, 16, and 50. This conclusion is based on the following eight findings:

1. The applicant has met the requirements of 10 CFR 50.55a and GDC 1 with respect to ensuring that the concrete containment is designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with its safety.
2. The applicant has met the requirements of GDC 2 by designing the concrete containment 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.
3. The applicant has met the requirements of GDC 4 by designing the concrete containment to withstand the dynamic effects associated with missiles, pipe whipping, and discharging fluids.

4. The applicant has met the requirements of GDC 16 by designing the concrete containment to be a leaktight barrier to prevent the uncontrolled release of radioactive effluents to the environment.
5. The applicant has met the requirements of GDC 50 by designing the concrete containment to accommodate, with sufficient margin, the design leakage rate, calculated pressure, and temperature conditions resulting from accident conditions and by ensuring that the design conditions are not exceeded during the full course of the accident condition.
6. The applicant has met the requirements of Appendix B to 10 CFR Part 50, in that the quality assurance program provides adequate measures for implementing guidelines relating to structural design.
7. The applicant has met the requirements of 10 CFR 50.44 by designing the concrete containment to accommodate the loads associated with hydrogen gas generated from a fuel cladding metal-water reaction so that there is no loss of containment structural integrity.
8. The criteria used in the analysis, design, and construction, testing and inservice surveillance of the concrete containment structure 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 2, and Section XI, Subsections IWL, and with the NRC guidance in SRP Section 3.8.1 and RGs 1.7, 1.35.1, 1.91, 1.136, 1.216, and 1.221.

The use of these criteria, as defined by applicable codes, standards, and guides; loads and loading combinations; design and analysis procedures; structural acceptance criteria; materials, quality control programs, and special construction techniques; and testing and inservice surveillance requirements, provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes and various postulated accidents occurring within and outside the containment, the structure will withstand the specified conditions without impairment of its structural integrity or safety function.

3.8.2 Steel Containment

3.8.2.1 Introduction

The APR1400 design does not use a steel containment. DCD Tier 2 Section 3.8.2, "Steel Containment," describes the steel portion of the RCB that is not backed by structural concrete and is intended to resist applicable loads including pressure. DCD Tier 2 Section 3.8.1, "Concrete Containment," addresses the concrete portions of the RCB and the steel liner backed by concrete. DCD Tier 2 Section 3.8.2, provides the following information on the steel portion of the RCB not backed by structural concrete:

- physical description
- applicable design codes, standards, and specifications

- loading criteria, including loads and load combinations
- design and analysis procedures
- structural acceptance criteria
- materials, quality control programs, and special construction techniques
- testing and inservice inspection programs

3.8.2.2 *Summary of Application*

DCD Tier 1: DCD Tier 1 Section 2.2.1 provides the Tier 1 information associated with this section.

DCD Tier 2: The applicant provided a system description in DCD Tier 2 Section 3.8.2, which includes information on the steel portion of the RCB penetrations that is not backed by structural concrete.

ITAAC: ITAAC associated with DCD Tier 2 Section 3.8.2, appear in DCD Tier 1 Section 2.2.1.2, "Inspection, Tests, Analyses, and Acceptance Criteria."

Technical Specifications: The applicable technical specifications are found in DCD Tier 2, Chapter 16, Section 3.6, and Section 3.9.3.

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

Technical Reports: There are no technical reports for this area of review.

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 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.

3.8.2.3 *Regulatory Basis*

The relevant requirements and associated acceptance criteria for this review are in SRP Section 3.8.2, "Steel Containment," Revision 3, issued May 2010, and are summarized below.

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

- GDC 2, as it relates to the ability of the steel containment to withstand the most severe natural phenomena, such as winds, tornadoes, floods, and earthquakes, and the appropriate combination of all loads.
- GDC 4, as it relates to the steel containment being appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.
- GDC 16, as it relates to the ability of the steel containment to act as a leaktight membrane to prevent the uncontrolled release of radioactive effluents to the environment.
- GDC 50, as it relates to the steel containment being designed with sufficient margin of safety to accommodate appropriate design loads.
- Appendix B to 10 CFR Part 50 as it relates to the quality assurance criteria for nuclear power plants.
- Section 50.44 of 10 CFR, as it relates to demonstrating the structural integrity of boiling water reactors with Mark III type containments, all pressurized water reactors with ice condenser containments, and all containments used in future water cooled reactors for loads associated with combustible gas generation.
- Section 52.47(b)(1) of 10 CFR, which requires that a DCA 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 NRC's regulations.

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

- SRP Section 3.8.2, Section II, which includes acceptance criteria for (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and loading combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs.
- RG 1.7, "Control of Combustible Gas Concentrations in Containment," Revision 3, issued March 2007.
- RG 1.57, "Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components," Revision 2, issued May 2013.
- RG 1.206, "Combined License Applications for Nuclear Power Plants," issued June 2007.

- RG 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design-Basis Pressure," issued August 2010.

SRP Section 3.8.2 lists the review interfaces with other SRP sections.

3.8.2.4 *Technical Evaluation*

The staff reviewed Tier 2 Section 3.8.2 to ensure that it represents the complete scope of information relating to this review topic. SRP Section 3.8.2 identifies seven specific SRP acceptance criteria to meet the relevant requirements of the NRC's regulations listed in SRP Section 3.8.2.II and included in SER Section 3.8.2.3. This section evaluates DCD Tier 2 Section 3.8.2, with regard to each of these seven SRP acceptance criteria.

SRP Section 3.8.2 provides guidelines for the staff to use in reviewing the technical areas related to the design of the steel portion of the RCB that is not backed by concrete, based on the requirements of 10 CFR 50.55a; GDC 1, 2, 4, 16, and 50; 10 CFR Part 50, Appendix B; 10 CFR 50.44; and 10 CFR 52.47(b)(1). Using the guidance in SRP Section 3.8.2, the staff reviewed APR1400 DCD Tier 2, Section 3.8.2 and the associated Section 3.8A containing the structural design summary. In particular, the review described in this section focused on (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and load combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs. The staff also reviewed applicable COL action items.

3.8.2.4.1 *Description of Steel Containment*

DCD Tier 2 Section 3.8.2.1, "Description of Containment," describes the physical characteristics of the steel portion of the RCB penetrations that are not backed by structural concrete and are intended to resist applicable loads including pressure. The RCB pressure boundary not backed by concrete includes the equipment hatch, personnel airlocks, and penetrations that include process piping and electrical penetrations, and the fuel transfer tube penetration. The RCB steel portions not backed by concrete are designated as Class MC Components, in accordance with American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, Division I, Subsection NE-3000.

The equipment hatch is a welded steel assembly that consists of a dished head door, a matching barrel frame with anchorage, and a lift beam that operates the hatch door. The equipment hatch is located at the centerline elevation of 51.09 m (167 ft., 6 in.) and has an inside diameter of approximately 7.93 m (26 ft.). The personnel airlocks, which provide access to the RCB, consist of two doors with gaskets in series, which are mechanically interlocked so that one door cannot be opened unless the second door is closed and sealed. The doors operate manually and can be accessed from inside the RCB, inside the access hatch, or outside the RCB. Each door is equipped with a valve for equalizing pressure on both sides of the door before the door can be operated. The containment wall penetrations, such as process piping penetrations and electrical penetrations, consist of a type of sleeve assembly that is embedded and anchored in the concrete wall.

DCD Tier 2 Section 3.8.2, states, "This subsection pertains to ASME Class MC Components that are part of the containment described in DCD Tier 2, Subsection 3.8.1. ASME Class MC Components include the equipment hatch, personnel airlocks, and piping and electrical

penetration sleeves.” DCD Tier 2 Section 3.8.2.1.3.2, “Component Classification,” states, “The penetration sleeve is designed as a Class MC component in accordance with ASME Code Section III, Division 1, Subsection NE.” The staff notes that a portion of the penetration sleeve is backed by concrete, while the remaining portion is not. According to ASME Code, Section III, Division 2, “Code of Concrete Containments,” Subsection CC, Article CC 3740, the portion of the penetration sleeve backed by concrete shall be designed to meet the requirements of CC-3700, “Liner Design,” and CC-3800, “Liner Design Details.”

The staff issued RAI 200-8225, Question 03.08.02-01 (ML15251A326), requesting the applicant to clarify the statements made in DCD Tier 2, Sections 3.8.2 and 3.8.2.1.3.2, and elsewhere, as appropriate, to indicate that the portion of the penetration sleeves that are not backed by concrete are classified as ASME Class MC components and are covered in DCD Tier 2 Section 3.8.2. The staff also asked the applicant to provide a description and figure of the fuel transfer tube penetration assembly that is comparable to the information provided for the other penetrations, provide design and analysis procedures, and provide the structural acceptance criteria.

In its response to RAI 200-8225, Question 03.08.02-01 (ML15365A551), the applicant stated that the portion of the concrete containment pressure boundary that is not backed by concrete, such as the equipment hatch, personnel airlocks, and Class MC penetration assemblies, including the fuel transfer tube penetration sleeve, are designed in accordance with ASME Code, Section III, Division I, Subsection NE. The applicant further stated that the equipment hatch, personnel airlocks, electrical penetrations, and fuel transfer tube penetrations are vendor designed components. The applicant included a COL 3.8(4), directing the COL applicant to provide a detailed analysis and design procedure for the fuel transfer tube penetration assembly. Additionally, the applicant described the fuel transfer tube sleeve and bellows in DCD Tier 2, Sections 3.8.2.4, “Design and Analysis Procedures,” and 3.8.2.5, “Structural Acceptance Criteria,” and included Figure 3.8-25, “Fuel Transfer Tube Sleeve and Bellows,” which shows the conceptual design of the fuel transfer tube sleeve and bellows.

The staff’s review of the applicant’s detailed description of its design and analysis approach for the steel portions of the concrete containment that are not backed by concrete revealed that the applicant provided sufficient information that demonstrates that the primary structural integrity of these portions of the RCB are maintained and are capable of performing their intended safety functions. The staff considers the response to be acceptable because the applicant (1) indicated in applicable sections of DCD Tier 2 that the design of the various penetrations that are not backed by concrete are analyzed and designed in accordance with ASME Code, Section III, Division I, Subsection NE; (2) provided a markup of the DCD that includes additional information and a figure of the fuel transfer tube penetration; and (3) provided information demonstrating that the portion of the RCB not backed by concrete, meet the requirements in 10 CFR 50.55a; and the guidance in RG 1.206 and SRP Section 3.8.2.II.1. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 200-8225, Question 03.08.02-01, is resolved and closed.

3.8.2.4.2 *Applicable Codes, Standards, and Specifications*

In DCD Tier 2, Section 3.8.2.2, “Applicable Codes, Standards, and Specifications,” and Table 3.8-1, “Codes, Standards, Specifications, and Regulations,” the applicant presented the following industry codes, standards, and specifications that are applicable for the design,

construction, materials, testing, and inservice inspections of the steel portion of the RCB pressure boundary not backed by concrete:

- ASME Code, Section III, Division 1, 2007 Edition through 2008 Addenda
- ASME Code, Section XI, Subsection IWE, 2007 Edition through 2008 Addenda
- RG 1.7, "Control of Combustible Gas Concentrations in Containment," Revision 3, March 2007.
- RG 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings above Design-Basis Pressure," issued August 2010.
- RG 1.57, "Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components," issued May 2013.

The staff reviewed the codes, standards, and specifications given in DCD Tier 2 Section 3.8.2.2, as to their application to the steel portion of the RCB that is not backed by concrete against the list in SRP Section 3.8.2.II.2. The staff found the use of these codes, standards, and specifications in the design and construction of this portion of the RCB to be in accordance with the acceptance criteria in SRP Section 3.8.2 and to meet the regulatory requirements in 10 CFR 50.55a. On this basis, the staff concluded that the information provided in DCD Tier 2 Section 3.8.2.2, on applicable codes, standards, and specifications is acceptable.

3.8.2.4.3 *Loads and Load Combinations*

In DCD Tier 2, Sections 3.8.2.3.1, "Loads for Instrument and Process Pipe Penetrations," through 3.8.2.3.2, "Load Combinations for Instrument and Process Piping Penetrations," the applicant specified all credible conditions of loading. The applicant stated that the Class MC Components are designed for the loads and load combinations specified in ASME Code, Section III, Division I, Subsection NE 3000. DCD Tier 2 Table 3.8-3, "Load Definitions and Load Combinations for ASME Class MC Containment Components," lists the design load combinations including the load factors for Class MC Components except for the instrument and process piping penetrations. The load combinations include loads during normal, severe environmental, extreme abnormal, and extreme environmental plant conditions, which encompass ASME Service Levels A, B, C, and D. DCD Tier 2 Section 3.8.2.3.2, "Load Combinations for Instrument and Process Piping Penetrations" refers to DCD Tier 2 Table 3.8 4, "Load Combinations for Penetration Sleeves and Head Fittings." The staff notes that this table, which is for penetration sleeves and head fittings, does not appear to be consistent with the text in DCD Tier 2 Section 3.8.2.3.2 which is applicable to instrument and process piping penetrations. DCD Tier 2 Table 3.8-5, "Allowable Stresses for Penetration Sleeves and Head Fittings," shows the stress categories along with the design and service levels for the penetration sleeves and head fittings.

The staff reviewed the loads given in DCD Tier 2, Section 3.8.2.3, "Loads and Load Combinations," which are defined in Section 3.8.1.3, "Loads and Load Combinations," for the portion of the RCB not backed by concrete, against the acceptance criteria in SRP Section 3.8.2.II and found that the applicant's description of certain loads did not provide sufficient detail to enable the staff to determine whether the loads complied with the acceptance

criteria in SRP Section 3.8.2.II.3 and RG 1.57. Also, there was an inconsistency between DCD Tier 2 Section 3.8.2.3.2, and DCD Tier 2 Table 3.8-4 regarding the load and load combinations for instrument and process piping penetrations. In addition, the staff was not able to review the load combinations in DCD Tier 2 Table 3.8-4 for consistency with DCD Tier 2, Tables 3.12-1, "Loading Combinations and Acceptance Criteria for ASME Section III, Class 1 Piping," and 3.12-2, "Loading Combinations for Acceptance Criteria for ASME Section III, Class 2 and 3 Piping," based on the information contained in DCD Tier 2 Table 3.8-4. The staff issued RAI 200-8225, Question 03.08.02-04 (ML15251A326), requesting the applicant to present the load combinations in DCD Tier 2 Table 3.8 4, in a manner that would allow the staff to compare the information with the load combinations in DCD Tier 2, Tables 3.12-1 and 3.12-2. In its response to RAI 200-8225, Question 03.08.02-04 (ML15365A551), the applicant provided marked-up copies that show, for each component of the penetration assemblies, the appropriate tabulation of the load combinations, which are defined to conform to the applicable requirements of the ASME Code. The load combinations for the ASME Class MC Components, such as the sleeves and head fittings for penetration Types 2 and 3 piping (DCD Tier 2 Figure 3.8-8) are given in DCD Tier 2 Table 3.8-3; and the load combinations for head fittings for penetration Type 1 (DCD Tier 2, Figure 3.8-8) are given in DCD Tier 2, Table 3.12-1 or Table 3.12-2.

The markup deleted DCD Tier 2, Tables 3.8-4 and 3.8-5, and clarified what portions of the penetration assemblies are governed by Class MC and the portions that are governed by the process piping design classification. In the case of the portion of the penetration assemblies that are classified as that of the process piping, the applicant referred to load combinations and acceptance criteria in DCD Tier 2, Tables 3.12-1 (Class 1 piping) and 3.12-2 (Class 2 and 3 piping). These changes preclude the need to check consistency with the deleted tables. SER Section 3.12 discusses the staff's review of DCD Tier 2, Tables 3.12-1 and 3.12-2. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 200-8225, Question 03.08.02-04, is resolved and closed.

In summary, the staff reviewed DCD Tier 2 Section 3.8.2, and found the loads and load combinations provided by the applicant to be in accordance with the specified codes governing the design of the steel components of the containment not backed by concrete and in accordance with the guidance in SRP Section 3.8.2, RG 1.7, and RG 1.57.

Design and Analysis Procedures

DCD Tier 2 Section 3.8.2.4, describes the design and analysis procedures for the various steel portions of containment penetrations that are not backed by concrete. In DCD Tier 2, Section 3.8.2.4.1, "Equipment Hatch, Personnel Airlocks, and Electrical Penetrations," the applicant stated, "The portions of the sleeves not backed by concrete are analyzed and designed according to the provisions of ASME Section III, Division 1, Subsection NE-3000." The staff noted that DCD Tier 2 Section 3.8.2.4, did not adequately describe the design and analysis approach for the various penetrations, including the equipment hatch, the personnel airlocks, the electrical penetrations, and the process piping penetrations.

The staff issued RAI 200-8225, Question 03.08.02-02 (ML15251A326), requesting the applicant to describe the design methodology for these penetrations in the application, such as the models, boundary conditions, the way loadings are applied, the analysis approach for the various loadings, and the way stresses are determined, including the approach to check for buckling. The description for the analysis of the various loads should include loads from internal

and external pressures; applied end loads from attached process piping or attachment to adjacent structures for the fuel transfer tube; and containment interface displacements and seismic inertial loadings at the attachment points to the containment. For penetrations that are considered to be a vendor-designed component, a description should still be provided of the criteria to be used for the analysis and design of the penetrations. This description should summarize, to the extent possible, the key analysis and design aspects discussed above in Item a, consistent with the provisions in ASME Code Section III, Division 1, Subsection NE, applicable to containment penetrations, and the existing criteria in the DCD Tier 2.

It should be noted that, even if the design of the containment penetrations is not completed or finalized at this time, SRP Section 3.8.1 and SRP Section 3.8.2, indicate that the ultimate pressure capacity of the containment, including its penetrations, needs to be determined. Therefore, some analysis of the critical containment penetrations (e.g., equipment hatch, personnel airlocks) would be needed to address the ultimate pressure capacity evaluation of the containment and Section 19 PRA/accident evaluations.

In its response to RAI 200-8225, Question 03.08.02-02 (ML16316A115), the applicant stated that the equipment hatch, personnel airlocks, and electrical penetrations are vendor designed components and that the COL applicant is to provide the detailed analysis and design procedures for these components. The applicant provided markups which stated that the design of the equipment hatch will consist of a flanged cover bolted to a matching flanged cylindrical sleeve embedded into the reactor containment building and that closure head assembly shall be designed in accordance with the requirements in Section NE-3000 of the ASME Code.

The design of the personnel airlock will consist of a cylindrical shell having a bulkhead and pressure retaining door at each end. The personnel airlock pressure retaining components will be evaluated for design and service conditions in accordance with the requirements in Subsection NE-3000 of the ASME Code. FMA programs will be used to analyze the stresses acting on the piping penetration assemblies. The penetration assemblies are required to meet the stress limits in accordance with the requirements and provisions in Section III of the ASME Code.

The staff reviewed the applicant's response and finds the information to be acceptable because the applicant provided markup copies that detailed the description of the key design aspect and criteria for each of these components. Moreover, the applicant included COL 3.8(3) which requires the applicant to provide detailed analysis and design procedure for the equipment hatch, personnel airlocks, and the electrical penetrations. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 200-8225, Question 03.08.02-02, is resolved and closed.

The staff reviewed the design and analysis procedures used for the steel portion of the RCB that is not backed by concrete against the acceptance criterion in SRP Section 3.8.2.II.4. This acceptance criterion states that the design and analysis procedures for a steel containment should be done in accordance with ASME Code, Section III, Division 1, Subsection NE, and RG 1.57. The procedures given in the ASME Code, as augmented by the applicable provisions of RG 1.57, constitute an acceptable basis for the design analysis of the steel portion of the RCB penetrations that are not backed by structural concrete.

The staff concluded that the design and analysis procedures in DCD Tier 2 Section 3.8.2.4, are acceptable on the basis that they are in accordance with ASME Code, Section III, Division 1, Subsection NE, and consistent with the acceptance criteria in SRP Section 3.8.2 and RG 1.57.

In DCD Tier 2 Section 3.8.2.5, the applicant stated that the equipment hatch, personnel airlocks, and electrical penetrations are designed in accordance with ASME Code, Section III, Division I, with emphasis on the stress limits, such as stress intensities (Subsection NE-3221); buckling stresses (Subsection NE-3222); primary, secondary, and peak stresses (Subsection NE-3213); thickness of components under external loading (Subsection NE-3133); stress limits for bolts (Subsection NE-3230); and the allowable stress for tests (Subsection NE-3226). The applicant further stated that the process piping penetrations are designed in accordance with ASME Code, Section III, Division I, Subsection NE, and that the stress intensities are limited to the values defined in Subsection NE-3220.

The staff reviewed the acceptance limits for the steel portion of the RCB in terms of stresses, strains, and deformations as described in DCD Tier 2 Section 3.8.2.3 and associated DCD tables (containing the load combinations and stress intensity limits) and determined that the stress, strain, and deformation limits are in accordance with the provisions in ASME Code, Section III, Subsection NE; SRP Section 3.8.2.II.5, and the guidance in RG 1.7 and RG 1.57.

Materials, Quality Control, and Special Construction Techniques

In DCD Tier 2 Section 3.8.2.6, "Materials, Quality Control, and Special Construction Techniques," the applicant described the requirements for the steel portion of the RCB that is not backed by concrete by stating that the materials conform to the requirements of ASME Code, Section III, Division I, Subsection NE. The applicant stated that the qualification of welders and welding procedures and the standard construction techniques used in the erection of the steel portion of the RCB that is not backed by concrete are in compliance with the ASME Code. The applicant provided DCD Tier 2 Table 3.8-6, "Physical Properties for Materials to be Used for Pressure Parts or Attachment to Pressure Part ASME Code Class MC Components," which lists the material specification for the plate, pipe, bolting, and forging and fittings to be used for the steel portion of the RCB.

The staff reviewed the acceptance criteria for the materials, quality control, and special construction techniques used for the steel portion of the RCB against the ASME Code and SRP Section 3.8.2.II.6. The staff finds the materials and the quality control program proposed for the fabrication and construction of the steel portion of the RCB in DCD Tier 2 Section 3.8.2.6, to meet the relevant regulatory requirements because they follow the regulatory guidance in SRP Section 3.8.2.II.6, and the requirements in ASME Code, Subsections NE-2000, NE-4000, and NE-5000.

Testing and Inservice Inspection Requirements

In DCD Tier 2 Section 3.8.2.7, "Testing and Inservice Inspection Requirements," the applicant described the procedures for the leak rate tests and the inservice inspection of the steel portion of the RCB that is not backed by concrete. The applicant stated that all Class MC Components will be tested at the same time as the containment tests. The applicant further stated that the MC components will be tested in accordance with ASME Code, Section III, Division I, Subsection NE-6000, and the inservice inspection requirements will conform to those in

ASME Code, Section XI, “Rules for Inservice Inspection and Tests of Nuclear Power Plant Components,” Subsection IWE, and the regulatory requirements of 10 CFR 50.55a.

The staff reviewed the acceptance criteria for the materials, quality control, and special construction techniques used for the steel portion of the RCB against the ASME Code and SRP Section 3.8.2.II.6. The staff finds the testing and inservice inspection requirements of the steel portion of the RCB in DCD Tier 2 Section 3.8.2.6, to meet the relevant regulatory requirements of 10 CFR 50.55a, because it follows the regulatory guidance in SRP Section 3.8.2.II.6, and the requirements in ASME Code, Section III, Division I, Subsection NE-6000, and Section XI, Subsection IWE.

3.8.2.5 Combined License Information Items

DCD Tier 2, Section 3.8.2, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.8.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.8(2)	The COL applicant is to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, and electrical and piping penetrations, in accordance with RG 1.216.	3.8.1.4.11
COL 3.8(3)	The COL applicant is to provide the detailed analysis and design procedure for the equipment hatch, personnel airlocks, and electrical penetrations.	3.8.2.4.1
COL 3.8(4)	The COL applicant is to provide the detailed analysis and design procedure for the transfer tube assembly.	3.8.2.4.3

The markup for COL 3.8(2), COL 3.8(3), and COL 3.8(4) were provided in the responses to RAI 129-8085, Question 03.08.01-05, RAI 200-8225, Question 03.08.02-01, and RAI 8225, Question 03.08.02-02, respectively. The staff found the list of COL information items to be complete because it adequately describes actions necessary for the COL applicant to perform. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above: therefore, RAI 129-8085, Question 03.08.01-05, RAI 200-8225, Question 03.08.02-01, and RAI 8225, Question 03.08.02-02, are resolved and closed.

3.8.2.6 Conclusion

The staff concludes that the design of the steel portion of the RCB not backed by concrete is acceptable and meets the relevant requirements of 10 CFR 50.44; 10 CFR 50.55a; and GDC 1, 2, 4, 16, and 50. This conclusion is based on the following six findings:

1. The applicant has met the applicable requirements of 10 CFR 50.44 by designing the steel portion of the RCB not backed by concrete to withstand the pressure loads generated by the fuel-cladding metal-water reaction, and either the subsequent burning

of hydrogen or the added pressure from post-accident inerting, using the appropriate ASME Code service limits.

2. The applicant has met the requirements of 10 CFR 50.55a and GDC 1 with respect to ensuring that the steel portion of the RCB not backed by concrete is designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with its safety function, to be performed by meeting the guidelines of the RGs and industry standards.
3. The applicant has met the requirements of GDC 2 by designing the steel portion of the RCB not backed by concrete to withstand the most severe earthquake that has been established for the site with sufficient margin and to withstand the combination of the effects of normal and accident conditions with the effects of environmental loadings, such as earthquakes and other natural phenomena.
4. The applicant has met the requirements of GDC 4 by designing the steel portion of the RCB not backed by concrete to withstand the dynamic effects associated with missiles, pipe whipping, and discharging fluids.
5. The applicant has met the requirements of GDC 16 by designing the steel portion of the RCB not backed by concrete to be a leaktight barrier to prevent the uncontrolled release of radioactive effluents to the environment.
6. The applicant has met the requirements of GDC 50 by designing the steel portion of the RCB not backed by concrete to accommodate, with sufficient margin, the design leakage rate, calculated pressure, and temperature conditions resulting from accident conditions and by ensuring that the design conditions are not exceeded during the full course of the accident condition. In meeting these design requirements, the applicant has used the recommendations of RGs and industry standards.

The criteria used in the analysis, design, construction, testing and inservice surveillance of the steel portion of the RCB not backed by concrete to account for anticipated loadings and postulated conditions that may be imposed upon the steel portion of the containment during its service lifetime are in conformance with established criteria, codes, standards, and RGs acceptable to the staff. These include compliance with the provisions of ASME Code Section III, Division 1, Subsection NE, and Section XI, Subsection IWE, and in accordance with the guidance in SRP Section 3.8.2, and RGs 1.7, 1.57, 1.206, and 1.216.

The use of these criteria, as defined by applicable codes, standards, and guides; loads and loading combinations; design and analysis procedures; structural acceptance criteria; materials, quality control programs, and special construction techniques; and testing and inservice surveillance requirements, provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes and various postulated accidents occurring within and outside the containment, the structure will withstand the specified conditions without impairment of its structural integrity or safety function.

3.8.3 Concrete and Steel Internal Structures of Steel or Concrete Containments

3.8.3.1 Introduction

DCD Tier 2, Section 3.8.3, "Concrete and Steel Internal Structures of Steel or Concrete Containment," describes the reactor CIS; specifically, the reactor support system, steam generator support system, reactor coolant pump support system, pressurizer support system, PSW and reactor cavity, SSW, refueling pool, IRWST, holdup volume tank, operating and intermediate floors, interior concrete fill slab, and polar crane supports. These internal structures are reinforced concrete and are classified as seismic Category I. Some of these structures provide radiation shielding and support to the reactor vessel, reactor coolant system (RCS), pressurizer, steam generators, and other components housed within the RCB. This section of the APR1400 DCD provides the following information on the CIS:

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

3.8.3.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Section 2.2.1.

DCD Tier 2: The applicant provided a system description in DCD Tier 2 Section 3.8.3, including information that describes the reactor building internal structures and its design requirements.

ITAAC: The ITAAC associated with DCD Tier 2 Section 3.8.3, appear in DCD Tier 1, Section 2.2.1.2, "Inspections, Tests, Analyses, and Acceptance Criteria."

Technical Specifications: The applicant provided the technical specifications in DCD Tier 2, Chapter 16, Section 3.6, and Section 3.9.3.

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

Technical Reports: There are no technical reports for this area of review.

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 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.

3.8.3.3 *Regulatory Basis*

The relevant requirements and acceptance criteria associated with this review are in SRP Section 3.8.3, "Concrete and Steel Internal Structures of Steel or Concrete Containment," Revision 4, issued September 2013, and are summarized below.

- Section 50.55a of 10 CFR and GDC 1 of Appendix A to 10 CFR Part 50, as these relate to the design, fabrication, erection, and testing of the CIS to quality standards commensurate with the importance of the safety function to be performed
- GDC 2, as it relates to the ability of the CIS to withstand the most severe natural phenomena, such as winds, tornadoes, floods, and earthquakes, and the appropriate combination of all loads
- GDC 4, as it relates to the CIS 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
- GDC 5, "Sharing of Structures, Systems, and Components," as it relates to the CIS not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair the ability of the CIS to perform their safety function
- Appendix B to 10 CFR Part 50, as it relates to the quality assurance criteria for nuclear power plants
- Section 52.47(b)(1) of 10 CFR, which requires that a DC application contain the proposed ITAACs 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 facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

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

- Acceptance criteria in SRP Section 3.8.3, Section II, includes acceptance criteria for (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and loading combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs.
- RG 1.69, "Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants," Revision 1, issued May 2009.

- RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 3, issued May 2012.
- RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, issued March 2007.
- RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Revision 3, issued September 2012.
- RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," Revision 2, issued November 2001.
- RG 1.199, "Anchoring Components and Structural Supports in Concrete," issued November 2003.

SRP Section 3.8.3 lists the review interfaces with other SRP sections.

3.8.3.4 *Technical Evaluation*

The staff reviewed DCD Tier 2 Section 3.8.3 to ensure that the DCD Tier 2 application represents the complete scope of information relating to this review topic. SRP Section 3.8.3 identifies seven specific SRP acceptance criteria for meeting the relevant requirements listed in SRP Section 3.8.3.II and included in SER Section 3.8.3.3. This section evaluates DCD Tier 2 Section 3.8.3, with regard to the seven SRP acceptance criteria.

SRP Section 3.8.3 provides guidelines for the staff to use in reviewing the technical areas related to the CIS based on the requirements of GDC 1, 2, 4, and 5; and Appendix B to 10 CFR Part 50. Using the guidance described in SRP Section 3.8.3, the staff reviewed DCD Tier 2, Section 3.8.3 and the associated Section 3.8A, containing the structural design summary. In particular, the review described in this section focused on (1) a description of the CIS, (2) applicable codes, standards, and specifications, (3) loads and load combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance programs. The staff also reviewed applicable COL items.

3.8.3.4.1 *Description of Containment Internal Structures*

In DCD Tier 2, Section 3.8.3.1, "Description of the Internal Structures," and Section 3.8A.1.1.2, "Containment Internal Structures," the applicant described the physical characteristics of the CIS and their design requirements. The CIS is a group of reinforced concrete structures that enclose and support the NSSS components inside the concrete containment. It serves as a radiation shielding and as a missile barrier to the various systems and components. Clearance is maintained between the containment wall and the CIS to preclude interaction under design basis loading conditions. With the exception of the platforms and miscellaneous steel, the CIS structures are classified as seismic Category I. The major internal structures are the reactor support system, steam generator supports, reactor coolant pump support system, pressurizer support system, PSW and reactor cavity, SSW, refueling pool, IRWST, holdup volume tank, and operating and intermediate floors.

DCD Tier 2, Sections 3.8.3.1.1, "Reactor Support System," 3.8.3.1.2, "Steam Generator Supports," 3.8.3.1.3, "Reactor Coolant Pump Support System," 3.8.3.1.4, "Pressurizer Support System," 3.8.3.1.5, "Primary Shield Wall and Reactor Cavity," 3.8.3.1.6, "Secondary Shield Wall," 3.8.3.1.7, "Refueling Pool," 3.8.3.1.8, "In-Containment Refueling Water Storage Tank," 3.8.3.1.9, "Holdup Volume Tank," 3.8.3.1.10, "Operating and Intermediate Floors," 3.8.3.1.11, "Interior Concrete Fill Slab," and 3.8.3.1.12, "Polar Crane Supports," provide details for each of the internal structures.

DCD Tier 2 Table 3.2-1, specifies the seismic classification of the SSCs. The containment internal structures are classified as seismic Category I with the exception of platforms and miscellaneous steel that do not support seismic Category I SSCs. The platforms and miscellaneous steel structures are designated as seismic Category II and are designed to ensure that, in the event of a safe-shutdown earthquake, the safety-related SSCs will be able to perform their intended function unimpaired.

The description in DCD Tier 2 Section 3.8.3 and Appendix 3.8A, for the various structures in the CIS listed above, provided sufficient information to determine the configuration, structural aspects, and load paths in accordance with the guidance of SRP Section 3.8.3.II.1, with the exception of the structures described below.

DCD Tier 2, Section 3.8.3.1.8 and Appendix 3.8A.1.4.3.2, "IRWST," describe the physical characteristics of the IRWST. The IRWST is a seismic Category I structure designed in accordance with American Concrete Institute (ACI) Code 349-97, "Code Requirements for Nuclear Safety Related Concrete Structures." The IRWST is an annulus-shaped, reinforced concrete structure that stores refueling water for the safety injection and containment spray pumps and serves as a heat sink for the safety depressurization system. The inner surface of the IRWST is lined with stainless steel fabricated from American Society for Testing Materials (ASTM) A240 Type 304 material to prevent leaks and interaction of the boric acid with the concrete structures.

During a public meeting with the applicant on October 6, 2015, the staff discussed the use of leak-chase channels in the design of the APR1400 application. As a result of the meeting and the staff's review of DCD Tier 2 Section 3.8.3, the staff noted that the applicant did not provide sufficient detail of the IRWST, such as a description of a leak chase channel system. Therefore, the staff issued RAI 332-8382, Question 03.08.03-08 (ML15348A038), requesting the applicant to: (1) describe and provide associated design drawings of the leak chase channel system and (2) describe how and where the leaked borated water from the IRWST leak chase channel system is collected, and in case of blockage from the crystalized boron, describe how the blockage can be opened before spilling borated water into the adjacent reinforced concrete.

In its response to RAI 332-8382, Question 03.08.03-08, (ML16225A554), the applicant stated that a leak chase channel collection system is provided to control potential leakage of the borated water from the IRWST. The applicant provided figures that show the typical cross section, plan views, and details of the leak chase channels for the overall IRWST, IRWST floor, IRWST wall, IRWST floor intersection, IRWST drain pipe and detection channel, collection points, and IRWST collection plumbing showing valves and sight glasses. The leak chase channel collection system consists of leak chase detection channels or angles seal welded to the back of the liner plate walls and floor to control the potential leakage of borated water from the IRWST. All leakage flows by gravity.

The leakage of borated water from the IWRST into the leak chase channel collection system is detected using valves or caps and is monitored using sight glasses. In the event that blockage of the leak chase collection system is detected, the applicant would perform further inspection and cleaning of the inside of the leakage collection pipes. The applicant included COL 9.3(5) directing the COL applicant to provide connection provisions at the nearest accessible area to the valve and sight glass room of the IRWST leakage pipe line for detecting and cleaning blockage from crystallized boron inside the leakage collection channel and pipes.

The staff reviewed the applicant's response and considers the response to be acceptable because the applicant (1) is committed to using a leak chase channel system to control potential leakage of the borated water from the IRWST and (2) included a COL item for monitoring and inspection of the leak chase channel connection system. Because the applicant has complied with the regulatory guidance in SRP Section 3.8.3.II and meets the regulatory requirements in 10 CFR Part 50.55a, Appendix A to 10 CFR Part 50, GDC 1, 2, 4, and 5, in the response to RAI 332-8382, Question 03.08.03-08, the staff considers the RAI to be resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 332-8382, Question 03.08.03-08, is resolved and closed.

DCD Tier 2, Section 3.8.3.1.11, "Interior Concrete Fill Slab," and Appendix 3.8A.1.4.3, "Internal Structures," indicate that the containment internal structures include concrete fill located on the surface of the liner plate of the RCB basemat for protection of the pressure boundary structures. The staff notes that this concrete fill also provides support to the CIS.

The staff issued RAI 208-8245, Question 03.08.03-07 (ML15295A509), requesting the applicant to determine whether the concrete fill is reinforced concrete. If the concrete fill is not reinforced concrete, then the applicant should provide detailed information that explains how the structural adequacy of the concrete fill is demonstrated. In addition, the staff requested the applicant to describe the connection details of the concrete fill to the reactor containment basemat to demonstrate its capability to withstand the various loads including seismic load.

In its response to RAI 208-8245, Question 03.08.03-07 (ML16203A269), the applicant provided a figure that shows the detailing of the concrete fill slab inside the containment. The applicant stated that the purpose of the concrete fill slab is to protect the liner plate on the basemat and that the concrete fill slab is not a structural member. The reinforcements of the structures that make up the CIS (i.e., the PSW and SSW) are calculated using all the applicable loads and load combinations for the CIS, and these reinforcements are fully developed into the basemat. Thus, the loads from these structures in the CIS can be transferred directly to the basemat without the concrete fill slab.

The concrete fill slab is reinforced too. The reinforcement of the concrete fill slab is computed based on the maximum moment of the SSW at the top elevation of the concrete fill slab, using the height of the concrete fill slab as the depth of the section to be designed. Therefore, the design load of the concrete fill slab is conservative when compared to the actual load. Further, because the vertical g-value of the concrete fill slab is less than 0.5g, uplift is not expected to occur.

The staff reviewed the applicant's response and concluded that the detailed information of the concrete fill presented by the applicant meets the acceptance criteria in 10 CFR Part 52 because the applicant (1) demonstrated that without the use of the concrete fill slab, the internal

structures are capable of transferring the CIS loads into the basemat, (2) adequately described the evaluation performed to confirm that contact is maintained everywhere between the concrete fill slab and the basemat, and (3) provided detailed information that is consistent with SRP Section 3.8.3, and RG 1.206. Therefore, RAI 208-8245, Question 03.08.03-07, is resolved and closed.

The descriptive information and referenced figures in DCD Tier 2, Section 3.8.3.1 and Appendix 3.8A, contain sufficient detail to define the primary structural aspects, the structural elements, and the load path that are relied upon for the CIS to perform their safety related function. Therefore, the staff finds this information acceptable.

3.8.3.4.2 *Applicable Codes, Standards, and Specifications*

In DCD Tier 2, Section 3.8.3.2, "Applicable Codes, Standards, and Specifications," and Table 3.8-1, "Codes, Standards, Specifications, and Regulations," the applicant presented the following key industry codes, standards, and specifications applicable to the design, construction, materials, testing, and inspections of the CIS:

- ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures," 1997 Edition.
- ANSI/AISC N690, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities," American National Standard Institute/ American Institute of Steel Construction, 1994 Edition, including Supplement 2, 2004.
- American Welding Society (AWS) D1.1, "Structural Welding Code – Steel Structures," 2010.
- American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, "Rules for Construction of Nuclear Facility Components," Division ASME Code, Section III, Division 2, "Concrete Containments," 2001 Edition through 2003 Addenda.
- ASME Code, Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," 2007 Edition through 2008 Addenda.
- RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, issued March 2007.
- RG 1.69, "Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants," Revision 1, issued May 2009.
- RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Revision 3, issued September 2012.
- RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," Revision 2, issued November 2001.

- RG 1.199, "Anchoring Components and Structural Supports in Concrete," issued November 2003.
- RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 3, issued May 2012.

The staff reviewed the codes, standards, and specifications from DCD Tier 2 Section 3.8.3.2, for applicability to the design of the APR1400 CIS. The applicant provided a list of the industry codes, standards, specifications, RGs, and SRP guidance applicable to the design, construction, materials, testing, and inspections of the APR1400 CIS design. The staff found the use of these codes, standards, and specifications in the design and construction of APR1400 CIS to be in accordance with the acceptance criteria in SRP Section 3.8.3 and meet the requirements prescribed in 10 CFR 50.55a. On this basis, the staff concludes that the information provided in DCD Tier 2 Section 3.8.3.2, on applicable codes, standards, and specifications is acceptable.

3.8.3.4.3 *Loads and Load Combinations*

In DCD Tier 2, Section 3.8.3.3, "Loads and Load Combinations," and Section 3.8A.1.3, "Loads and Load Combinations," the applicant specified all credible conditions of loading, including dead load, equipment operating loads and other live loads, pipe reactions, seismic load, internal missiles, pipe rupture jet impingement, compartment accident pressure, and operating and accident temperatures. The applicant stated that CIS are designed for the loads and load combinations specified in ACI 349-97 (DCD Tier 2, Table 3.8-1), with additional guidance provided in RG 1.142.

The staff reviewed the loads given in DCD Tier 2, Sections 3.8.3.3, and 3.8A.1.3, against the acceptance criteria specified in SRP Section 3.8.3.II and found that certain loads described in the application were not described in detail sufficient to demonstrate that the applicant complied with the acceptance criteria in 10 CFR 50.55a and SRP Section 3.8.3.II.3.

DCD Tier 2 Section 3.8.3.3, indicates that the typical loads and load combinations used for the internal structures are detailed in DCD Tier 2 Section 3.8.4.3. Then it lists the loads for which the CIS are designed. A comparison of these loads listed in DCD Tier 2 Section 3.8.3.3, with those of DCD Tier 2 Section 3.8.4.3, shows that some loads, such as the operating pressure loads, construction loads, and internal flooding, are not included.

The staff issued RAI 208-8245, Question 03.08.03-03 (ML15295A509), requesting the applicant to confirm that all applicable loads described in DCD Tier 2 Section 3.8.4.3 are used for the CIS. This issue of consideration of all applicable loads also applies to the list of loads identified in DCD Tier 2, Section 3.8.3.4.1, "Analysis Procedures."

In addition, DCD Tier 2, Appendix 3.8A.1.4.3.1.2, "Load Combinations Considered," identifies load combinations that are critical for the analysis and design of the PSW. It is not clear to the staff whether the applicant evaluated just these load combinations or if the applicant evaluated all load combinations but identified just these loads as critical. There are also some loads that are not included in the critical load combinations, such pipe, cable tray, duct, and ties reactions (R_o) for the normal and extreme environmental load combinations, pipe accident reactions (R_a) for the abnormal load combination and R_a , jet impingement load (Y_j), missile impact load (Y_m), and flood load (Y_f) for the abnormal and extreme load combination. The staff also asked the

applicant to address the above items for the other containment internal structures (e.g., IRWST and SSW).

In its response to RAI 208-8245, Question 03.08.03-03, (ML17095B038), the applicant stated that some of the loads and load combinations described in DCD Tier 2 Section 3.8.4.3, will be used in its design of the CIS which includes the PSW, IRWST, and the SSW. The applicant provided markup copies of DCD Tier 2 Section 3.8.3.3, which showed the additional loads and load combinations that will be used in its design of the CIS. The applicant further stated that DCD Tier 2 Section 3.8.3.3, will be revised to describe the applicable loads used in the design of the CIS.

To address the staff's concern regarding the missing loads such as R_o , R_a , Y_j , Y_m , and Y_f , the applicant provided markup copies of the applicable sections of DCD Tier 2 Appendix 3.8A, which showed the load combinations that are critical for the analysis and design of the PSW, the SSW, and the IRWST. The applicant also updated DCD Tier 2, Table 3.8-7A, "Seismic Category I Structures Excluding Containment Structure Reinforced Concrete – Ultimate Strength Design Load Combination," to include hydrostatic and hydrodynamic loads, such as pressure operated safety relief valve (POSRV) load for the design of the IRWST.

The staff reviewed the applicant's response and considered its analysis approach for considering the additional loads in its design of the CIS to be acceptable because the applicant (1) included the applicable loads and load combinations in the analysis and design of the PSW, the SSW, and the IRWST that are consistent with the regulatory requirements in 10 CFR Part 50, Appendix A, and GDC 1, 2 and 4, (2) meets the guidance provided in SRP Section 3.8.3, and (3) the applicant's approach meets the requirements in ACI 349. Accordingly, the staff considers RAI 208-8245, Question 03.08.03-03, resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-03, is resolved and closed.

In DCD Tier 2 Section 3.8.3.1.8, the applicant stated that, "The design of the IRWST considers pressurization as a result of the reactor containment building systems design basis accident." The applicant further stated in DCD Tier 2, Appendix 3.8A, "Structural Design Summary," and Section 3.8A.1.4.3.1.3, "Analysis Methods and Results," that "The hydrodynamic pressure load, which is generated by the expulsion of air in the pilot-operated safety relief valve (POSRV) discharge, is applied to the wall and bottom slab of the IRWST through the two spargers. For the hydrodynamic pressure load, by multiplying the dynamic impact factor (DIF), the maximum pressure is conservatively considered as the static load in the analysis." The staff notes that additional information was needed in order to better understand the hydrodynamic pressure loads that are being considered for the analysis and design of the IRWST.

The staff issued RAI 208-8245, Question 03.08.03-01 (ML15295A509), requesting the applicant to provide additional information that fully describes the hydrodynamic pressure loads that are being considered in the analysis and design of the IRWST. Specifically, the staff requested a description of the process used to develop the pressure transient (including the steady state portion) for a single sparger activation; the possible scenarios of sparger activation (i.e., one sparger alone, two spargers simultaneously, or some lag between the two activations); how the total pressure transients on the walls and floor were developed based on the scenarios identified; and how the DIF discussed in DCD Tier 2 Section 3.8A.1.4.3.1.3, was determined.

The staff also requested an explanation of why applying the hydrodynamic pressure load as a static load is considered conservative.

In its response to RAI 208-8245, Question 03.08.03-01 (ML16273A563), the applicant provided detailed information on the parameters considered in its analysis of the IRWST pressurization system. The applicant indicated that the pressure load acting on the IRWST during activation of the POSRVs is governed by the air bubble dynamics during the discharge of air present in the piping. When the air is discharged into the IRWST, air bubbles form and create a transient dynamic pressure time history load. The applicant performed an air clearing load test on Units 3 and 4 of the Shin Kori Nuclear Power Plant, which are similar to the APR1400 design, to verify the results calculated using the ABB Atom methodology, which was applied to System 80+. The applicant noted that the maximum air bubble pressure and frequency estimated from the test results are within the range computed using the System 80+ methodology.

The applicant assumed that multiple spargers are activated following a postulated POSRV actuation. The IRWST consists of 12 spargers, with 6 spargers on each of the two submerged pipe lines located 90 degrees west and 180 degrees north. The air in each sparger is assumed to be discharged simultaneously in the form of a bubble, which acts as a hydrodynamic load on the submerged IRWST wall boundaries. The air bubble discharge load from a particular sparger is not expected to impact the entire submerged boundary of the IRWST due to the interference of the IRWST interior cylindrical concrete wall. The applicant used the square root of the sum of squares (SRSS) method to obtain the combined hydrodynamic load at the location of interest from the individual load 12 spargers.

The RAI response provided the pressure transient showing the POSRV sparger bubble pressure as a function of time. The applicant further stated that the hydrodynamic transient pressure load generated by a sparger, that is used in the design of the IRWST, has a pressure magnitude and frequency range larger than from the ABB-based methodology (i.e., provides more margins on magnitude and frequency range). In the structural analysis of the CIS, the maximum pressure value of the total pressure transient is conservatively obtained by applying a DIF. By applying the DIF to the pressure transient, the maximum pressure value is transformed to a static load with the same effect on the structure. The static load is distributed on the walls and floor of the IRWST in accordance with the locations and distances from the 12 spargers.

The staff reviewed the applicant's response and concluded that the computation of the pressure transient of the air bubble through the POSRV spargers is consistent with industry practices. The applicant's use of the SRSS technique for combining loads from multiple bubbles is consistent with the empirically based approach by which individual bubble loads are calculated. The applicant also demonstrated that the hydrodynamic load from POSRV discharge that is used for design is a short transient and has a margin applied to the magnitude and frequency range of the transient. Based on the above discussion, the use of this approach with the application of a DIF, to represent the dynamic nature of this load, is considered to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-01, is resolved and closed.

3.8.3.4.4 *Design and Analysis Procedures*

DCD Tier 2, Section 3.8.3.4, "Design and Analysis Procedures," and Sections 3.8A.1.4.3.1.3 through 3.8A.1.4.3.3.3, describe the design and analysis procedures for the CIS. The applicant stated that the CIS are modeled with beam elements using the ANSYS computer program. The applicant further stated that the design loads for the CIS are dead load, live load, hydrostatic and hydrodynamic loads, temperature load, accident pressure load, pipe break load, and seismic load.

DCD Tier 2, Section 3.8.3.4.1, states, "The thermal stress analysis is carried out by inputting the normal operating thermal load into the corresponding FEM [Finite Element Model] for the internal structure." In reviewing this section, the staff noted that the applicant did not provide any description about accidental thermal loads, that is, loads generated by a postulated pipe break.

The staff issued RAI 208-8245, Question 03.08.03-04 (ML15295A509), requesting the applicant to confirm that accident thermal loads were considered and to describe how the accident thermal loads were evaluated in the analysis and design of the internal structures. In its response to RAI 208-8245, Question 03.08.03-04, (ML16203A269), the applicant provided data that show the comparison between the operating thermal loads and the accident thermal loads. For the CIS, the data showed that for the worse-case accident condition, the equivalent linear temperature profile for normal operating condition, is more severe than that of the accident temperature. The difference in temperature between the inside and the outside of the surface of the CIS during accident conditions was found to be negligibly small. As a result, the applicant conservatively applied the normal operating thermal load in its design of the internal structures.

The staff reviewed the applicant's response and considered its analysis approach for considering the accident thermal loads in its design of the CIS to be acceptable because the applicant (1) demonstrated that the equivalent linear temperature profile for normal condition is more severe than that of the accident conditions and (2) the applicant's approach meets the requirements in ACI 349. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-04, is resolved and closed.

DCD Tier 2 Section 3.8A.1.4.3.1.3, describes the analysis methods and results for the containment internal concrete structures. It states that, "Operating concrete floor slabs are modeled to mass in a finite element model (FEM), such as slabs between the SSWs and containment shell." The applicant stated that 50 percent of the weights and equipment weights on the floor between the containment shell and the SSW are assumed to be distributed to the containment shell and the SSW, respectively. This implies that there is a connection between the containment internal floors and the containment. The applicant further stated that, "An equivalent uniform temperature gradient is input directly in the ANSYS model at the appropriate nodes. The temperature profiles during normal operating condition are more severe than those of the accident condition, thus represent the limiting temperature for all the plant conditions." To better understand the analysis methods and results for the containment internal concrete structures, the staff issued RAI 208-8245, Question 03.08.03-05 (ML15295A509), requesting the applicant to do the following:

- a. Clarify whether the operating floor slabs between the SSW and the containment shell are included as masses in the FEM. If this is the case, then explain why it is acceptable to decouple these slabs from the overall FEM analysis of the internal structures and how is the analysis and design for such subelements performed for all of the various loadings.
- b. Explain in what directions (radial, tangential, and/or vertical) are the connections made and the details of how they are designed. Also, identify the gap provided between the containment and the floor slabs/connections to prevent impact/interaction and describe how the relative displacements between the containment and the floor slabs/connections from all loads including thermal and seismic were determined to demonstrate the gap is adequate.

In part (a) of the applicant response dated August 21, 2017 (ML17233A76), the applicant stated that the operating floor slabs between the SSWs and the containment wall are included as reaction forces obtained from local analyses to represent dynamic amplification in the finite element model. The applicant further stated that a separate analysis model simulating each floor level was prepared and evaluated for all of the specified design loading conditions. To incorporate the proper seismic load on the operating floor slabs, the applicant used the response spectrum analyses method described in SRP Section 3.7.2. The response spectrum analyses were performed using the floor response spectra which envelope both sides of the containment shell and the secondary shield wall at each elevation. The applicant also noted that the seismic anchor movements is considered in the seismic design analyses of the operating floor slabs. The applicant concluded that considering the behavior of the connection between the slab and the containment wall, the decoupling method of the slab for the containment does not affect the integrity of the containment wall. The staff reviewed the response and found it to be acceptable because the applicant demonstrated that (a) the frequency ratios of the slab to containment and the slab to SSW satisfy the decoupling criteria in SRP Section 3.7.2, (b) lumping 50 percent of the mass of the slab to the containment wall does not induce additional moments to the containment wall, and (c) the floor slabs are designed for all member forces as recommended in ACI 349 based on the enveloping of the results of the FEA.

In part (b) of the applicant response, the applicant stated that the internal floors are supported by structural steel beams which span the secondary shield wall and the containment wall. The applicant provided a figure which depicts the connection of the concrete slab and steel beam between the containment wall and the SSW. Each end of the steel beams has a SSW side connection at the SSW wall and a sliding connection at the containment wall. The beam seat supports the vertical load at the SSW side connection. The sliding connection at the containment wall is composed of a beam seat, a lower key bumper, and a gap between the end of the steel beam and the containment wall to allow radial displacements due to seismic and thermal loads. The lower key bumper supports the vertical upward load. The friction forces are considered for design of the beam seat and beam and welding of the beam seat. The gap between the end of the steel beam and the containment wall is 2 1/16 in., which is larger than the maximum displacement of 2.04 in. The staff reviewed the response and found it to be acceptable because the applicant (a) provided markup copies of the DCD Tier 2 which describe in detail the design connection of the concrete slab and the steel beam between the containment wall and the SSW and (b) demonstrated that the gap is adequate to allow the relative displacements between the containment internal floors and the containment wall.

Accordingly, the staff considers RAI 208-8245, Question 03.08.03-05, resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-05, is resolved and closed.

DCD Tier 2 Section 3.8A.1.4.3.1.3, describes the analysis parameters used for the IRWST in the containment internal structure FEM. The section indicates that the damping ratio for water in the IRWST or refueling pool is the same as that for reinforced concrete structures; the seismic response of water is only considered as impulsive (rigid) mode for structural analysis. The staff issued RAI 208-8245, Question 03.08.03-06 (ML15295A509), requesting the applicant to explain why the damping ratio for water is included in the model or whether the water is included using finite elements to represent the water. If the latter, the applicant should describe the methodology for representing the water as finite elements.

The staff also asked the applicant to explain why it only considered the impulsive (rigid) mode in the analysis. To fully understand the process for evaluating water in pools to design the pool walls and slabs, the staff also asked the applicant to provide a full description of how water in the various pools is modeled in the FEM and how member forces are determined to design the walls and floors of the pools. The staff also, asked the applicant to explain if the approach followed the methodology presented in ASCE 4-98, Section 3.5.4, "Above-Ground Vertical Tanks," or what alternative methods were used and the basis for those methods.

In its response to RAI 208-8245, Question 03.08.03-06, (ML16203A269), the applicant stated that for the analysis of the IRWST, the water is not included as a finite element to represent water in its analysis. The water is only considered as a mass, and the damping ratio for the IRWST is equal to the value used for reinforced concrete structures. The applicant provided a marked-up copy of the change to DCD Tier 2 Section 3.8A.1.4.3.1.3, which clarified the value used for the damping ratio.

The applicant further stated that the hydrodynamic pressure in the IRWST that results from seismic excitation can be considered as impulsive and convective modes depending on the depth, but not in phase with each other. The impulsive pressure is associated with inertial force produced by acceleration of the wall, and the convective pressure is produced by the oscillations of the water. The impulsive mode acts primarily to stress the wall, whereas the convective mode acts primarily to uplift the wall. The sloshing from the convective mode could both increase and decrease the water pressure on the wall, and the water pressure from the sloshing effect is smaller than that of the impulsive effect. Therefore, considering the impulsive mode over the water level is more conservative than considering both the impulsive and convective modes. Fifty percent of the mass of the total water is applied to the inner wall and the outer wall of the IRWST, respectively, in the horizontal direction (radial and tangential) direction, and 100 percent of the mass of the total water is applied to the bottom slab of the IRWST in the vertical direction.

The RCB has two water tanks—the IRWST and the refueling pool. Water is not expected to be in both tanks simultaneously. The hydrostatic pressure loads are applied as surface pressure on both the IRWST and the refueling pool walls and bottom slabs. The applicant computed the hydrodynamic pressure load using the approach in ASCE 4 98, Section 3.5.4. The member forces and stresses for the design of the IRWST are computed in accordance with Position 1.1.1, "Square Root of the Sum of the Squares (SRSS) Method," of RG 1.92.

The staff reviewed the applicant's response and concluded that the information provided by the applicant adequately describes the parameters used in its analysis of the IRWST. The procedures given in ASCE 4-98, as augmented by the applicable provisions of RG 1.92, constitute an acceptable basis for the design analysis of the IRWST. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-06, is resolved and closed.

3.8.3.4.5 *Structural Acceptance Criteria*

In DCD Tier 2, Section 3.8.3.5, "Structural Acceptance Criteria," the applicant stated that the acceptance criteria for the CIS are outlined in DCD Tier 2, Section 3.8.4.5, "Structural Acceptance Criteria."

The staff reviewed the acceptance criteria for the design strengths and allowable stresses for the CIS described in DCD Tier 2 Section 3.8.4.5, against the acceptable limits specified in SRP Section 3.8.3.II and determined that the stress, strain, and deformation limits are in accordance with the requirements in ACI 349, AISC N690, and RG 1.142.

The staff found the structural acceptance criteria described in DCD Tier 2 Section 3.8.3.5, applicable to the CIS acceptable because the information provided by the applicant is in compliance with the ACI 349, AISC N690, SRP Section 3.8.3.II.5, and RG 1.142.

3.8.3.4.6 *Materials, Quality Control, and Special Construction Techniques*

In DCD Tier 2, Section 3.8.3.6, "Materials, Quality Control, and Special Construction Techniques," the applicant described the requirements for the CIS by stating that the materials – concrete, reinforcing steel, structural steel, and stainless steel pool liners – conform to the requirements of ACI 349, AISC N690, applicable ASTM standards, and ASME Code, Section III, Division 2, Section CC-4540, "Rules Governing Making, Examining, and Repairing Welds," and ASME Section IX. DCD Tier 2 Section 3.8.4.6.3, stated that there are no special construction techniques and DCD Tier 2 Section 3.8.3.6, did not identify any special construction techniques.

The staff reviewed the acceptance criteria for the materials, quality control, and special construction techniques used for the steel portion of the concrete containment against the acceptance criteria in SRP Section 3.8.3.II.6 and ASME Code Sections III and IX (for welding procedures of stainless steel pool liners). The staff found the information provided on the materials and the quality control program proposed for the fabrication and construction of the CIS in DCD Tier 2 Section 3.8.3.6 acceptable because the information provided by the applicant meets the relevant requirements in 10 CFR 50.55a, the regulatory guidance in SRP Section 3.8.3.II.6, and the provisions in ACI 349, AISC N690, and the ASME Code.

3.8.3.4.7 *Testing and Inservice Inspection Requirements*

In DCD Tier 2, Section 3.8.3.7, "Testing and Inservice Inspection Requirements," the applicant indicated that the testing and inservice inspection requirements for the CIS are addressed in DCD Tier 2, Section 3.8.4.7, "Testing and Inservice Inspection Requirements." The applicant stated that there is no testing or inservice surveillance beyond the quality control tests performed during construction. The applicant further states that the quality control tests will be done in accordance with the requirements in ACI 349 and AISC N690.

The staff reviewed DCD Tier 2 Section 3.8.4.7, and noted that the applicant did not identify and discuss the requirements for monitoring the effectiveness of maintenance of the CIS and other structures, specifically, the requirements of 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," and the supplemental guidance of RG 1.160.

The staff issued RAI 208-8245, Question 03.08.03-02 (ML15295A509), requesting the applicant to identify and discuss the examination requirements of the CIS and other structures, specifically 10 CFR 50.65 and the supplemental requirements of RG 1.160 in the applicable sections of DCD Tier 2. In its response to RAI 208-8245, Question 03.08.03-02, (ML15313A533), the applicant provided a marked-up copy of the change to DCD Tier 2 Section 3.8.4.7, indicating that monitoring of the seismic Category I structures will be done in accordance with RG 1.160.

The staff reviewed the applicant's response to ensure that the CIS could perform their intended safety function. The staff verified that the testing and the inservice inspection surveillance program meets relevant requirements in 10 CFR 50.55a and 10 CFR 50.65 and the supplemental guidance of RG 1.160. The staff found the information provided on the testing and inservice surveillance program for the CIS in DCD Tier 2 Section 3.8.3.7, acceptable because the applicant's method for monitoring the effectiveness of maintenance for the CIS is in compliance with 10 CFR 50.65 and meets the regulatory guidance in RG 1.160 and SRP Section 3.8.3.II.6. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 208-8245, Question 03.08.03-02, is resolved and closed.

3.8.3.5 Combined License Information Items

DCD Tier 2, Section 3.8.3, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.8.3 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.8(8)	The COL applicant is to determine the environmental condition associated with the durability of concrete structures and to provide the concrete mix design that prevents concrete degradation including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.	3.8.4.6.1.1
COL 3.8(9)	The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.	3.8.4.6.3
COL 3.8(10)	For safety and serviceability of seismic Category I structures during the operation of the plant, the COL applicant is to provide appropriate testing and inservice inspection programs to examine the condition of normally inaccessible, below-grade concrete for signs of degradation and to conduct periodic site monitoring of ground water chemistry.	3.8.4.7

	Inservice inspection of the accessible portion of concrete structures is also to be performed.	
COL 3.8(16)	The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation to monitor groundwater chemistry.	3.8.5.7

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 concrete internal structures.

3.8.3.6 Conclusion

The staff concludes W that the design of the CIS is acceptable and meet the relevant requirements of Appendix B to 10 CFR Part 50, 10 CFR 50.55a, and GDC 1, 2, 4, 5, and 50. This conclusion is based on the following six findings:

1. The applicant has met the requirements of 10 CFR 50.55a and GDC 1 with respect to ensuring that the CIS is designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with its safety function to be performed by meeting the guidelines of the RGs and industry standards.
2. The applicant has met the requirements of GDC 2 by designing the CIS 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.
3. The applicant has met the requirements of GDC 4 by designing the CIS to withstand the dynamic effects associated with missiles, pipe whipping, and discharging fluids.
4. The applicant has met the requirements of GDC 5 by demonstrating that the CIS is not shared between units or that sharing will not impair the CIS ability to perform its intended safety functions.
5. The applicant has met the requirements of GDC 5 by designing the CIS to accommodate, with sufficient margin, the design leakage rate, calculated pressure, and temperature conditions resulting from accident conditions and by ensuring that the design conditions are not exceeded during the full course of the accident condition.
6. The applicant has met the requirements of Appendix B to 10 CFR Part 50, in that the quality assurance program provides adequate measures for implementing guidelines relating to structural design of the CIS.

The criteria used in the analysis, design, and construction of the CIS to account for anticipated loadings and postulated conditions that may be imposed upon the CIS during its service lifetime are in conformance with established criteria, codes, standards, and RGs acceptable to the staff. This includes compliance with the criteria of ASME Code, Section III, Division 2; ACI 349; and AISC N690 and the guidelines in SRP Section 3.8.3, and RGs 1.69, 1.61, 1.92, 1.142, 1.160, and 1.199.

The use of these criteria, as defined by applicable codes, standards, and guides; loads and loading combinations; design and analysis procedures; structural acceptance criteria; materials, quality control programs, and special construction techniques; and testing and inservice surveillance requirements provide reasonable assurance that, in the event of earthquakes and various postulated accidents occurring within and outside the containment, the structure will withstand the specified conditions without impairment of its structural integrity or safety function.

3.8.4 Other Seismic Category I Structures

3.8.4.1 Introduction

DCD Tier 2 Section 3.8.4, "Other Seismic Category I Structures," describes other seismic Category I structures are the AB and EDGB. This section of the APR1400 DCD provides the following information on other seismic Category I structures:

- description of structures
- applicable codes, standards, and specifications
- loads and load combinations
- design and analysis procedures
- structural acceptance criteria
- materials, quality control, and special construction techniques
- testing and inservice inspection requirements

In DCD Tier 2 Section 3.8.4, the applicant stated that a COL applicant is to provide the design of site-specific seismic Category I structures in addition to the above structures, such as the ESWB, component cooling water heat exchanger building, essential service water conduits, and class 1E electric duct runs per the COL 3.8(1).

3.8.4.2 Summary of Application

DCD Tier 1: DCD Tier 1 information associated with this section is found in DCD Tier 1, Sections 2.2.1, and 2.2.2, "Emergency Diesel Generator Building."

In DCD Tier 1, Section 2.2.1, the applicant describes the safety related, and seismic Category I structure of the AB. The AB is a reinforced concrete structure which consists of the electrical and control area, the fuel handling area, the CVCS area the main steam valve house, and the emergency diesel generator area.

In DCD Tier 1, Section 2.2.2, the applicant describes the safety related, and seismic Category I structure of the EDGB. The EDGB is located adjacent to the east side of the AB, but is separated from the AB by 3 feet as a seismic isolation gap. The EDGB (referred to as the EDGB block elsewhere in the DCD) comprises two structures: one that houses the additional two generators (EDGB) and the other for the DFOT. The two structures are built on separate basemats with a seismic isolation gap of three (3) feet between them.

DCD Tier 2: DCD Tier 2 information associated with this section is found in DCD Tier 2, Section 3.8.4, “Other Seismic Category I Structures,” and Appendix 3.8A, “Structural Design Summary.”

DCD Tier 2, Section 3.8.4 and Appendix 3.8A, provide description of the layout of physical plant structures, design and design summary, construction, and inspection of the other seismic Category I structures.

ITAAC: The ITAAC associated with DCD Tier 2 Section 3.8.4, are provided in DCD Tier 1 Section 2.2.

In DCD Tier 1, Table 2.2.2-1, “Definition of Wall Thicknesses for Emergency Diesel Generator Building,” the applicant tabulated the key dimensions of the DFOT building. However, the applicant did not provide any ITAAC items for the DFOT building. In DCD Tier 1, Table 2.2.1-3, “Seismic Classification of the Building,” the applicant identified the essential service water structure and component cooling water heat exchanger structure (ESW/CCW HX buildings) as seismic Category I structures. In DCD Tier 2 Section 3.8.6, “Combine License Information,” the applicant provided COL 3.8(1), for the COL applicant to provide the design of site-specific seismic Category I structures, which included the ESW/CCW HX buildings. However, the applicant did not describe for the COL applicant the requirements of ITAAC items associated with the ESW/CCW HX buildings. Therefore, the staff issued RAI 255-8285, Question 03.08.05-6 (ML15529A569), as discussed in SER Section 3.8.5, requesting that the applicant provide the ITAAC items, associated figures, and related information for the DFOT building in DCD Tier 1, Section 2.2.2, and describe for the COL applicant the requirements of the ITAAC items associated with the ESW/CCW HX building in COL 3.8(1) in Section 3.8.6 of DCD, Tier 2. The staff evaluated RAI 255-8285, Question 03.08.05-6, in SER Section 3.8.5.4.7, and found the RAI response acceptable because the applicant provided the requested information. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-6, is resolved and closed.

Technical Specifications: The technical specifications associated with DCD Tier 2 Section 3.8.4 are provided in DCD Tier 2 Chapter 16.

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

Technical Reports: The technical report associated with DCD Tier 2 Section 3.8.4 is APR1400-E-S-NR-14006, “APR1400 Stability Check for NI [Nuclear Island] Common Basemat,” Revision 1, February 2015.

Crosscutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): There are no cross cutting requirements for this area of review.

APR1400 Interface Issues Identified in the DCD: See DCD Tier 2, Table 1.8-2.

Site Interface Issues Identified in the DCD: See DCD Tier 2, Table 1.8-2.

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

3.8.4.3 *Regulatory Basis*

The relevant requirements for this area, and the associated acceptance criteria, are given in SRP Section 3.8.4, "Other Seismic Category I Structures," Revision 4 and are summarized below. SRP Section 3.8.4 also identifies review interfaces with other SRP sections.

- Section 50.55a of 10 CFR and GDC 1, of Appendix A, "Licensing of Production and Utilization Facilities," as they relate to seismic Category I structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.
- GDC 2, as it relates to the ability of seismic Category I structures, without loss of capability to perform their safety function, to withstand the effects of natural phenomena, such as earthquakes, wind, tornadoes, hurricanes, floods, and the appropriate combination of all loads.
- GDC 4, as it relates to the protection of seismic Category I structures against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.
- GDC 5, as it relates to safety related structures not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.
- Part 50 of 10 CFR, Appendix B as it relates to the quality assurance criteria for nuclear power plants.
- Section 52.47(b)(1) of 10 CFR, which requires that a DC application contain the proposed ITAACs 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 facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

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

- SRP Section 3.8.4, Section II, includes acceptance criteria for (1) a description of the containment, (2) applicable codes, standards, and specifications, (3) loads and loading combinations, (4) design and analysis procedures, (5) structural acceptance criteria, (6) materials, quality control, and special construction techniques, and (7) testing and inservice surveillance requirements.
- RG 1.69, "Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants," Revision 1, issued May 2009.
- RG 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Revision 2, issued April 2013.

- RG 1.115, "Protection Against Low-Trajectory Turbine Missiles," Revision 2, issued January 2012.
- RG 1.127, "Inspection of Water Control Structures Associated with Nuclear Power Plants," February 2016.
- RG 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," Revision 2, issued November 2001.
- RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Revision 2, issued February 2001.
- RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 3, issued May 2012.
- RG 1.199, "Anchoring Components and Structural Supports in Concrete," issued November 2003.
- Technical Evaluation

Using the guidance described in SRP Section 3.8.4, the staff reviewed DCD Tier 2 Section 3.8.4, "Other Seismic Category I Structures." In particular, the review described in this section focused on: (1) description of the other seismic Category I structures; (2) applicable codes, standards, and specifications; (3) loads and load combinations; (4) design and analysis procedures; (5) structural acceptance criteria; (6) materials, quality control, and special construction techniques; and (7) testing and inservice surveillance requirements. Applicable COL action items are also reviewed.

3.8.4.3.1 *Description of Other Seismic Category I Structures*

The staff reviewed the descriptions of the other seismic Category I structures to ensure that they contain sufficient information to define the primary structural aspects and elements that are relied upon to perform the safety related functions of these structures. The staff's review also ensures that their design meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; GDC 1, GDC 2, GDC 4, and GDC 5; and 10 CFR 52.47(b)(1); and are in accordance with the guidance provided in SRP Section 3.8.4.II.1.

In DCD Tier 2, Section 3.8.4, the applicant described the AB and EDBG block (EDGB block consisting of the EDGB and DFOT) as the seismic Category I structures.

The applicant specified that a COL applicant shall provide site-specific seismic Category I structures, such as ESWB, component cooling water heat exchange building, essential service water conduits and class 1E electric duct runs per the COL 3.8(1).

3.8.4.3.2 *Description of the Structures*

The applicant described the seismic Category I structures as follows:

Auxiliary Building

The applicant described the AB in DCD Tier 2 Section 3.8.4.1.1, as follows:

The general arrangement of AB are shown in Figures 1.2-9 through 1.2-19 in DCD Tier 2. The AB encompasses the RCB, and is on a common basemat that forms a monolithic structure with the RCB. The AB is rectangular with dimensions of 106.0 m × 107.6 m (348 ft. × 353 ft.). The AB houses the mechanical and electrical equipment used for normal plant operation and safe-shutdown of the reactor. The AB is separated from other buildings by isolation gaps.

The AB is comprised from the following areas:

- Electrical control area
- Main steam valve house
- CVCS area
- Emergency diesel generator area
- Fuel handling area

The Class 1E electrical equipment rooms at elevation 78 ft., 0 in., and those areas located at upper elevations are considered to be electrical control areas. Two physically separate divisions were provided for electrical distribution, control, and instrumentation systems leading to the main control room (MCR). The upper floor of the electrical and control areas containing the MCR were designed to provide security, fire, and environmental protection to the control equipment and the MCR operators.

Main steam valve house is a compartment located from elevations 137 ft. 6 in. to 175 ft. 0 in. The main steam valve house is designed to provide environmental protection, primarily missile protection, for the main steam and feedwater line safety-related valves and piping.

CVCS area consists of a number of small rooms that are used to isolate components for water treatment required by operating systems. Individual rooms are used for radiation shielding. In DCD Tier 1, Table 2.2.1-1, "Definition of Wall Thicknesses for Nuclear Island Structure," tabulates wall sections, column lines, elevations, concrete thickness and shield wall applicability within the NI structure.

There are four Emergency Diesel Generator units. Two are located in the AB, which are separated on the opposite sides of the AB in a mirror configuration. The other two are located in the EDGB.

The fuel handling area includes spent fuel pool, refueling canal, cask loading pit, cask decontamination pit, truck/rail shipping bay, and new fuel storage area. The spent fuel pool is an open stainless steel lined reinforced concrete vessel used for submerged storage of radioactive spent fuel assemblies. The pool is approximately 10.8 m × 12.8 m (35 ft. 6 in. × 42 ft.) with a depth of 12.8 m (42 ft.). The walls and floor of the spent fuel pool have a minimum of 1.7 m (5 ft. 6 in.) thick of concrete.

Fuel assemblies are transferred from the fuel handling area to the refueling pool via the refueling canal in the AB and then the fuel transfer tube in the RCB. The refueling canal measures 1.8 m (6 ft.) wide by 20.5 m (67 ft. 3 in.) long. The minimum wall thickness on the fuel pool side is 1.8 m (6 ft.). An opening in the fuel pool wall allows for passage of fuel between the fuel pool and the refueling canal. A steel divider is provided for the opening. Seals are incorporated to allow draining of the refueling canal while maintaining the water level in the spent fuel pool. An overhead bridge crane with a capacity of 150 tons is provided over the shipping bay and extending over the fuel pool and refueling canal. Interlocks are provided to prevent the crane from moving over the spent fuel storage area during cask handling operations. A new fuel-handling crane, running on rails mounted over the operating floor, is provided to handle the new fuel assemblies.

The two auxiliary feedwater (AFW) tanks consist of three stainless steel lined reinforced concrete rooms. Each room has a single tank. The tanks extend from elevation 100 ft. 0 in. to the underside of the floor slab at elevation 137 ft. 6 in.

SRP Section 3.8.4, Appendix A, "Criteria for Safety-Related Masonry Walls Evaluation," contains the acceptance criteria for the safety-related masonry walls. However, in DCD Tier 2, Section 3.8.4, the applicant did not provide any discussions for the safety-related masonry walls. Therefore, the staff issued RAI 227-8274, Question 03.08.04-02 (ML15270A001), requesting that the applicant describe whether there are any safety-related masonry walls in the APR1400 design. If there are, then provide the description of the masonry walls; applicable codes, standards, and NRC regulatory guidance; loads and load combinations; and analysis and design approach.

In its response to RAI 227-8274, Question 03.08.04-02, (ML16006A121), the applicant stated that there are no safety-related masonry walls in the APR1400 design. In its response, the applicant also provided markups to DCD Tier 2, Sections 3.8.4.1.1 and 3.8.4.1.2, for the AB and EDGB, respectively, to clarify that there are no safety-related masonry walls in these buildings. The staff considers this response acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-02, is resolved and closed.

Emergency Diesel Generator Building

The applicant described the EDGB block in DCD Tier 2 Section 3.8.4.1.2, as follows.

The EDG building block comprises two single story reinforced concrete buildings, one that houses the two additional generators (EDGB) and the other for the DFOT. The EDG and DFOT buildings are independent seismic Category I reinforced concrete rectangular structures built on separate basemats with a 1.2 m (4 ft.) thick continuous mat foundation at elevations 100 ft. 0 in. and 63 ft. 0 in.; respectively, and are separated by an isolation gap of 900 mm (3 ft.).

Spent Fuel Rack

The applicant described the spent fuel racks in DCD Tier 2 Section 3.8.4.1.3, as follows.

The spent fuel storage racks were considered to be a seismic Category I structure, and are free-standing structures. The spent fuel storage racks were designed to meet the following criteria under the plant abnormal condition, such as seismic or fuel handling accident.

- Protect the stored fuel against a physical damage.
- Maintain the stored fuel in a subcritical configuration.
- Maintain the capability to load and unload fuel assemblies.
- Maintain the stored fuel in a coolable geometry.

The safety review of the new and spent fuel rack is further discussed in SER Section 9.1.2.

Compound Building

The compound building (CB) is adjacent to the south side of the AB, and is classified as a non-safety related seismic Category II reinforced concrete structure. As indicated in DCD Tier 2 Table 3.2-1, those portions of the CB that house certain systems are classified at a higher level as a seismic Category IIa structure in accordance with RG 1.143. The CB houses the systems and components related to radwaste management, access control, and the operation support center (OSC). The CB consists of an access control facility, radwaste management facility, hot machine shop, and sampling facilities and laboratory. The CB is supported by a reinforced concrete foundation that is separated from the foundation of the AB. DCD Tier 2 Section 1.2.14.4, "Compound Building," stated that the CB is so designed that it will not affect safety-related structures system and components in the AB under the safe-shutdown earthquake (SSE) condition. SRP Section 3.8.4.1.4, "Design and Analysis Procedures," states, "The review of the design and analysis procedures used for other structures that are important to safety (e.g., radwaste structure) are reviewed against applicable staff guidance (e.g., RG 1.143 for the radwaste structure)." Therefore, staff issued RAI 227-8274, Question 03.08.04-01 (ML15270A001), requesting that the applicant provide a description of the CB; applicable codes, standards, and NRC regulatory guidance; loads and load combinations; and analysis and design approach.

In its response to RAI 227-8274, Question 03.08.04-01, (ML16110A463), the applicant stated that the description in DCD Tier 2 Section 3.8.4.1.4, will be updated to state that the structures related to radwaste management of the CB will use ACI 349 and/or N690 as applicable in accordance with RG 1.143, and that the CB shall be designed to preclude a structural failure during SSE by using design codes, standards, specifications, regulations, RGs, and other industry standards for seismic Category I structures. The staff considers this response acceptable because the compound building is designed as seismic Category I structure although it is classified as a seismic Category II structure (which is conservative). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-01, is resolved and closed.

In DCD Tier 2, Section 3.8.6, "Combine License Information," the applicant specified that a COL applicant that references the APR1400 DCD design needs to describe the site-specific seismic Category I structures such as the ESWB, component cooling water heat exchanger building, essential service water conduits and class 1E electric duct runs. This COL information is identified as COL 3.8(1).

The descriptive information and referenced figures in the DCD Tier 1, Section 2.2, and DCD Tier 2, Section 3.8.4.1 and Appendix 3.8A, contain sufficient detail to define the seismic Category I structures to perform their safety related functions. The staff finds the description of

the seismic Category I structures in DCD Tier 2 Subsection 3.8.4.1, to be acceptable on the basis that it is consistent with SRP Section 3.8.4.II.1 and RG 1.206 acceptance criteria.

3.8.4.3.3 *Applicable Codes, Standards, and Specifications*

The staff reviewed the applicable codes, standards and specifications used for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.2.

In DCD Tier 2, Section 3.8.4.2.1, “Design Criteria and Standards,” the applicant described the applicable design criteria and standards for the seismic Category I structures.

Design Codes, Regulatory Guides, and Industry Standards

DCD Tier 2, Section 3.8.4.2, “Applicable Codes, Standards, and Specifications,” identifies the codes, specifications, and US regulations applicable to the design, fabrication, construction, testing, and inservice inspection of other seismic Category I structures. However, the applicant did not provide the year or edition of the applicable codes, standards, specifications, and regulations. This occurred throughout the DCD, and the staff also identified discrepancies related to the applicable codes, standards, specifications, and regulations.

Examples of inconsistencies within the DCD are as follows:

- DCD Tier 2 Section 3.8.4.2.2, identifies some RGs that are applicable to the design, construction, testing, and inspection of seismic Category I structures. A comparison of the RGs with those listed in SRP Section 3.8.4 shows that some RGs are not included (e.g., RG 1.127, RG 1.136, RG 1.160, and RG 1.221).
- In DCD Tier 2 Section 3.8.4.6.1.1, “Concrete,” the applicant referenced ASTM D1888-78, “Method of Test for Particulates and Dissolved Matter in Water,” which was withdrawn in 1989 without a replacement.
- ASCE 4, ASCE 7, & ASCE 37 were referenced in various sections of the DCD, but are not included in DCD Tier 2 Table 3.8-1. Furthermore, ASCE 4 was not referenced in DCD Tier 2 Section 3.8.7, “References.”
- In DCD Tier 2 Section 3.8.4.6.1.2, “Reinforcing Steel,” the applicant stated, “The fabrication of reinforcing bars, including fabrication tolerances, is in accordance with CRSI, MSP-1.” However, the Manual of Standard Practice-1 (MSP-1) of Concrete Reinforcing Steel Institute (CRSI) was not referenced in Section 3.8.7 and no edition was provided. There were also other references included in Section 3.8.7 without identification of the year or edition.
- In DCD Tier 2, Section 3.8.4.6.1.4, “Stainless Steel,” and Table 3.8-1 “Codes, Standards, Specifications, and Regulations,” the applicant did not provide the welding code for the stainless steel material, and DCD Tier 2, Sections 3.8.3 and 3.8.4, did not identify other potentially applicable American Welding Society Codes (e.g., AWS D1.4, AWS D 1.6, and AWS D 1.8). Furthermore, applicant referred to DCD Tier 2, Sections

3.8.3.6.3, “Stainless Steel Pool Liners,” and 3.8.3.6.4, “Stainless Steel Other Than Pool Liners,” for additional requirements.

- In DCD Tier 2 Section 3.8.3.6.3, “Stainless Steel Pool Liners,” the second paragraph states, “Welding procedures are in accordance with ASME Section, Division 2, Subarticle CC-4540 and ASME Section IX.” However, this paragraphs should read as, “Welding procedures are in accordance with ASME Section III, Division 2, Subarticle CC-4540 and ASME Section IX.”

Regulatory Guides

In DCD Tier 2 Section 3.8.4.2.2, “Regulatory Guides,” the applicant referred to, and described, the applicable RGs in Section 1.9, “Conformance with Regulatory Criteria,” for the design of seismic Category I structures.

In DCD Tier 2 Section 1.9.8, “Combined License Information,” the applicant specified in COL 1.9(1) that if the COL applicant refers to the APR1400 DCD, the applicant shall determine whether the regulatory criteria for the site-specific portions and operational aspects of the facility conform to the DCD. In DCD Tier 2, Table 1.9-1, “Conformance with Regulatory Guides,” the applicant tabulated all the applicable RGs that conform to the AP1400 design.

In DCD Tier 2 Section 3.8.4.2.2, “Regulatory Guides,” the applicant provided the following applicable RGs: 1.29, 1.60, 1.61, 1.69, 1.91, 1.92, 1.115, 1.122, 1.142, 1.143, and 1.199. The staff reviewed this list against DCD Tier 2 Table 1.9-1, and determined that RG 1.127 and RG 1.160, were not identified in DCD Tier 2 Section 3.8.4.2.3 or in any COL items.

Industry Standards

In DCD Tier 2, Section 3.8.4.2.2, “Industry Standards,” the applicant described that nationally recognized industry standards, such as those published by ASTM, are used where practicable to define material properties, testing procedures, and fabrication and construction methods.

The staff reviewed the codes, standards, and specifications given in the DCD Tier 2 Section 3.8.4.2. The applicant provided a detail list of the industry codes, standards and specifications, per the SRP guidance that are applicable for the design, construction, materials, testing and inspections of the other seismic Category I structures for the APR1400 design. The staff raised some questions regarding some of these which are summarized in SER Section 3.8.4.4.2.

As a result of the questions discussed in SER Section 3.8.4.4.2, the staff issued RAI 227-8274, Question 03.08.04-03 (ML15270A001), requesting the applicant to ensure the completeness and accuracy of the codes, standards, specifications, and RGs in the various sections of DCD Tier 2 Section 3.8, including DCD Tier 2, Table 3.8-1, “Codes, Standards, Specifications, and Regulations,” and DCD Tier 2, Section 3.8.7, “References.” The staff requested that the response include correction of discrepancies such as those described above and the specification of the year or edition of each of the referenced documents.

In its response to RAI 227-8274, Question 03.08.04-03, (ML16309A060), the applicant corrected all the discrepancies and incompleteness of the codes, standards, and specifications. As such, the staff considers the response acceptable. Based on the review of the DCD, the

staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-03, is resolved and closed.

The staff found the use of these codes, standards, and specifications in the design and construction of the other seismic Category I structures for the APR1400 design to be in accordance with the guidance given in SRP Section 3.8.4.II.2. On this basis, the staff concludes that the information provided in the DCD Tier 2 Subsection 3.8.4.2, on applicable codes, standards, and specifications for the other seismic Category I structures of APR1400 design, is acceptable.

3.8.4.3.4 *Loads and Load Combinations*

The staff reviewed the loads and load combinations used for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.3.

Loads

In DCD Tier 2, Subsection 3.8.4.3, "Loads and Load Combinations," the applicant describes the loads and load combinations for other seismic Category I structures. The DCD indicates that loads are classified as normal loads, abnormal loads, severe environmental loads, extreme environmental loads, and other loads.

The applicant specified that a COL applicant who refers to the APR1400 DCD design shall identify any site-specific loads such as site proximity explosions and missiles, potential aircraft crashes, and the effects of seiches, surges, waves, and tsunamis, which were included in DCD Tier 2, subsection 3.8.6, "Combined License Information." The applicant identified this as COL 3.8(2).

In DCD Tier 2, Section 3.8.3.1.1, "Normal Loads," the applicant defined these loads as follows: Dead Loads (D); Live Loads (L) which include Soil and Surge Loads (L_g), Hydrostatic Loads (L_h), and Snow Loads (L_s); Thermal Operating Loads (T_o); Pipe, Cable, Duct Supports and Ties (R_o); Crane and Trolley Loads (C); Operating Pressure (P_o); Miscellaneous Normal Loads (M_o); and Construction Loads.

DCD Tier 2, Section 3.8.3.1.2, "Abnormal Loads," defined these loads as follows: Accident Pressure (P_a) from the Main Steam Valve House and Other Areas; Accident Temperature (T_a); Accident Reactions of Pipe, Cable Tray, Duct Supports and Ties (R_a); Pipe Break Reactions (Y_r) which include Pipe Whip Restraint Reactions and Pipe Hanger Loads; Jet Impingement Load (Y_j); Missile Impact Load (Y_m); Flooding Loads (Y_f); Miscellaneous abnormal loads (M_a); and Internal Flooding (H_a).

DCD Tier 2, Section 3.8.3.1.3, "Severe Environmental Loads," defined these loads as follows: Wind Loads (W); Design Flood Precipitation (H), and Operating Basis Earthquake.

DCD Tier 2, Section 3.8.3.1.4, "Extreme Environmental Loads," defined these loads as follows: Safe Shutdown Earthquake (E_s), Tornado or hurricane (W_t), and Probable Maximum flood/precipitation (H_s).

DCD Tier 2, Section 3.8.3.1.5, "Other Loads," defined these loads as follows: Other loads resulting from aircraft hazard and explosion pressure wave that are not included in the design. These loads are evaluated separately because they are beyond the design basis condition.

The applicant defined the flood load as a load within or across a compartment and/or building due to flooding generated by a postulated pipe break. The loads are calculated considering the design basis flood heights.

The staff reviewed the detailed description of the above loads in DCD Tier 2, Section 3.8.4 and Appendix 3.8A, and compared them to the SRP Section 3.8.4.II.3, which includes the various loads and load combinations to be considered in design.

In DCD Tier 2, Section 2.4, "Hydrologic Engineering," the applicant described the types of hydrodynamic loads on the safety-related structures. In DCD Tier 2, Section 2.4.15, "Combined License Information," the applicant requires a COL applicant to provide the site-specific hydrological events in COL 2.4(1). In DCD Tier 2 Section 3.4, the applicant described the flood loads due to design basis flood levels from external and internal events on seismic Category I structures. In DCD Tier 2 Section 3.4.3, the applicant requires a COL applicant to provide site-specific internal and external flooding sources in COL 3.4(2) and COL 3.4(3). In DCD Tier 2 Section 3.8.4.3, "Loads and Load Combinations," the applicant requires a COL applicant to identify the site-specific loads such as effects of seiches, surges, waves, and tsunamis in COL 3.8(2). However, it was not clear whether the applicant considered all the hydrological events described in DCD Tier 2, Sections 2.4 and 3.4, in the load and load combinations for the other seismic Category I structures in DCD Tier 2 Section 3.8.4, "Design of Other Seismic Category I Structures," and whether there's enough allowable margin(s) in loading combinations to accommodate the potential flooding loads of site-specific internal and external flooding sources, including the factors of safety given in DCD Section 3.8A (Tables 3.8A-15 and -38), and APR1400-E-S-NR-14006, Revision 1, Table 4-5. Therefore, the staff issued RAI 227-8274, Question 03.08.04-04 (ML15270A001), requesting the applicant to describe how the various water/flood related loads are classified (e.g., normal, severe environmental, abnormal, etc.); how they are calculated in terms of the loads used in DCD Tier 2 Section 3.8.4; how they are applied in the design of seismic Category I structures; and whether there is sufficient design margin(s) in the loading combinations to accommodate the potential flooding loads of site-specific internal and external flooding sources.

In its response to RAI 227-8274, Question 03.08.04-04 (ML16147A625) the applicant stated the following:

Classification of Loadings

The classification of effective loadings complies with code specification (ACI 349 Chapter 9) and the classified effective loadings are as follows:

Hydrostatic load (L_h) are Hydrostatic loads due to weight and pressure of fluids with well-defined densities and controllable maximum heights or related internal moment and forces. The response referred to DCD Tier 2 Section 3.8.4.3.1.b.2. This load is generally not related to natural phenomena. It is calculated as a linearly distributed pressure on the external walls.

Soil and surcharge load (L_g) is a normal load as described in DCD Tier 2 Section 3.8.4.3.1.b.1. This load is applied up to maximum elevation of groundwater specified in DCD Tier 2 Table 2.0-1 (0.61 m (2 ft.) below plant grade).

Flooding load (Y_f) is an abnormal load as described in DCD Section 3.8.4.3.2.g. This load is applied due to internal flooding generated by a postulated pipe break in the abnormal extreme environmental loading condition.

Design flood/precipitation (H) is a severe environmental load as described in DCD Tier 2, Section 3.8.4.3.3.b. This load is applied up to the maximum site flood elevation which is specified in DCD Tier 2, Table 2.0-1 (0.30 m (1 ft.) below plant grade).

Probable maximum flood/precipitation (PMF/PMP) (H_s) is an extreme environmental load as described in DCD Tier 2, Section 3.8.4.3.4.c. This load is applied based on the maximum flood elevation which is specified in DCD Tier 2, Table 2.0-1 (0.30 m (1 ft.) below plant grade).

Hydrodynamic load in the seismic loads (E_s) is an extreme environmental load as described in DCD Tier 2, Section 3.8.4.3.4.a.1. This load is included in the SSE loads (E_s) and is applied based on the maximum elevation of groundwater specified in DCD Tier 2, Table 2.0-1 (0.61 m (2 ft.) below plant grade).

The dynamic soil pressure load and hydrodynamic load in the seismic loads (E_s) are applied to the design. Design flood/precipitation (H) and PMF/PMP (H_s) are not governing loads in the design of APR1400 since the load combinations including those loadings are negligibly small compared to the other load combinations.

Design loads for water head

The water heads are transformed into hydrostatic or hydrodynamic loadings as described below.

Hydrostatic load: Hydrostatic loads are calculated as a linearly distributed pressure on external walls depending on the design water level according to the basic equation of hydrostatics. The design groundwater elevation for the APR1400 standard plant design is based on the EPRI ALWR Utility Requirement Document (URD) Table 1.2-6,

“Envelope of ALWR Plant Site Design Parameter.” Therefore, the maximum design ground water level is determined to be 0.61 m (2 ft.) below the plant grade in the vicinity of the SSCs important to safety. An equation was provided which is the product of the unit weight of water times the depth of water for the maximum hydrostatic load.

Surcharge load: An equation was provided which is the product of the static surcharge pressure times the coefficient of earth pressure at rest condition for the maximum surcharge load.

Earth Pressure loads: An equation was provided which is the product of the soil density in the saturated or submerged condition times the coefficient of earth pressure at rest condition times the soil depth for the maximum earth pressure load.

Dynamic groundwater pressure (Hydrodynamic water pressure): Dynamic groundwater pressure is calculated based on the hydrodynamic formula suggested by Matsuo and O’Hara in “Principles of Soil Dynamics,” written by Braja M. Das. Based on the hydrodynamic formula, the hydrodynamic water pressure due to seismic load is expressed as a parabolic distribution. The design water level (EL. 96 ft. 8 in.) is considered in the calculation of hydrodynamic water pressure.

Application of Loads and Design Margins

These loads were applied to the exterior walls of all seismic Category I structures and the direction of the loads were toward inside of buildings below grade. Seismic Category I structures are designed to have sufficient margins for the maximum flood load based on the maximum flood elevation specified in DCD Tier 2, Table 2.0-1.

The staff considers the RAI response acceptable because it complies with regulatory guidance in SRP Sections 3.8.4.II.3 and 3.8.4.II.4. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-04, is resolved and closed.

Load Combinations

The load combinations are provided in DCD tier 2, Table 3.8-9A and Table 3.8-9B, “Seismic Category I Structures Structural Steel – Elastic Design Load Combination Table.” DCD Tier 2 Section 3.8.4, indicates that the design load combinations in DCD Tier 2 Table 3.8-9A are in accordance with the ACI 349-97, “Code Requirements for Nuclear Safety Related Concrete Structures,” supplemented by RG 1.142, and the design load combinations in DCD Tier 2 Table 3.8-9B, are in accordance with AISC N690-1994, “Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities,” including Supplement 2 (2004).

The staff reviewed the load combinations for the concrete and steel structures in the DCD and compared them to the guidance provided in SRP Section 3.8.4.II.3, “Load and Load Combinations,” which specifies loads and load combinations that are acceptable for the seismic Category I structures.

In DCD Tier 2, Section 3.8.4.3, “Loads and Load Combinations,” the staff identified items that need to be addressed to ensure that the correct loads and load combinations are used.

Therefore, the staff issued RAI 227-8274, Question 03.08.04-05 (ML15270A001), requesting the applicant to address the following, and if applicable, include this information in the DCD:

- a. In DCD Subsection 3.8.4.3.1, "Normal Loads," the applicant identified R_o as being applicable to pipe, cable tray, duct supports, and ties. This section indicates that this load includes their dead load, live load, thermal load, seismic load, thrust load, and unbalanced internal pressure under normal and severe environmental conditions.

The applicant is requested to explain why this definition is not consistent with the definition given in ACI 349 nor AISC N690, including Supplement 2. As an example, for ACI 349, R_o is applicable to piping and equipment (not limited to the four components given above). Also, it is applicable to normal and shutdown conditions excluding dead load and seismic load. The seismic load for piping and equipment should be under the load E_{ss} . A similar situation occurs for the definition of R_a in DCD Subsection 3.8.4.3.2, "Abnormal Loads."

- b. In DCD subsection 3.8.4.3.4, "Extreme Environmental Loads," the applicant identified the use of the 100-40-40 percent method which is described in ASCE 4, Subsection 3.2.7, as an alternative to the SRSS method. The applicant was requested to explain how the 100-40-40 method was implemented in the seismic analysis and design.
- c. In DCD subsection 3.8.4.3.4, "Extreme Environmental Loads," in Item 2, "Combination of SSE Loads," the applicant stated that the stresses due to seismic loads from different directions are combined by the SRSS method using the following expression; however, no expression is provided. The applicant was requested to provide the expression.
- d. In DCD Table 3.8-9A, the applicant identifies a load labeled as, "M=." The applicant was requested to clarify or correct this load condition.
- e. In Table 3.8-9B, the applicant identified a load "S." Since this load was not described in the DCD, the applicant was requested to define the load, "S."
- f. In Table 3.8-9B, the applicant used a load factor 1.33 for the construction and test load combinations (numbers 1 through 4). The applicant was requested to describe why a factor of 1.33 times the design strength was used.
- g. In Table 3.8-9B, the applicant did not provided footnote, "a," and footnote, "i," from Table Q1.5.7.1, "Load Combinations And Applicable Stress Limit Coefficients," in accordance with AISC N690-94, including Supplement 2. Applicant is to include footnote, "a," and footnote, "i," from Q1.5.7.1 in AISC N690-94, including Supplement 2.
- h. NRC DC/COL-ISG-7, "Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures," clarify the NRC's position on identifying winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of Seismic Category I structures. The applicant was requested to describe how the criteria of NRC DC/COL-ISG-7 were considered in the load combinations in Section 3.8.4.3.

In its response to RAI 227-8274, Question 03.08.04-05, (ML16225A559), the applicant stated the following:

- a. DCD subsection 3.8.4.3.1 d. and 3.8.4.3.2 c. for the definition of the R_o and R_a load will be revised as shown below and as given in Attachment 1 to the response.
 - Equipment, Pipe, cable, duct support and ties - (R_o)
 - Accident reactions of equipment, pipe, cable, duct supports and ties - (R_a)

ACI 349 and AISC N690 define a dead load (D) and seismic load (E_s or E_{ss}) for the piping and equipment loads respectively. These loads are distinguished from R_o and combined in the loading combinations. But In DCD Subsection 3.8.4.3.1 and 3.8.4.3.4, Dead load and Seismic Loads for the piping and equipment loads are not defined separately. These loads are included in R_o and are considered in each loading combination.

Even though these loads are not separated into D and E_s (or E_{ss}), since the load factor of R_o is equal to or larger than the dead load or seismic load factor (refer to DCD Tier 2, Table 3.8-9A) those results are equal to or more conservative than the ACI 349 or AISC N690 load combination results.

DCD Subsection 3.8.4.3.2, "Abnormal Loads," load R_a is the same situation as R_o .

- b. The earthquake responses for all three directions are combined simultaneously. There are two methods to combine the directional responses, the SRSS method and the 100-40-40 percent rule described in ASCE 4, Subsection 3.2.7.

For the analysis of seismic Category I structures of APR1400, the SRSS method was selected to combine the independent directional responses of the SSE in order to obtain the maximum seismic response for design. The 100-40-40 percent rule was used for the basemat analysis to combine independent directional loads from superstructures. Therefore, Subsection 3.8.4.3.4 and 3.8.5.3 will be revised as shown in Attachment 2 to the response.

- c. The equation for the SRSS method was unintentionally omitted from DCD Tier 2, Subsection 3.8.4.3.4. Therefore, Subsection 3.8.4.3.4 will be revised to complete the description regarding the SRSS method.
- d. This typo will be corrected to "Ma" as shown in Attachment 4 to the response.
- e. "S" represents stability load, and this load will be deleted from Table 3.8-9B of loading combinations.
- f. There is no provision in ASCE 37-02, "Design Loads on Structures during Construction," that allows for the one third increases in allowable stress. Therefore, Table 3.8-9B will be revised to have a load factor of 1.00 for items 1 through 4 in Table 3.8-9B, as shown in Attachment 6 to this response.

- g. Table 3.8-9B (2 of 2) will be revised to identify footnote, “a,” and footnote, “i,” in AISC N690.
- h. In the APR1400 design, the criteria of NRC DC/COL-ISG-7 are not considered in the load combinations in Section 3.8.4.3 (Refer to the response of RAI 126-8012, Question 02.03.01-04 (ML15295A494), but, extreme winter precipitation roof load may be considered as an extreme environmental load that does not occur with other extreme environmental loads (e.g., seismic, tornado and probable maximum flood loads) simultaneously, and seismic loads govern in most extreme environmental loading conditions.

The staff considers the applicant’s responses acceptable because they have resolved all the questions raised by the staff, are consistent with the industry codes ACI 349 and AISC N690, including Supplement 2, and are in accordance with SRP Section 3.8.4.II 3 and applicable RGs. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-05, is resolved and closed.

3.8.4.3.5 *Design and Analysis Procedures*

The staff reviewed the applicable design and analysis procedures applied for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.4.

In DCD Tier 2, Section 3.8.4.4, “Design and Analysis Procedures,” and Appendix 3.8A, “Structural Design Summary,” the applicant describes the design and analysis procedures for the other seismic Category I structures. The applicant identified the AB and EDGB block as seismic Category I structures. The applicant described that the EDGB block comprises two buildings, one that houses two additional generators (EDGB) and the other for the DFOT. Therefore, the applicant also identified the DFOT building as a seismic Category I structure. The design analyses of the AB and EDGB block, including their critical sections, are provided in DCD Tier 2, Sections 3.8A.2.4 and 3.8A.3.4. Furthermore, DCD Tier 2, Appendix 3.8A, Figures 3.8A-25, -26, -27, and -28, provide the locations of the critical sections in the AB at different elevations, and Figure 2.8A-53 provides the locations of the critical sections in the EDGB.

The AB and EDGB are composed of basemat foundations, rectangular walls, floor slabs, columns, and beams and are design for numerous loading conditions. In addition, they are designed to provide biological shielding and protection against tornado, hurricane, and turbine missiles.

The applicant described that the other seismic Category I structures were analyzed using computer modeling with ANSYS or GTSTRUDL codes for the loads and loading combinations described in DCD Tier 2 Section 3.8.4.3.

The applicant described that the other seismic Category I concrete structures were designed and analyzed per the requirements of ACI 349-97 Code with the exceptions delineated in RG 1.142. Other seismic Category I steel structures were designed per the requirements of AISC N690-94 using the allowable stress design method.

In DCD Tier 2, Section 3.8.4.1.3, "Spent Fuel Storage Rack" the applicant provided a general description of the spent fuel storage racks. In DCD Tier 2, Section 3.8.4.4, "Design and Analysis Procedures," the applicant described that the spent fuel storage rack is designed to withstand the seismic loads applied simultaneously in orthogonal directions. In DCD Tier 2, Section 3.8.4.5, "Structural Acceptance Criteria," the applicant described that the spent fuel storage rack meets the load combinations in DCD Tier 2, Table 3.8-9C, "Spent Fuel Storage Rack – Design Loading Combination Table," which is in accordance with SRP Section 3.8.4, Appendix D. However, the applicant did not reference DCD Tier 2, Section 9.1.2, "New and Spent Fuel Storage," in DCD Tier 2 Section 3.8.4, and vice-versa to provide an association between these sections. In addition, DCD Tier 2 Section 3.8.4, does not discuss the new fuel storage racks which are classified as seismic Category I and are also described in DCD Tier 2 Section 9.1.2. Therefore, the staff issued RAI 227-8274, Question 03.08.04-06 (ML15270A001), requesting that the applicant revise DCD Tier 2 Section 3.8.4, to also describe the new fuel storage racks and then revise DCD Tier 2 Section 3.8.4, and DCD Tier 2 Section 9.1.2, to cross reference each other to associate these sections.

In its response to RAI 227-8274, Question 03.08.04-06 (ML15352A041) the applicant stated, "[t]he DCD will be revised to include the description of the new fuel storage rack in DCD Tier 2, Subsections 3.8.4.1.3, 3.8.4.4, 3.8.4.5, and Table 3.8-9C. A cross reference between DCD Tier 2, Subsections 3.8.4 and 9.1.2 will be added."

The staff reviewed the applicant's response and considers it to be acceptable because it describes both the new and spent fuel storage racks, and provides a cross reference in the DCD between the two sections on fuel racks. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-06, is resolved and closed.

The re-analysis and design of new and spent fuel storage racks is addressed in SER Section 9.1.2.

SRP Section 3.8.4.II.4.H indicates that consideration of dynamic lateral soil pressures on embedded walls is acceptable if the lateral earth pressure loads are evaluated for the governing of the following three cases. The cases are: (1) lateral earth pressure equal to the sum of the static earth pressure plus the dynamic earth pressure calculated in accordance with ASCE 4-98, Section 3.5.3.2(2); (2) lateral earth pressure equal to the sum of the static earth pressure plus the dynamic earth pressure calculated using an embedded SSI/FEM analysis model; and (3) lateral earth pressure equal to the fraction of the passive earth pressure that is effectively mobilized, which is dependent on the relative magnitude of the wall displacements against the soil that may occur for a given wall configuration. For case (3), the analysis should include, as a minimum, the fraction of the passive earth pressure assumed in the stability calculations performed in accordance with SRP Section 3.8.5.

In DCD Tier 2, Section 3.8.4.4, "Design and Analysis Procedures," the applicant did not describe the analysis and design of below grade walls for lateral earth pressure loads. In DCD Tier 2, Section 3.8A.2.4.2, "Shear Walls," for the AB, the applicant states, "The exterior walls below the grade are designed to resist the worst-case lateral earth pressure loads (static and dynamic), soil surcharge loads, and loads due to groundwater. Lateral earth pressure equal to the summation of the static earth pressure plus the dynamic earth pressure is calculated in accordance with ASCE 4. The hydrodynamic effect of pure water is determined

based on the hydrodynamic formula suggested by Matuo and O'Hara." However, in DCD Tier 2, Section 3.8A.3.4.2, "Shear Walls," the applicant did not provide design and analysis procedures for the below grade walls of the EDGB and diesel fuel oil storage tank rooms.

Furthermore, in DCD Tier 2, Section 3.8.4.3.4, "Extreme Environmental Loads," the applicant stated, "For seismic Category I structures, E_s are the loads generated by the SSE. Hydrodynamic load and dynamic soil pressure are included in E_s ." However, it is not clear how the hydrodynamic load and dynamic soil pressure were included in loads generated by the SSE. The staff issued RAI 227-8274, Question 03.08.04-07 (ML15270A001), the staff requested that the applicant address the following, and include this information in the DCD:

- a. Describe how all walls below grade were analyzed and designed for dynamic lateral earth pressures for all structures, and if the approach was consistent with that described in SRP Section 3.8.4 II.4.H. If not, provide the basis for using the alternative approach. In addition, for the calculation of the hydrodynamic effect of pure water, determined based on the hydrodynamic formula suggested by Matuo and O'Hara, the formula used should be provided and the full reference designation for this, as well as any other references discussed in the DCD should be identified in the DCD.
- b. Provide how the hydrodynamic load and dynamic soil pressure were included in loads generated by the SSE.

In its response to RAI 227-8274, Question 03.08.04-07, (ML17011A334), the applicant stated the following:

- a. According to SRP Section 3.8.4 II.4.H, lateral earth pressure is considered by the following items.
 1. Exterior walls below grade in all structures were analyzed with consideration of the surcharge pressure, the static soil pressure, the dynamic earth pressure and the dynamic groundwater pressure. Lateral earth pressure was calculated by taking the sum of the static earth pressure plus the dynamic earth pressure calculated in accordance with ASCE 4-98.
 2. For the calculation of the hydrodynamic effect of pure water, dynamic groundwater pressure was calculated by using the equation suggested by Matsuo and O'Hara on Westergaard theory shown in "Principles of Soil Dynamics," by Braja M. Das.
 3. The fraction of the passive earth pressure assumed in the stability check should be considered in the NI common basemat analysis. In APR1400 basemat analysis, the passive earth pressure is not considered because the passive earth pressure effect is not used in overturning and sliding check for basemat stability.
 4. The lateral earth pressure equal to the sum of the static earth pressure plus the dynamic earth pressure calculated using an embedded SSI/FMA model will be checked.

- b. The hydrodynamic load and dynamic soil pressure were included in the abnormal/extreme environmental loading condition with seismic load. To consider the effect of seismic direction, the lateral earth load (hydrodynamic load and dynamic soil pressure) was added to the seismic load using the SRSS method. The sign of the seismic load was chosen both plus (+) and minus (-) to give the most severe loading combination. In other words, hydrodynamic load and dynamic soil pressure were included in the load combination according to the seismic load's sign. Therefore, Subsection 3.8.4 will be revised with this response.

The applicant further stated that it will perform the following additional steps:

1. The dynamic earth pressure profile applicable to the subsequent structural analysis based on the results from both SSI/SSSI analyses will be generated.
2. The dynamic earth pressure profile generated from SSI/SSSI analyses will be compared with the dynamic earth pressure profile determined in accordance with ASCE 4-98, Section 3.5.3.2 (2). If the dynamic earth pressure profile determined in accordance with ASCE 4-98, Section 3.5.3.2 (2) is governing, no further justification is needed. If the dynamic earth pressure profile generated from SSI/SSSI analyses is governing, the structural analysis will be performed considering the dynamic earth pressure profile generated from SSI/SSSI analyses.
3. If the dynamic earth pressure profile generated from SSI/SSSI analyses is governing, the structural design will be performed based on the member forces from the structural analysis considering the dynamic earth pressure profile generated from SSI/SSSI analyses to check the design margin of structures and re-design the structural members, if necessary.

The applicant submitted the analyses results to resolve this RAI on January 11, 2017. The SSI/SSSI analysis results had yielded higher soil pressure on walls than those from the ASCE 4-98 method previously used for the design of the walls. Therefore, the applicant redesigned the wall with these higher earth pressure and, used more reinforcement for the wall, as a result of these higher earth pressure. The staff finds that the applicant has used the higher earth pressure, obtained from the two methods (ASCE 4-98 and SSI/SSSI), to design its embedded walls, which is conservative, and thus acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-07, is resolved and closed.

Analysis of Structures

In DCD Tier 2, Section 3.8.4.4.1, "Analysis of Structures," the applicant described the analytical methodology performed to evaluate the structural integrity of AB subject to global loads. The applicant developed a detailed three-dimensional ANSYS FEM, which is shown in DCD Tier 2, Figure 3.8-23, "Finite Element Model for AB Global Structural Analysis." The model included all walls and floor slabs modeled with three-or four-node shell elements, and major structural beams and columns modeled with two-node beam elements. The applicant performed the equivalent static seismic analyses by applying the accelerations, obtained from seismic analysis of the AB model, at corresponding elevations to the FEM, and the results are combined using

the load combinations in DCD Tier 2 Section 3.8.4.3.6. For the EDGB block, DCD Tier 2 Section 3.8A.3.4.2, describes the design and analysis approach. The computer program ANSYS is used in a static analysis to evaluate the loadings. The staff considers the approach used for the AB and EDGB block to be acceptable because it is in accordance with industry practice and SRP Section 3.8.4.II.4.

Structural Design

Concrete Structures

In DCD Tier 2, Section 3.8.4.4.2.1, "Concrete Structures," the applicant described that other seismic Category I concrete structures are designed to the requirements of ACI 349-97, and RG 1.142. The applicant indicated that the requirements of special provisions for impulsive and impact effects from Appendix C of ACI 349, was applied for seismic Category I structures. The applicant indicated that the requirement of Appendix A of ACI 349, and ACI Report, ACI 349.1R, or computer analysis was applied to determine the forces and moments from temperature variations for the other seismic Category I structures. The applicant applied the requirement in Chapter 10 and Chapter 11 of ACI 349, for flexural and axial, and in-plane and out-of-plane shear loads, respectively. The applicant applied the requirement in Chapter 7 and Chapter 10 of ACI 349, to determine minimum reinforcement of sections. The applicant applied the requirement of Sections 21.5 through 21.7 of ACI 349, to design the lateral load resisting systems, concrete frames, concrete beams and columns. The applicant indicated that other seismic Category I concrete support anchorages conform to Appendix D of ACI 349-01, and the guidelines of RG 1.199. The staff considers the applicant's approach for concrete structural design acceptable because it is in accordance with and the applicable code and standard prescribed in SRP Section 3.8.4.II.4.

Steel Structures

In DCD Tier 2, Section 3.8.4.4.2.2, "Steel Structures," the applicant indicates that other seismic Category I steel structures including bolted connections are designed to the requirements of ANSI/AISC N690-94, including Supplement 2-04, and the welding activities are performed to the requirements of AWS D1.1, 2010. The staff finds the applicant's approach for steel structure design acceptable because it is in accordance with industry practice and SRP Section 3.8.4.II.4.

Missile Protection

As described in DCD Tier 2 Section 3.5, SSCs important to safety are required to be protected from internal and external missiles per the requirements of GDC 2 and 4 of Appendix A to 10 CFR Part 50. In DCD Tier 2, Section 3.8.4.4.2.3, "Missile Protection," the applicant described that the exterior walls and roof slabs of other seismic Category I structures were designed to withstand and absorb missile impact loads to avoid damage of safety-rated SSCs. Furthermore, the applicant described that when it is evaluated to be necessary, interior walls and floors were designed to function as missile barriers. The applicant described that the safety-rated SSCs are protected from secondary missiles and from back face scabbing. The staff considers the applicant's approach for missile protection design acceptable because it is in accordance with industry practice and SRP Section 3.8.4.II.4.

Flooding

In DCD Tier 2, Section 3.8.4.4.2.4 “Flooding,” the applicant indicated that flooding is addressed in DCD Tier 2 Section 3.4. SER Section 3.4 addressed the flooding associated with the design of structures in SER Section 3.8.4.

Wall/Floor Penetrations

Penetration sleeves usually consist of a pipe embedded in a concrete wall or concrete floor. The applicant stated that these penetration sleeves are designed in accordance with ACI 349 and AISC N690.

For rectangular openings in concrete walls or slabs, the applicant stated that reinforcement will be provided at each corner of the openings in accordance with ACI 349 Code.

The staff considers the applicant’s approach for wall/floor penetrations acceptable because it is in accordance with industry practice and SRP Section 3.8.4.II.4.

Embedment Plates

In DCD Tier 2, Section 3.8.4.4.2.6, “Embedment Plates,” the applicant described that the embedment plates are located throughout the plant to support various structures and components. The embedment plate anchorages to concrete are designed to ACI 349-97, including Appendix B (2001), and RG 1.199. The staff considers the applicant’s approach for embedded plate design acceptable because it is in accordance with industry practice and SRP Section 3.8.4.II.4.

Design Summary Report

In DCD Tier 2, Section 3.8.4.4.3, “Design Summary Report,” the applicant describes the critical sections of other seismic Category I structures of the AB and EDGB in DCD Tier 2, Appendix 3.8A.2 and 3.8.A.3, respectively.

In DCD Tier 2, Appendix 3.8A.2, “Auxiliary Building,” provides the analysis and design of the critical sections of AB.

In DCD Tier 2, Appendix 3.8A.3, “Emergency Diesel Generator Building,” provides the analysis and design of the critical sections of EDGB.

3.8.4.3.6 Structural Acceptance Criteria

The staff reviewed the applicable design and analysis procedures applied for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.5.

In DCD Tier 2, Section 3.8.4.5, “Structural Acceptance Criteria,” the applicant described the structural acceptance criteria of concrete and steel seismic Category I structures. The DCD describes that the concrete for other seismic Category I structures are designed according to ACI 349 -97 and RG 1.142. The DCD states that the steels for other seismic Category I

structures are designed according to the requirements of ANSI/AISC N690-94, including Supplement 2. Structural acceptance criteria for design strength and allowable stress for the concrete and steel members, respectively, of other seismic Category I structures are provided in DCD Tier 2, Tables 3.8-9A and 3.8-9B, respectively. The DCD also states that the concrete for other seismic Category I structures that are subjected to thermal effects conform to the provisions of ACI 349, Appendix A.

The DCD states that the structural acceptance criteria for spent fuel storage racks is performed in accordance with the Appendix D of SRP Section 3.8.4. Furthermore, the DCD requires that the minimum safety factors of sliding and overturning in DCD Table 3.8-9C, which are in accordance with SRP Section 3.8.4, Appendix D, be used for the spent fuel storage racks under the various load combinations including seismic loads.

The DCD did not provide any information in the structural acceptance criteria of using modular construction methods. The staff concluded that the APR1400 design does not have modular constructions, and therefore, the staff did not review such methods per the requirements provided in SRP Section 3.8.4.II.4.J.

The staff reviewed the structural acceptance criteria given in the DCD Tier 2 Section 3.8.4.5, as to their application to the concrete and steel seismic Category I structures and the spent fuel storage racks. The staff found the use of these structural acceptance criteria in the design and construction of the concrete and steel for other seismic Category I structures and the spent fuel storage racks for the APR1400 design to be in accordance with the guidance given in SRP Section 3.8.4.II.5 and Appendix D of SRP Section 3.8.4. On this basis, the staff concluded that the information provided in DCD Tier 2 Section 3.8.4.5, on the structural acceptance criteria is acceptable.

3.8.4.3.7 Materials, Quality Control, and Special Construction Techniques

The staff reviewed the applicable materials, quality control, and special construction techniques applied for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.6.

In DCD Tier 2, Subsection 3.8.4.6, "Materials, Quality Control, and Special Construction Techniques," the applicant describes the material, quality control programs, and special construction techniques for other seismic Category I structures.

Material

In DCD Tier 2, Section 3.8.4.6.1, "Material," the applicant describes the major materials used in the construction of other seismic Category I structures.

Concrete

In DCD Tier 2, Section 3.8.4.6.1.1, "Concrete," the applicant stated that the minimum concrete compressive strength in the other seismic Category I structures is 34.5 MPa (5000 psi) at 91 days with cement, fine aggregates, coarse aggregates, water and/or if required admixtures as basic elements of concrete. The applicant stated that the concrete conforms to ACI 349 and ASTM C94.

In DCD Tier 2, Section 3.8.4.6.1.1, the applicant specified that the COL applicant that refers to the APR1400 DCD shall determine the environmental condition associated with the durability of concrete structures and provide the concrete mix design to prevent concrete degradation caused by factors such as reactions of sulfate and other chemicals, the corrosion of reinforcing bars, and effects of reactive aggregates. The applicant identified this information in COL 3.8(3).

In DCD Tier 2, Section 3.8.4.6.1.1, the applicant described the ASTM requirements for cement, aggregate, water and admixtures.

The ingredient materials are stored in accordance with the recommendations in ACI 304R. Concrete mixes are designed in accordance with ACI 301. The batching, mixing, and transporting of concrete conform to ACI 301. The placement of concrete, consisting of preparation before placing, conveying, depositing, protection, and bonding is in accordance with ACI 301.

Reinforcing Steel

In DCD Tier 2, Section 3.8.4.6.1.2, "Reinforcing Steel," the applicant stated that the material of the reinforcing bars conform to ASTM A615, Grade 60 or ASTM A706, Grade 60. The applicant stated that the fabrication of reinforcing bars, including fabrication tolerances will be in accordance with CRSI, MSP-1. Furthermore, the applicant stated that placing of reinforcing bars, including field tolerances, concrete protection of reinforcement, spacing and splicing of bars is in accordance with ACI 349. The DCD also prescribes the use of epoxy coated reinforcing steel where corrosive environment is encountered.

Structural Steel

In DCD Tier 2, Section 3.8.4.6.1.3, "Structural Steel," the applicant stated that fabrication and erection of structural steel in other seismic Category I structures are design per the requirements of AISC N690-94, including Supplement 2. The applicant stated that the welding materials meet the requirements of the Structural Welding Code of AWS D1.1.

The applicant stated that the bolts used in structural steel connections conform to the standard material specifications of ASTM A325, A490 and A307. Furthermore, the applicant stated that bolts listed in AISC N690-94 could be used as well.

Stainless Steel

In DCD Tier 1 Section 3.8.4.6.1.4, the applicant stated that the stainless steel pool liner are fabricated from ASTM A240, Type 304 material. The applicant provided additional requirements in DCD Tier 2, Sections 3.8.3.6.3, "Stainless Steel Pool Liners," and 3.8.3.6.4, "Stainless Steel Other Than Pool Liners." The applicant described the welding procedures in DCD Tier 2 Section 3.8.3.6.3, which are in accordance with ASME Section III, Division 2, Subarticle CC-4540 and ASME Section IX. All seam welds are full-penetration butt welds. The liner plate seam welds are examined and tested as follows:

- a. Liquid penetrant examination is performed on austenitic materials. The weld surfaces and at least 12.7 mm (1/2 in.) of the adjacent base material on each side of the weld are examined. The examination coverage is 100 percent of all shop and field seam welds.

- b. Vacuum leak test is performed for leak-tightness on all liner plate seam welds.

Quality Control

In DCD Tier 2, Section 3.8.4.6.2, "Quality Control," the applicant stated that the quality of materials are controlled by mill test reports, which is provided by the suppliers, and is performed under appropriate ASTM standards as delineated in DCD Tier 2 Section 3.8.4.6.4. The applicant further stated that the mill test reports are reviewed and approved per the quality assurance program outlined in DCD Tier 2 Chapter 17, and supplemented by the provisions of the appropriate codes and specifications for design listed in DCD Tier 2 Section 3.8.4.2. The applicant stated that erection tolerances are in accordance with referenced design codes, and wherever special tolerances that influence the erection of equipment, they are indicated on the design drawings.

Special Construction Techniques

In DCD Tier 2, Section 3.8.4.6.3, "Special Construction Techniques," the applicant describes that no special construction techniques are used in the construction of other seismic Category I structures.

SRP Section 3.8.4.III.6, "Materials, Quality Control, and Special Construction Techniques," prescribes the review of any new quality control procedures or construction techniques to ensure that there will be no degradation of structural quality that might affect structural integrity.

In DCD Tier 2 Section 3.8.4.6.3, the applicant stated that the slab in AB will be constructed using in-place metal decks. The applicant further described in the second paragraph that "the corrosion protection of the AB reinforcing steel is provided by an adequate cover of high quality concrete over the reinforcing bar. Unless the concrete penetrated by chlorides or sulfide ions, the reinforcement bar remains passive and will not corrode." Based on this information, the staff issued RAI 227-8274 Question 03.08.04-08 (ML15270A001), requesting that the applicant address the following, and include this information in the DCD:

- a. Describe how to ensure that the concrete will be prevented from the penetration of chloride or sulfide ions.
- b. Provide a list of the slabs constructed using in-place metal deck in other seismic Category I structures.

In its response to RAI 227-8274, Question 03.08.04-08, (ML16006A121), the applicant stated the following:

- a. According to the ACI 349 Section 3, concrete to be exposed to chlorides shall conform to maximum water-cementitious material (w/cm) ratio of 0.40 and minimum compressive strength (f'c) of 5,000 psi. Also concrete to be exposed to very severe sulfate exposure shall conform to maximum w/cm ratio of 0.45 and minimum f'c of 4,500 psi.

Since the APR1400 concrete structures are built with concrete possessing maximum w/cm ratio of 0.4 and minimum f'c of 5,000 psi, it is ensured that the concrete will be prevented from penetration of chloride or sulfide ions. DCD Tier 2, Subsection 3.8.4.6.3 will be revised to this effect.

- b. Most concrete slabs in other seismic Category I structures are to be constructed using in-place metal deck that are supported by steel beams. In case of intermediate slabs which have insufficient room height and irregular shape slabs may be constructed using form and shoring as conventional method.

The staff considers the applicant's response acceptable, because they have followed the provisions of ACI 349. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-08, is resolved and closed.

In DCD Tier 2 Section 3.8.4.6.3 the applicant specified that the COL applicant that refers to the APR1400 DCD shall determine construction techniques to minimize the effects of thermal expansion and construction due to hydration heat, which could result in cracking of concrete. This information is identified in COL 3.8(4).

The staff reviewed the applicant's material, quality control and special construction techniques for other seismic Category I structures. The applicant described that the material, quality control, and special construction techniques are in accordance with the requirements of the ACI 349 and ASME Section III, Division 2 Codes and ASTM and AWS standards. The staff found that the use of ACI 349 and ASME Codes for the design and construction of the seismic Category I structures for the APR1400 is in accordance with the acceptance criteria given in SRP Section 3.8.4. On this basis, the staff concludes that the information provided in the DCD Tier 2 Section 3.8.4.6, is acceptable.

3.8.4.3.8 *Testing and Inservice Surveillance Requirements*

The staff reviewed the applicable testing and inservice inspection requirements used for the other seismic Category I structures to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.4.II.7.

In DCD Tier 2 Section 3.8.4.7, the applicant specified that the COL applicant that refers to the APR1400 DCD shall determine appropriate maintenance as necessary to monitor safety and serviceability of seismic Category I structures during the operation of the plant. This information is identified in COL 3.8(5).

SRP Section 3.8.4.II.7 provides guidance on testing and inservice surveillance requirements which indicates that, for seismic Category I structures, monitoring and maintenance requirements for structures are given in 10 CFR 50.65, RG 1.127, and RG 1.160.

DCD Tier 2 Section 3.8.4.7, states, "There is no testing or in-service surveillance beyond the quality control tests performed during construction, which is in accordance with ACI 349, AISC N690, or ANSI N45.2.5, in accordance with RG 1.127 and NUMARC 93-01. However, the COL applicant is to monitor the safety and serviceability of seismic Category I structures during the operation of the plant, and appropriate maintenance will be provided as necessary (COL 3.8(5) and COL 3.8(9))." The staff notes that DCD Tier 2, Section 3.8.4.2, "Applicable Codes, Standards and Specifications," refers to DCD Tier 2, Section 1.9, "Conformance with Regulatory Criteria," where Table 1.9-2, "APR1400 Conformance with Regulatory Guides," indicates that RG 1.127 and RG 1.160, are "N/A" under the column heading "DCD Tier 2, Section." For the

structures within the scope of DC, the DCD should describe the testing and inservice inspection requirements even though these will be implemented by the COL applicant under COL 3.8(5).

Therefore, the staff issued RAI 227-8274, Question 03.08.04-09 (ML15270A001), requesting the applicant describe the testing and inservice inspection requirements including extent of compliance with 10 CFR 50.65, RG 1.160, and RG 1.127. Unless otherwise justified, these RGs are applicable to the testing and inservice inspection requirements for seismic Category I structures, and thus they should be included in the various applicable Sections of the DCD.

In its response to RAI 227-8274, Question 03.08.04-09, (ML16110A463) the applicant stated the following:

A description of the testing and inservice inspection requirements, including complying with 10CFR 50.65 and RGs 1.127 and 1.160, will be added to DCD Tier 2, Subsection 3.8.4.7 and the corresponding Combined License Information item will be revised as shown below:

For other seismic Category I structures outside containment, the structures monitoring and maintenance requirements program is to be in accordance with 10 CFR 50.65 and RG 1.160.

The structures are monitored in accordance with Paragraph (a)(2) of 10 CFR 50.65, provided there is not significant degradation of the structures. The condition of all structures is assessed periodically. The appropriate frequency of the assessments is commensurate with the safety significance of the structures and their condition.

For water control structures, the inservice inspection program is to be in accordance with RG 1.127. Water control structures covered by this program include concrete structures, embankment structures, reservoirs, cooling water channels and canals, intake and discharge structures, and safety and performance instrumentation.

It is important to accommodate inservice inspection of critical areas. Monitoring and maintaining the condition of the other seismic Category I structures is essential for plant safety. Special design provisions (e.g., providing sufficient physical access, providing alternative means for identification of conditions in inaccessible areas that can lead to degradation, remote visual monitoring of high-radiation areas) to accommodate inservice inspection of other seismic Category I structures is provided on a case-by-case basis.

For plants with nonaggressive ground water/soil, (i.e., pH>5.5, chlorides < 500 ppm, sulfate < 1,500 ppm), an acceptable program for normally inaccessible, below-grade concrete walls and foundations is to examine the exposed portion of below-grade concrete, when excavated for any reason, for signs of degradation, and to conduct periodic site monitoring of ground water chemistry to confirm that the ground water remains non-aggressive.

For plants with aggressive ground water/soil, (i.e., exceeding any of the limits noted above), an acceptable approach is to implement a surveillance program to monitor the condition of normally inaccessible, below-grade concrete for sign of degradation.

Therefore, for safety and serviceability of seismic Category I structures during the operation of the plant, the COL applicant is to provide appropriate testing and inservice inspection programs to examine the condition of normally inaccessible, below-grade concrete for signs of degradation and to conduct periodic site monitoring of ground water chemistry. Inservice inspection of the accessible portion of concrete structures is also to be performed. (COL 3.8(5)).

The staff considers the applicant's responses acceptable because they are in accordance with 10 CFR 50.65, SRP Section 3.8.4.II.7, and RG 1.160. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 227-8274, Question 03.08.04-09, is resolved and closed.

3.8.4.4 Combined License Information Items

DCD Tier 2, Section 3.8.4, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.8.4 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 1.9(1)	The COL applicant is to provide an evaluation of the conformance with the regulatory criteria for the site-specific portions and operational aspects of the facility.	1.9
COL 2.4(1)	The COL applicant is to provide the site-specific hydrologic information on probable maximum precipitation (PMP), probable maximum flood (PMF) of streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami hazards, ice effects, cooling water canals and reservoirs, channel diversions, flood protection requirements, low water considerations, groundwater, potential accidental release of liquid effluents in ground and surface water, and Technical Specifications and emergency operation requirements in accordance with RG 1.206, RG 1.59, and NRC JLD-ISG-2012-06.	2.4
COL 3.8(5)	The COL applicant is to provide the design of site-specific seismic Category I structures, such as the essential service water building and the component cooling water heat exchanger building, essential service water conduits, component cooling water piping tunnel, and class IE electrical duct runs.	3.8.4
COL 3.8(6)	The COL applicant is to evaluate any applicable site-specific loads, such as explosive hazards in proximity to the site, projectiles and missiles generated from activities of nearby military installations, potential non-terrorism-related aircraft crashes, and the effects of seiches, surges, waves, and tsunamis.	3.8.4.3
COL 3.8(8)	The COL applicant is to determine the environmental condition associated with the durability of concrete structures and to provide the concrete mix design that prevents concrete degradation	3.8.4.6.1.1

	including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.	
COL 3.8(9)	The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.	3.8.4.6.3
COL 3.8(10)	For safety and serviceability of seismic Category I structures during the operation of the plant, the COL applicant is to provide appropriate testing and inservice inspection programs to examine the condition of normally inaccessible, below-grade concrete for signs of degradation and to conduct periodic site monitoring of ground water chemistry. Inservice inspection of the accessible portion of concrete structures is also to be performed.	3.8.4.7
COL 3.8(12)	The COL applicant is to provide reasonable assurance that the design criteria in Table 2.0-1 are met or exceeded.	3.8.5.5
COL 3.8(16)	The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation to monitor groundwater chemistry.	3.8.5.4

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 other seismic Category I structures.

3.8.4.5 Conclusion

The staff reviewed DCD Tier 2 Section 3.8.4, to determine whether the design, fabrication, construction, testing, and ISI of other seismic Category I structures comply with 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5. The staff concludes that, the applicant meets the relevant requirements of 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5. The basis for this conclusion is summarized below.

- The applicant meets the requirements of 10 CFR 50.55a and GDC 1, to ensure that the other seismic Category I structures are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed, by meeting the guidelines in SRP Section 3.8.4; RG 1.69, RG 1.127, RG 1.142, RG 1.143, RG 1.160, RG 1.199, RG 1.136, and RG 1.221; ACI 349-97 with additional guidance provided by RG 1.142 and RG 1.199; and ANSI/AISC N690-94, including Supplement 2 (2004).
- The applicant meets the requirements of GDC 2 to ensure that the other seismic Category I structures are able to withstand the most severe natural phenomena, by analyzing and designing these structures to withstand the most severe earthquake, wind, tornado, and external flood loads that have been established for the APR1400 certified design.

- The applicant meets the requirements of GDC 4 to ensure that the other seismic Category I structures are appropriately protected against other dynamic effects, by analyzing and designing these structures, where applicable, to withstand the dynamic effects due to pipe whipping, missiles, and discharging fluids associated with the LOCA.
- The applicant meets the requirements of GDC 5 to ensure that SSCs are not shared between units or that sharing will not impair their ability to perform their intended safety functions, since this DC is for only one unit.
- The applicant meets the requirements of 10 CFR Part 50, Appendix B, to provide a quality assurance program for the design, construction, and operation of SSCs, by meeting the guidelines in SRP Section 3.8.4; RG 1.69, RG 1.127, RG 1.142, RG 1.143, RG 1.160, RG 1.199, and RG 1.221; ACI 349-97 with additional guidance provided by RG 1.142 and RG 1.199; and ANSI/AISC N690-94, including Supplement 2 (2004).

The use of these criteria, as defined by applicable codes, standards, and guides; loads and loading combinations; design and analysis procedures; structural acceptance criteria; materials, quality control programs, and special construction techniques; and testing and inservice surveillance requirements provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes and various postulated accidents occurring within and outside the seismic Category I structures, the seismic Category I structures will withstand the specified conditions without impairment of their structural integrities or safety functions

3.8.5 Foundations

3.8.5.1 Introduction

DCD Tier 2 Section 3.8.5, "Foundations," describes the foundations for seismic Category I structures. The common basemat for the NI, that includes the reactor containment building (RCB) and auxiliary building (AB), is described in this section. For the EDGB block, two independent basemats of the EDGB and diesel fuel oil tank (DFOT) are also described in this section. Additional information is provided in DCD Tier 2 Appendix 3A, where a summary of the structural design for the foundations of seismic Category I structures is provided.

3.8.5.2 Summary of Application

DCD Tier 2, Section 3.8.5, "Foundations," of the DCD describes the following information on the foundations of seismic Category I structures.

- Description of the Foundations
- Applicable Codes, Standards, and Specifications
- Loads and Load Combinations
- Design and Analysis Procedures
- Structural Acceptance Criteria

- Material, Quality Control, and Special Construction Techniques
- Testing and Inservice Inspection Requirements

DCD Tier 1: The Tier 1 information associated with this section is presented in DCD Tier 1, Sections 2.2.1, and 2.2.2, “Emergency Diesel Generator Building.”

ITAAC: DCD Tier 1, Tables 2.2.1-2, “Nuclear Island Structures ITAAC,” and 2.2.2-2, “Emergency Diesel Generator Building ITAAC,” provide ITAAC items for seismic Category I structures.

DCD Tier 2: The applicant provided a description of foundations in DCD Tier 2 Section 3.8.5, which includes information on the physical layout, design, construction, and inspection.

Technical Specifications: There are no technical specifications described in DCD Tier 2, Chapter 16 that is specifically associated with DCD Tier 2 Section 3.8.5. However, DCD Tier 2, Chapter 16, Section B 3.6, “Containment Systems,” requires the containment with its steel liner to maintain a leak tight barrier. This is achieved by the overall leakage rate testing described under DCD Tier 2, Chapter 16, Section 3.6.1, “Containment.”

Technical Report: The technical report associated with DCD Tier 2 Section 3.8.5, is APR1400-E-S-NR-14006, Revision 1, “Stability Check for NI Common Basemat,” and Appendix A, “Stability Evaluation of EDGB Basemat and DFOT Basemat.” This report provided stability evaluations and construction sequence analysis of the common basemat.

Crosscutting Requirements (Three Mile Island [TMI], Unresolved Safety Issue/ [USI]/Generic Safety Issue [GSI], Operating Experience [Op Ex]): There are no cross-cutting regulatory requirements for this area of review.

APR1400 Interface Issues Identified in the DCD: DCD Tier 2, Table 1.8-2 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.

3.8.5.3 *Regulatory Basis*

The relevant requirements of the Commission’s regulations for this area of review, and the associated acceptance criteria are given in SRP Section 3.8.5, “Foundations,” Revision 4, and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 3.8.5.

- Section 50.55a of 10 CFR and GDC 1 of Appendix A, to 10 CFR Part 50, as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

- GDC 2, as it relates to the capability of safety-related structures to perform their safety function, to withstand the effects of natural phenomena, such as earthquakes, wind, tornadoes, hurricanes, floods, and the appropriate combination of all loads.
- GDC 4, as it relates to the protection of safety-related structures against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.
- GDC 5, as it relates to safety related structures not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.
- Part 50 of 10 CFR, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants,” as it relates to the quality assurance criteria for nuclear power plants.
- Section 52.47(b)(1) of 10 CFR, which requires that a DC application contain the proposed ITAACs 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 facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act of 1954, and the Commission’s rules and regulations.

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

- RG 1.127, “Inspection of Water Control Structures Associated with Nuclear Power Plants,” issued February 2016.
- RG 1.136, “Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments,” Revision 3, issued March 2007.
- RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments),” Revision 2, issued November 2001.
- RG 1.199, “Anchoring Components and Structural Supports in Concrete,” issued November 2003.
- RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” Revision 3, issued May 2012.
- RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” issued June 2007.
- RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,” issued October 2011.

3.8.5.4 *Technical Evaluation*

The staff reviewed DCD Tier 2 Section 3.8.5, "Foundations," to ensure that the DCD Tier 2 application represents the complete scope of information relating to this review topic. SRP Section 3.8.5, identifies seven specific SRP acceptance criteria for meeting the relevant requirements of the NRC's regulations listed in SRP Section 3.8.5.II and included in SER Section 3.8.5.3. This section evaluates DCD Tier 2 Section 3.8.5, with regard to the seven SRP acceptance criteria.

SRP Section 3.8.5, provides guidance for reviewing the technical areas related to the design of foundations based on the requirements of 10 CFR Part 50, Appendix A GDC 1, 2, 4, and 5; 10 CFR Part 50, 50.55a, and Appendix B; and 10 CFR 50.47(b)(1). The technical areas reviewed include: (a) description of the foundations; (b) applicable codes, standards, and specifications; (c) loads and load combinations; (d) design and analysis procedures; (e) structural acceptance criteria; (f) materials, quality control, and special construction techniques; and (g) testing and inservice surveillance requirements. The staff also reviewed applicable COL information items.

3.8.5.4.1 *Description of Foundations*

The staff reviewed the descriptions of the foundations to ensure that they contain sufficient information to define the primary structural aspects and elements that are relied upon to perform the safety related functions of these structures. The primary function of a foundation is to transmit the loads imposed by the superstructure to the underlying supporting media, rock, or soil. The staff's review also ensures that the foundation design meets the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.1.

In DCD Tier 2, Section 3.8.5.1, "Description of Foundation," the applicant described the physical and functional characteristics of the reinforced concrete basemats of the NI, and independent reinforced concrete basemats of the EDGB and DFOT building for the APR1400 plant. The NI is a common basemat for the RCB and AB.

SRP Section 3.8.5, Section I.1.A, "Containment Structure Foundation," indicates that in prestressed concrete containments with a tendon inspection gallery, the staff's review includes the arrangement of the gallery and means of either isolating it from the remainder of the base slab or relying on it for some function, such as resisting shears. SRP Section 3.8.5.II.4.1, indicates that a detailed explanation of the load path from all superstructures to the mat foundation to the subgrade be provided. However, in DCD Tier 2, Section 3.8.5.1, "Description of Foundations," the applicant did not describe the tendon gallery and its safety-related function. Furthermore, in DCD Tier 2, Section 3.8.5.4, "Design Analysis Procedures," the applicant did not provide a description of the analysis and design approach used for the tendon gallery. Therefore, the staff issued RAI 255-8285, Question 03.08.05-2, (ML15293A569) requesting that the applicant describe the tendon gallery, any safety-related function that the tendon gallery may have as part of the foundation in a prestressed containment and its supporting foundation, as well as applicable loads and load combinations, and analysis and design approach in the APR1400 foundation design.

In its response to RAI 255-8285, Question 03.08.05-2, (ML16036A129), the applicant described that a hollow rectangular toroid tendon gallery is located entirely within the NI common basemat as shown in DCD Tier 2, Figures 3.8-1, "Typical Section of Containment Structures (Looking North)," and 3.8-2, "Typical Section of Containment Structures (Looking East)." The tendon gallery provides a space to install and inspect the inverted "U" shaped vertical tendons. The applicant further described that the tendon gallery was analyzed, and was designed as a part of the common basemat. The codes and standards, loads and load combinations, design and analysis procedures, and structural materials for the tendon gallery are the same as those for the NI common basemat, and are also described in DCD Tier 2, Sections 3.8.5.2 through 3.8.5.4, 3.8A.1.2.1, 3.8A.1.2.3, and 3.8A.1.4.2.2 through 3.8A.1.4.2.4. The applicant described that the analysis model, design section forces and design results of the NI common basemat, including the tendon gallery, were provided in DCD Tier 2, Tables 3.8A-5 through 3.8A-13, and Figures 3.8A-13 through 3.8A-17. The applicant also referred to DCD Tier 2, Figures 3.8A-16 and 3.8A-17, and Table 3.8A-12, for identifying and listing the flexural reinforcement around the tendon gallery. In its response, the applicant also committed to incorporate this information in DCD Tier 2, Section 3.8A1.4.2.1, "Description."

Based on the review, the staff finds the response acceptable because the applicant provided the description, analysis, and design information and associated figures regarding the tendon gallery in accordance with SRP Section 3.8.5.II.4.I guidance. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-2, is resolved and closed.

SRP Section 3.8.5, Section I.1.A, "Containment Structure Foundation," indicates that if shear keys are used for transferring horizontal shears, the review should address the general arrangement of the keys. However, in DCD Tier 2, Section 3.8.5.I.1, "Description of Foundations," the applicant did not provide any description of the shear keys below the containment foundation. Therefore, the staff issued RAI 255-8285, Question 03.08.05-3 (ML15293A569), requesting that the applicant provide a description of the foundation shear keys and the analysis and design approach, as well as to include this information in DCD Tier 2 Section 3.8.5.

In its response to RAI 255-8285, Question 03.08.05-3 (ML16036A129), the applicant described that APR1400 has a structural mat foundation, referred to as the common basemat for the RCB and AB, and the bottom of the common basemat is not flat; the thickness of the mat varies, as shown in Figure 1-2, "APR1400 NI Common Basemat Section View – E-W View," and Figure 1-3, "APR1400 NI Common Basemat Section View – N-S View," of APR1400-E-S-NR-14006, Revision 1. The applicant further described that, in the stability check for sliding resistance of the basemat, the basemat friction force was considered to resist the sliding of the common basemat only, and the effects of the shear keys were conservatively neglected. However, the applicant described that the shear key areas, as shown in Figure 3-5, "Basemat Structural Analysis FE Model," of the APR1400-E-S-NR-14006, Revision 1, were modeled using ANSYS, analyzed and designed as a part of the basemat. The applicant also describe that the foundation of the DFOT room is an underground structure with two sump parts, as shown in Figure A-2, "Plant View of DFOT Room," and Figure A-3, "Elevation View of DFOT Room," of APR1400-E-S-NR-14006, Revision 1. The sump parts of the DFOT, as shown in Figure A-5, "FE Model for DFOT," APR1400-E-S-NR-14006, Revision 1, were modeled using ANSYS, analyzed and designed. However, the shear key effect of the sump parts was conservatively neglected in the sliding check.

In its response, the applicant provided a description of the variation in basemat thickness of the RCB and AB which includes the shear keys, as well as the analysis and design approach for the effects of these differences in thickness. The applicant further considered and modeled the variations in thickness of the basemat in the analysis and design of the basemat. In the case of sliding stability analysis, neglecting the effect of the convex (shear key) areas is conservative. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-3, is resolved and closed. In addition, the staff confirmed that the "Siding Acceptance Criteria," as shown in the attachment to the applicant's response to RAI 255-8285, Question 03.08.05-14, was incorporated into the DCD.

SRP Section 3.8.5, Section I.1.A, "Containment Structure Foundation," states, "If waterproofing membranes are used, the review addresses their effect on the shear resistance of the foundation." In DCD Tier 2, Section 3.8.5.1.1, "Description of Foundations," the applicant did not provide any description whether waterproofing membranes are used. Therefore, the staff issued RAI 255-8285, Question 03.08.05-4 (ML15293A569), requesting that the applicant provide a description whether waterproofing membranes are used in APR1400 design, and if used, provide their effects on the containment and NI common basemats.

In its response to RAI 255-8285, Question 03.08.05-4 (ML17026A463), the applicant stated that the waterproofing membranes will be used for the exterior horizontal and vertical surfaces of seismic Category I structures in APR1400 design. The applicant also provided figures showing a typical detail for installation of the waterproofing membranes. The applicant provided markups for DCD Tier 2, Section 3.8.5.1, "Description of the Foundations," and Figure 3.8-27, "Typical Detail for Installation of Waterproofing Membrane," to indicate that the waterproofing membranes will be used for exterior horizontal and vertical surfaces of structures and will be installed between the lower and upper lean concrete beneath the basemat. The COL applicant is to verify that the coefficient of friction (CoF) between the lean concrete and waterproofing membrane is equal to or greater than 0.55 (COL 3.8(13)). The applicant also provided COL 3.8(14) which indicates the COL applicant is to verify the CoF between the lean concrete and supporting medium at the site is equal to or greater than 0.55 and referred to DCD Tier 2 Figure 3.8-17, depicting the typical installation details of waterproofing membrane. The staff also noted that RAI 255-8285, Question, 03.08.05-14, discussed below in this SER, addresses the determination of the governing CoF value between the various potential sliding interfaces and the sliding evaluation of the NI common basemat.

In its response, the applicant provided markups to DCD Tier 2, Section 3.8.5.1, Figure 3.8-17, COL 3.8(13), and COL 3.8(14), to incorporate detailed requirements for CoF and installation details waterproofing membrane. Based on staff's review, all of the markups are acceptable because the applicant is including waterproofing membranes on the exterior horizontal and vertical surfaces of seismic Category I structures, has identified this in DCD Tier 2, and also included the CoF criteria in COL information items to ensure that the site specific conditions are consistent with those used in the design calculations. Therefore, the staff finds the response to RAI 255-8285, Question 03.08.05-4, acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-4, is resolved and closed.

The applicant presented an overview of its seismic analysis approach of the APR1400 structure to the staff on October 5, 2015. During the presentation, the applicant stated that 3-foot lean concrete will be placed beneath the bottom of the basemat and that the lean concrete is

classified as a non-safety related structure. The staff reviewed DCD Tier 2 Section 3.8, along with APR1400-ES-NR-14006, Revision 1, and noted that the applicant did not provide any description on the use of lean concrete in its design of the APR1400. Therefore, the staff issued RAI 320-8383, Question 03.08.05-19 (ML15328A503), requesting that the applicant describe in detail the following:

- a. design criteria for the lean concrete,
- b. how the lean concrete is used in the soil-structure-interaction analysis model,
- c. whether the lean concrete will be considered a seismic Category I structure,
- d. whether the lean concrete will be 0.91 m (3 ft.) thick throughout the NI, and why is it 0.91 m (3 ft.), and
- e. whether the lean concrete is reinforced.

The staff also requested the applicant to update the applicable portion of DCD Tier 2 Section 3.8, and the technical report, accordingly.

In its response to RAI 320-8383, Question 03.08.05-19 (ML16203A452), with an enclosure (ML16203A454), the applicant described that DCD Tier 2 Section 3.8.5, and APR1400-E-S-NR-14006, Revision 1, provide methodologies and results of structural analysis and design for basemats of seismic category I structures above the lean concrete. Information regarding the lean concrete will be provided in applicable sections of DCD Tier 2, and the technical report as discussed below.

- a. In its response, the applicant provided the properties for the lean concrete as follows: compressive strength of 2,000 psi, a Poisson's ratio of 0.17, and a density of 0.137 kcf. The applicant further described that DCD Tier 2, Section 2.5.4.5 will be revised to state the required compressive strength, as indicated in the attachment associated with this response. The required Poisson's ratio and density are presented in Table 5-2 of APR1400-E-S-NR-14003, "SSI Analysis Methodology and Results of NI Buildings." The applicant response included calculations of in-plane shear strength at the surface of lean concrete based on the ACI 318, and determination that the lean concrete has enough strength to resist base shear and transfer it to the ground. Furthermore, the applicant calculated average bearing pressures under static loading case (Dead + Live) for soil profiles of S1, S4 and S8 (weak, moderate and strong) as 0.508 MPa (10.6 ksf), 0.528 MPa (11.03 ksf), and 0.537 MPa (11.21 ksf), respectively. These values are much less than the lean concrete compressive strength.

Based on the review of this information, the staff concluded that the applicant's response addressed the question of the design criteria of lean concrete. The applicant provided the physical properties of the lean concrete (strength, Poisson's ratio, density), and design criteria. The staff also recognized that the lean concrete is considered to be a replacement of the excavated soil, and thus is not a structural member. Therefore, it is reviewed as part of DCD Tier 2, Section 2.5, "Geology, Seismology, and Geotechnical Engineering." Regarding the strength to transfer the shear load to the soil, the layer of the lean concrete is considered to be stronger than the soil that it replaces. In addition, the applicant performed a calculation based on ACI 318 Code, which showed the shear

strength of the lean concrete is greater than the shear force demand. Regarding the bearing pressure beneath the NI basemat, the minimum allowable static and dynamic bearing demands from DCD Tier 1, are less than the bearing strength of the lean concrete. Based on the above discussion, the use of lean concrete is acceptable for meeting the shear force and bearing pressure demands. Therefore, item "a," in RAI 320-8383, Question 03.08.05-19, is resolved and closed.

- b. The applicant responded that Section 6.4, "Bottom Lean Concrete and Side Soil Backfill with SFG," of the APR1400-E-S-NR-14002, Revision 0, "Finite Element Seismic Models for SSI Analyses of the NI Buildings," describes the three feet of lean concrete backfill as being modeled between the bottom of the basemat and the top surface of soil below the excavation. ACS SASSI solid elements are used to model the lean concrete. The applicant further described that the APR1400-E-S-NR-14002, Revision 0, Section 6.4, "Bottom Lean Concrete and Side Soil Backfilled with structural fill granular (SFG)," will be revised, as indicated in the attachment associated with this response.

Based on the review of this information, the staff finds the response to item "b," in RAI 320-8383, Question 03.08.05-19, acceptable because the applicant provided an explanation of how the lean concrete under the basemat was modeled using ACS SASSI solid elements, and Section 6.4 "Bottom Lean Concrete and Side Soil Backfilled with SFG," in APR1400-E-S-NR-14002, Revision 0, will be revised to incorporate this information. The acceptability of this approach is reviewed separately in SER Section 3.7.2. Based on the review of the DCD and APR1400-E-S-NR-14002, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, item "b," in RAI 320-8383, Question 03.08.05-19, is resolved and closed.

- c. The applicant responded that the three feet of lean concrete backfill is used for all seismic Category I structures. DCD Tier 2, Section 2.5.4.5, "Excavations and Backfill," Section 2.5.6, "Combined License Information," and the associated DCD Tier 2 Table 1.8-2, will be revised to state three feet of lean concrete backfill is used for all seismic Category I structures.

Based on the review, the staff finds the response to item "c," in RAI 320-8383, Question 03.08.05-19, acceptable because the applicant response indicated that all seismic Category I structures will use the 3 foot concrete backfill and the markups provided are consistent with this statement. Also, as discussed under item "a," above, the lean concrete is considered to be a replacement of the excavated soil, and thus is not a structural member. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, item "c," in RAI 320-8383, Question 03.08.05-19, is resolved and closed.

- d. The applicant responded that the three foot thickness is consistent throughout the seismic soil structure interaction (SSI) model. Since the APR1400 standard design considers nine generic soil profiles, including soft soil conditions, the inclusion of three feet of lean concrete below the basemat of the seismic Category I structures is selected based on consideration of the worst soil conditions of other previously-constructed nuclear power plant(s).

Based on the review, the staff finds the response to item “d,” in RAI 320-8383, Question 03.08.05-19 acceptable because the applicant considered 0.91 m (3 ft.) of lean concrete in the analysis and design of APR1400 throughout the basemat, and committed to revise APR1400 Tier 2, Section 2.5.4.5, “Excavation and Backfill,” and COL 2.5(11) to describe that a layer of approximately 0.91 m (3 ft.) thick lean concrete with minimum concrete strength of 140 kg/cm² (2,000 psi) be backfilled between the bottom of the basemat and the top surface of soil. Furthermore, the staff recognized that the use of 0.91 m (3 ft.) of lean concrete is a decision made by the applicant to consider poor soil conditions that might have to be excavated. If a particular site has to be excavated deeper than 0.91 m (3 ft.), then this would require a site-specific evaluation. Therefore, the staff considers item “d,” resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, item “d,” in RAI 320-8383, Question 03.08.05-19, is resolved and closed.

- e. The applicant responded that the lean concrete is not considered as a structural member and will not have any reinforcement. Based on the review, the staff concluded that this item was addressed as part of items “a,” “b,” and “c,” above; and therefore, the staff considers the response acceptable.

In summary, all of the items in RAI 320-8283, Question 03.08.05-19, are resolved since the applicant incorporated its responses in the DCD for Section 2.5.4.5, “Excavation and Backfill,” Section 2.5.6, “Combine License Information,” Table 1.8-2, “Combine License Information Items,” Section 3.8.6 “Combine License Information.” In addition, the staff confirmed that the applicant incorporated its responses in Section 6.4, “Bottom Lean Concrete and Side Soil Backfilled with SFG,” of TR APR1400-E-S-NR-14002, Revision 2. Therefore, RAI 320-8383, Question 03.08.05-19, is resolved and closed.

The descriptive information and referenced figures in the DCD Tier 2, Section 3.8.5.1, “Description of the Foundation,” contain sufficient detail to define the foundations of the RCB and the other seismic Category I structures to perform their safety related functions. The staff finds the description of the foundations of the RCB and the other seismic Category I structures in DCD Tier 2 Section 3.8.5.1, to be acceptable on the basis that they are consistent with SRP Section 3.8.5.1 and RG 1.206 acceptance criteria.

3.8.5.4.2 *Applicable Codes, Standards, and Specifications*

The staff reviewed the applicable codes, standards and specifications used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.2.

In DCD, Tier 2, Section 3.8.5.2, “Applicable Codes, Standards, and Specifications,” the applicant indicated that DCD Tier 2, Section 3.8.1.2 describes the applicable codes, standards, and specifications for the foundation of RCB. Therefore, SER Section 3.8.1.4.2, contains the staff’s evaluation of referenced codes, standards, and specifications of the foundations of RCB. Furthermore, DCD Tier 2 Section 3.8.5.2, indicates that DCD Tier 2 Section 3.8.4.2, describes the applicable codes, standards, and specifications for the foundations of other seismic Category I structures. Therefore, SER Section 3.8.4.4.2, contains the staff’s evaluation of

referenced codes, standards, and specifications of the foundations of other seismic Category I structures.

SRP Section 3.8.5, Section II.2, “Applicable Codes, Standards, and Specifications,” refers to SRP Section 3.8.1, Section II.2, and SRP Section 3.8.4, Section II.2, for the applicable codes, standards, and guidance that apply to seismic Category I foundations. However, in Figure 3-11, “Justification Boundary for Design of NI Common Basemat,” in APR-E-S-NR-14006, Revision 1, the applicant indicated that the applicable codes for the containment basemat is ASME Section III, Division 2, 2001, Edition through 2003 Addenda, and for the AB portion of the NI basemat is ACI 349-97. Since both structures are on a common basemat, it was not clear to the staff whether the applicant performed a comparative study between the two design codes to determine the differences in the loads and load combinations. Therefore, the staff issued RAI 255-8285, Question 03.08.05-5 (ML15293A569), requesting that the applicant describe whether a comparative study was performed of the loads and load combinations between ASME Section III, Division 2, 2001, Edition through 2003 Addenda, and ACI 349-97, to determine the differences.

In its response to RAI 255-8285, Question 03.08.05-5 (ML16036A129), the applicant described that each code has different philosophies and design methods as well as different loads and load combinations, and concluded that it is difficult to identify which code is always conservative or always produces adverse design results. However, the applicant referred to the response of RAI 199-8223, Question 03.08.01-11, for the code application scope and jurisdiction boundary of the NI common basemat. The staff’s evaluation of the code jurisdiction and design of the NI common basemat considering the use of two different codes for the NI basemat is presented in SER Section 3.8.1.4.3.

Based on the review, the staff finds the response to RAI 255-8285, Question 03.08.05-5, acceptable because the applicant stated in the RAI 199-8223, Question 03.08.01-11, response that the AB foundation area was conservatively designed using the larger member forces from the analysis results of the ASME Code and ACI 349, and at the interface between the RCB and the AB, the larger amount of reinforcement required by either code is used. Furthermore, the applicant committed to revise DCD Tier 2, Section 3.8.5.3, “Loads and Load Combinations,” to describe the design approach for the foundations considering the use of the two codes.

The applicant updated DCD Tier 2, Section 3.8.5.3, “Load and Load Combinations.” In this section, the applicant correctly referred to DCD Tier 2 Table 3.8-9A, reinforced concrete, ultimate strength design load combination for seismic Category I structures, excluding containment structure.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-5, is resolved and closed.

The staff reviewed the codes, standards, and specifications given in the DCD Tier 2, Sections 3.8.1.2 and 3.8.4.2, as to their application to the foundations of the RCB and other seismic Category I structures, respectively. The staff determined that the applicant provided a list of the industry codes, standards, specifications, and RGs in accordance with the SRP guidance that are applicable for the design, construction, materials, testing and inspection of the APR1400 foundations of the RCB and other seismic Category I structures. The staff found the use of these codes, standards, specifications, and RGs in the design and construction of the

foundations of RCB and other seismic Category I structures for the APR1400 design to be in accordance with the guidance given in SRP Sections 3.8.1.2 and 3.8.4.2. On this basis, the staff concluded that the information provided in the DCD Tier 2 Section 3.8.5.2, on applicable codes, standards, and specifications for the foundations of the RCB and other seismic Category I structures of APR1400 design is acceptable.

3.8.5.4.3 *Loads and Load Combinations*

The staff reviewed the loads and load combinations used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.3.

In DCD Tier 2, Section 3.8.5.3, "Loads and Load Combinations," the applicant indicated that DCD Tier 2, Table 3.8-2, "Seismic Category I Structure Load Combination for the Reactor Containment Building," describes the design loads and load combinations for the foundation of the RCB. Therefore, SER Section 3.8.1.4.3, contains the staff's evaluation of loads and load combinations of the foundation for the RCB. Furthermore, DCD Tier 2 Section 3.8.5.3, indicates that the design loads and load combinations for the foundations of the AB and EDGB are described in DCD Section 3.8.4.3, "Loads and Load Combinations," applicable to other seismic Category I structures. Therefore, SER Section 3.8.4.4.3, contains the staff's evaluation of loads and load combinations of the foundations for the AB and EDGB.

The staff reviewed the loads and load combinations given in the DCD Tier 2 Section 3.8.1.3 and associated Table 3.8-2 for the RCB, and DCD Tier 2 Section 3.8.4.3 and associated Table 3.8-3 for other seismic Category I structures, for the application to the foundations of these structures. The applicant provided a detailed list of the loads and load combinations in the two tables and identified RGs in accordance with the SRP guidance that are applicable for the loads and load combinations. The staff found the use of these the loads and load combinations in the design and construction of the foundations of the RCB and other seismic Category I structures to be in accordance with the guidance given in SRP Section 3.8.5.II.3.

The staff reviewed APR1400-E-S-NR-14006, Revision 1, Section 3.2.6, "Load Combinations," that states, "The division of the basemat by code jurisdiction at the thickness transition is a logical choice, and the boundary of the code jurisdiction is conservatively designed using the greater forces from the analysis results of ASME and ACI codes." It is not clear to the staff whether the division of the basemat code jurisdiction at the thickness transition is in accordance with the ASME Code Interpretation 111-2-83-01, which addresses this design configuration and how do they define the transition region. Per 10 CFR 50.55a; Appendix A to 10 CFR Part 50, GDC 1, 2, 4, 16 and 50; and SRP Section 3.8.5, the applicant was requested to describe in detail how the loads and load combinations for the basemat of the containment and the AB were considered in the analysis, and how the transition region is designed.

Therefore, the staff issued RAI 255-8285, Question 03.08.05-13 (ML15293A569), requesting the applicant to describe in detail how the loads and load combinations for the basemat of the containment and the AB were considered in the analysis, and how the transition region is designed.

In its response to RAI 255-8285, Question 03.08.05-13 (ML16036A129), the applicant described that the load combinations and load factors for the RCB and the AB basemats are selected based on their relevant design codes, ASME and ACI. The applicant referred to the response to RAI 199-8223, Question 03.08.01-11, which provides the details of the code jurisdiction boundary of the RCB and the AB basemats within the NI basemat. The applicant further provided Figure 1, "Jurisdiction Boundary for Design of Common Basemat," (the applicant also referred to Subsection 3.8.1.1.2 and Figure 3.8-26 as provided in response of RAI 199-8223, Question 03.08.01-11), that clearly outlines the code jurisdiction between the ASME and ACI codes within the NI basemat. In its response, the applicant provided two tables showing the selected loads with applicable load factors and critical load combinations for analyses of the NI basemat. Table 1, "Selected Loading Conditions of Superstructures for Basemat Analysis (RCB)," includes five critical loading combinations, (1) test, (2) normal, (3) severe, (4) abnormal, and (5) abnormal/ extreme environmental for the RCB basemat. Table 2, "Selected Loading Conditions of Superstructures for Basemat Analysis (AB)," includes four critical loading combinations: (1) test, (2) normal, (3) abnormal, and (4) abnormal/extreme environmental for the AB basemat. The applicant further referred to Table 3-5, "Load Combinations for NI Common Basemat Analysis," summarizing the load combinations of the RCB and AB basemats in APR1400-E-S-NR-14006, Revision 1. Finally, the applicant described that at the interface between the ASME and ACI codes, the largest amount of reinforcement required by the two codes will be used for the design of the NI basemat.

The staff identified some items in Tables 1 and 2 of the response that should be addressed, as described below.

Table 1, "Selected Loading Conditions of Superstructures for Basemat Analysis (RCB)":

- a. Why was the Severe Accident load combination that includes P_s (hydrogen generation loads) not included in the basemat analysis and design?
- b. Why were the loads G (safety relief valve) and T_a (accident temperature) not included in the basemat analysis and design?

Table 2, "Selected Loading Conditions of Superstructures for Basemat Analysis (AB)":

- a. Why is the construction load combination not included? This load combination is needed in order to add these AB superstructure loads to the Service load category from the RCB. The footnotes provided do not address this issue and only indicate which load combination gives higher loads.
- b. Why is the Severe Environmental load combination not included? This load combination is needed in order to add these AB superstructure loads to the Service load category from the RCB. The footnotes provided do not address this issue and only indicate which load combination gives higher loads.

In its response to RAI 255-8285, Question 03.08.05-13, (ML17251A119), the applicant revised the title of Table 1 to state, "Selected Loading Conditions of Containment for RCB Basemat Analysis," and provided the following:

- a. The applicant described that the combustible gas load under the Severe Accident load combination was not considered in the design of the NI basemat. The applicant

described that the basemat is very thick, and determined that the maximum displacement of the basemat is very small (maximum vertical displacement equals 0.168 in.) under a combustible gas load. The applicant further described that the liner strain in the containment wall governs over the liner strain in the basemat because the calculated maximum radial displacement in the containment wall is larger than the calculated vertical displacement of the basemat. Based on the review, the staff finds the response acceptable because the resulting strain in the containment wall governs the design, and therefore, this load combination was not evaluated in the basemat analysis.

- b. The applicant described that the valve actuation loads (G) do not affect the global behavior of the basemat, and it is a short transient pressure load in the expansion and collapse of an air-bubble. The staff found the applicant's conclusion acceptable since the valve actuation loads (G) are localized short term transient pressure loads that are contained within the IRWST, which is located on top of the basemat and separated from the containment structure. Therefore, these valve actuation loads are not expected to have a significant effect on the overall building response.

The applicant indicated that T_a (accident temperature) was not included in the basemat analysis and design because the accidental temperature gradient is approximately 50 °F. The applicant explained that ACI 349 indicates that, for a thermal gradient less than 100 °F, there is no need to consider the thermal gradient in the analysis. The staff concludes that not considering T_a is acceptable because the accidental temperature level is less than the code limit of thermal gradient equal to 100 °F.

In its response, the applicant revised the title of Table 2 to state, "Selected Loading Conditions of AB and CIS for AB Basemat Analysis."

- a. The applicant revised the footnotes in Table 2 to indicate that the severe environmental load combination governs over the construction load combination. This occurs because the loads in the construction load combination are included in the severe environmental load combination with higher load factors. Therefore, the staff concludes and agrees with the applicant's description provided by the footnotes of Table 2 that the severe environmental load governs over the construction load combination.
- b. For all loads applicable to the AB basemat analysis, the normal load combination is analyzed instead of the severe load combination because it contains the same loads and load factors as the severe environmental load combinations. Therefore, the staff concludes and agrees with the applicant's description provided in Table 2 that the severe load combination does not need to be evaluated separately.

As part of the review of the different load combinations considered in the design of the basemat, the staff noted that the polar crane lifting load was not included in a number of the load combinations. The RAI response indicates that the self-weight (for all load conditions) and live load (for construction and normal load condition) are applied at the parking position of the crane for design, and footnotes 12 and 13 were added in Table 1, to include that the self-weight and lifting loads of the crane in the appropriate load combinations. The applicant also explained that when not in use, the polar crane is required to be in the parking position during plant operation. This information and identification of the parking position is specified in the new COL 3.8(21).

The staff concludes that the approach used by the applicant, for consideration of the polar crane loads, is acceptable because the crane is required to be in the parking position during plant operation and under that condition, the crane loads were included in the design of the containment. Furthermore, the applicant provided a new COL item to ensure that the crane is located in the identified parking position during plant operation.

Therefore, the staff finds the response to RAI 255-8285, Question 03.08.05-13, acceptable. Based on the review of the DCD and APR14006-E-S-NR-14006, Revision 4, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-13, is resolved and closed.

3.8.5.4.4 *Design and Analysis Procedures*

The staff reviewed the design and analysis procedure used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.4. The staff also reviewed the DCD to establish that the design is essentially complete, as required by 10 CFR 52.47(c).

In DCD Tier 2, Section 3.8.5.4, "Design and Analysis Procedures," the applicant described that the reinforced concrete basemat of the RCB is designed in accordance with ASME Section III, Division 2, Subsection CC, and reinforced concrete basemats of other seismic Category I structures were designed in accordance with ACI 349 and the provisions of RG 1.142, where applicable. The NI common basemat was analyzed using the ANSYS computer program that included the RCB superstructure, internal concrete structures, and AB for stiffness. The NI basemat was modeled with eight-node solid elements in the FEM. The isometric figure of the solid FEM is shown in DCD Tier 2, Figure 3.8A-29, "Solid Element Model of NI Common Basemat." The applicant indicated that the design and analysis details for the foundations of the safety-related structures are described in DCD Tier 2, Sections 3.8A.1.4.2, 3.8A.2.4.1, and 3.8A.3.4.1 for the RCB, AB, and EDGB, respectively. The applicant further described that the maximum differential settlement of foundation as 12.7 mm per 15.24 m (0.5 in per 50 ft.) within NI common basemat, and as tabulated in DCD Tier 1, Table 2.1-1, "Site Parameters," and in DCD Tier 2, Table 2.0-1, "Site Parameters." The maximum differential settlement between buildings is 12.7 mm (0.5 in.) based on enveloping properties of subsurface materials. In addition, the applicant described that the common basemat was analyzed for construction sequence to minimize any potential differential settlement during construction.

In DCD Tier 2, Sections 3.8.1.4.13, 3.8.3.4.3, and 3.8.4.4.3, and DCD Tier 2, Section 3.8.5.4.3, "Design Summary Report," the applicant indicates that a design summary report is prepared for the seismic Category I structures in Appendix 3.8A where the design summaries for the representative critical sections of the structures are described. In DCD Tier 2 Section 3.8A.1.4.1.3.5, "Design Sections," the applicant identified that the critical sections for design of the RCB are (a) the base of the containment wall, (b) the mid-height of the containment wall, (c) the polar crane bracket level and springline, and (d) the thickened sections around large penetrations, such as the equipment hatch and the personnel airlock. However, the applicant did not provide sufficient information regarding the methodology used to determine the critical sections. Furthermore, it was not clear to the staff why other important and/or representative structural members are not included as critical sections.

Therefore, the staff issued RAI 248-8295, Question 03.08.05-1 (ML15296A016), requesting the applicant to explain whether any other sections should be identified as critical sections such as the containment dome, the containment liner plate, floor slab between the SSW and the containment, a steel beam and/or column, and mainsteam and feedwater penetrations. In addition, the applicant was requested to provide the required steel reinforcement properties and margins of safety for all critical sections.

In its response to RAI 248-8295, Question 03.08.05-1 (ML17157B581), the applicant described that the APR1400 critical design sections are the portions of safety related, seismic Category I steel and concrete structures, which are credited in preventing or mitigating the consequences of postulated design basis accidents, expected to experience the largest structural demands during design basis conditions, or needed for safety evaluation of an essentially complete design. In addition, the applicant considers the safety related functional role in selecting the critical sections. This would include some of the APR1400 structures whose failure could degrade systems or equipment or pose a safety hazard to plant personnel or to the public. The applicant described the specific contents for the design of the critical sections in the markups for DCD Tier 2, Sections 3.8A.1, 3.8A.2, and 3.8A.3 for the RCB, AB, and EDGB, respectively.

In the RCB, the applicant described that there are no concrete columns, concrete beams, or steel columns. The applicant also described that there are three major elevations in the annulus area of the RCB for the steel beam structures, located between the containment wall and secondary shield wall at EL.114'-0", 136'-6", and 156'-0". The applicant described that the steel beam, beam connection, and beam seat on each level were designed for the highest load case. The applicant added the detailed design procedure for the steel beams and results in the markups to DCD Tier 2, Section 3.8A.1.4.3.4.

The applicant selected the concrete floor slabs at EL.156'-0" between the containment wall and secondary shield wall as critical sections because the accelerations (g-values) and seismic anchor movement at this elevation are larger than the floor slabs at other elevations. The applicant provided the forces and moments, design results, and associated margins of safety in the markups to DCD Tier 2, Sections 3.8A.1.4.3.3.3 and 3.8A.1.4.3.3.4, and associated tables and figures.

The applicant also provided updated analysis methods, results, and rebar arrangement (where applicable) for the PSW, SSW, and IRWST in DCD Tier 2, Sections 3.8A.1.4.3.1, 3.8A.1.4.3.2, and 3.8A.1.4.3.3, respectively, along with the associated tables and figures.

Containment

The applicant added the containment dome and containment liner plate/anchorage as critical sections for the containment in the markups to DCD Tier 2 Section 3.8A.1.4.1.3.5. The design forces and moments, design results (including rebar arrangements), and margin of safety for the containment wall and dome were provided in the markups to DCD Tier 2, Section 3.8A.1.4.1.3.4 through Section 3.8A.1.4.1.3.7, and the corresponding figures and tables. The applicant described the containment liner plate and anchorage, design procedure and criteria in the markups to DCD Tier 2, Sections 3.8.1.4.10 and 3.8A.1.4.1.3.8. The design results, including the margin of safety for the liner plate/anchorage, are provided in the markups to DCD Tier 2 Table 3.8-12.

Auxiliary Building

The applicant considered shear walls and diaphragm slabs as the primary load resisting system in the AB. The applicant described that there are some concrete frames to support partial slab loads that are transferred to them. The applicant described that the stiffness of the frames is small in comparison to that of the shear wall/slab systems. Therefore, the applicant neglected the frames' contribution in resisting lateral loads in the analysis, and consequently did not consider them as critical sections. The staff finds this approach acceptable because the contribution of the frames are not expected to have a significant effect on the building load resisting system, which is provided by the reinforced concrete shear walls. For the AB, the RAI response did not identify any changes in the analysis approach or results, and so no markups to the DCD were provided.

The staff finds the responses and markups to RAI 248-8295, Question 03.08.05-1, regarding the analysis and design of the critical sections, are acceptable for several reasons. The applicant described the criteria for selection of the critical sections appropriately in terms of: the members' safety functions, severity of the loads the experience, being representative for various types of members (beams, walls, and slabs), and the types of materials (structural steel and reinforced concrete). The analysis and design of the critical sections demonstrated that the applicant implemented the load and load combinations, analysis approach, and design in accordance with the criteria in the DCD and applicable codes and standards. Thus, the design of the critical sections provides a reasonable assurance that the design is acceptable. Also, the information presented in the DCD for the critical sections provides the key design information consistent with SRP Section 3.8.4, Appendix C for Design Reports.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 248-8295, Question 03.08.05-1, is resolved and closed.

In DCD Tier 2, Section 3.8.5.4.2, "Analysis of Settlement during Construction," the applicant provided limited description as to how settlement is evaluated. In APR1400-ES-NR-14006, Revision 1, the applicant described the evaluation of the settlement of the NI basemat; however, DCD Tier 2, Section 3.8.5.4, "Design and Analysis Procedures," did not reference the report. Furthermore, it was not clear to the staff how the criteria in SRP Section 3.8.5.II.4 E, J, and K, are implemented.

Therefore, the staff issued RAI 255-8285, Question 03.08.05-9 (ML15293A569), requesting the applicant to describe the design and analysis procedures and to explain how the elements

described in SRP Section 3.8.5.II.4 E, J, and K, are incorporated in the APR14000 design, and to include this information in DCD Section 3.8.5.

In its response to RAI 255-8285, Question 03.08.05-9 (ML17009A400), the applicant's response followed by the staff's evaluation for each item of this RAI are given below.

1. Criteria related to SRP Section 3.8.5.II.4.E - evaluation of settlement:

The effects of: (a) static and dynamic settlements, (b) short term and long term settlements, (c) of soil type on settlement, and (d) of foundation type and size on settlement are addressed under RAI 255-8285, Question 03.08.05-7, which is evaluated below in this SER. Therefore, item 1 under RAI 255-8285, Question 03.08.05-9, is resolved and closed.

2. Criteria related to SRP Section 3.8.5.II.4.G - evaluation of stiff and soft spots:

The applicant responded that the stiff and soft spots are not predictable before the site survey or site excavation for the specific site. The applicant further described that if stiff and soft spots were found during excavation, the COL applicant shall perform basemat analysis considering stiff and soft spots per item 2 of COL 3.8(12) within RAI 255-8283, Question 03.08.05-7. Therefore, item 2 under RAI 255-8285, Question 03.08.05-9, is resolved and closed.

3. Criteria related to SRP Section 3.8.5.II.4.J - evaluation of settlement during construction:

The applicant responded that the evaluation of settlement during the construction sequence is described in RAI 255-8285, Question 03.08.05-7. The applicant also described that if the actual soil status and loss of cement from the mudmat were to be expected after the site survey or site excavation, loss of subgrade contact due to loss of cement from a mudmat is considered corresponding to the actual site status as specified in items 4 and 5 of COL 3.8(12) within RAI 255-8285, Question 03.08.05-7. Therefore, item 3 under RAI 255-8285, Question 03.08.05-9, is resolved and closed.

4. Criteria related to SRP Section 3.8.5.II.4.K - stiffness modeling of soil material in seismic analysis:

The applicant described two methods to represent soil stiffness parameters, which are applied to the NI common basemat analysis. Under static loading combinations, soil spring were used based on sugared moduli of the soil. Under seismic loading combinations, the foundation media was modeled to represent the soil using finite elements. The applicant provided further details of the soil modeling in the response to RAI 255-8285, Question 03.08.05-8. Therefore, item 4 under RAI 255-8285, Question 03.08.05-9, is resolved and closed.

The staff determined that the adequacy of the response cannot be determined until the detailed analysis, to be provided in RAI 255-8285, Question 03.08.05-7, is submitted. Based on the staff's review of the applicant's final response to RAI 255-8285, Question 03.08.05-9, on January 1, 2016 (ML17009A400), the applicant deferred to RAI 255-8283, Question 03.08.05-7, to resolve items 1, 2 and 3, and the applicant provided further details of the soil modeling in the

response to RAI 255-8283, Question 03.08.05-8 for item 4. Therefore, RAI 255-8285, Question 03.08.05-9, is resolved and closed.

In DCD Tier 2, Section 3.8.6.4, "Design and Analysis Procedures," the applicant stated, "The maximum differential settlement of foundation is 12.7 mm per 15.24 m (0.5 in. per 50 ft.) within NI common basemat. The maximum differential settlement between buildings is 12.7 mm (0.5 in.) based on enveloping properties of subsurface materials. In addition, the common basemat is analyzed for construction sequences to minimize any potential differential settlement during construction." The applicant further described the differential settlement of foundations in APR1400-E-S-NR-14006, Revision 1, for the NI and in Appendix A to this technical report for the EDGB and DFOT building. Based on the review of these documents, it was not clear to the staff how the construction sequence and differential settlement of foundations were considered in the load and load combinations. Therefore, the staff issued RAI 255-8285, Question 03.08.05-7 (ML15293A569), requesting the applicant to describe how the construction sequence and differential settlement of foundations were considered in the load and load combinations.

In its response to RAI 255-8285, Question 03.08.05-7 (ML16222A402), the applicant described the differential settlement analysis approach based on the applied loads under the static load case (dead plus live load) and dynamic load case (seismic) for the three selected soil profiles S1, S4, and S8 corresponding to soft, medium, and stiff, respectively. For the construction sequence evaluation, information was only provided for the basemat. For the construction sequence evaluation of the entire NI (i.e., basemat and superstructures), the response indicated that it will be performed and submitted at a later date. To determine which soil profile should be used for the construction sequence of the NI, the response provided some comparisons of the basemat response due to the S1 and S8 soil profiles. The response also provided COL 3.8(11) and COL 3.8(12), to identify what the COL applicant should evaluate regarding site-specific aspects of construction sequence and the various potential site-specific soil conditions such as stiff/soft soil spots, different soil types (e.g., cohesive soils), loss of cement for the mudmat, and non-uniformity of soil layers.

Based on the review, the staff requested the applicant to address the following:

1. The staff noted that the applicant did not make any conclusion in the response whether the S1 soil condition governs, in which case only the soft soil condition will be evaluated for construction sequence or not. Since in some regions of the basemat, it appeared that S8 member forces were larger than S1, the staff requested the applicant to explain whether both cases of S1 and S8 will be analyzed, and the design will be based on the envelop/governing loads from these cases.
2. The staff provided some comments for clarification of COL 3.8(11). The staff noted that the COL 3.8(11) describes the construction sequence and corresponding differential settlement analysis, however, the site-specific analysis should also consider post-construction settlement analysis through the life of the plant per the guidance in SRP Section 3.8.5.II.4.
3. The staff also noted that the applicant did not provide acceptance criteria for all aspects of settlement which consist of the maximum vertical settlement, tilt settlement, differential settlement between adjacent structures, and angular distortion. The

settlement should be based on static (gravity) loads not seismic load because the settlements to be monitored during the COL monitoring program cannot include seismic. Using an upper bound of 0.5 in. per 15 m (50 ft.) is not conservative because the design was based on much lower values. Using one value for settlement does not capture the bending distortion throughout the basemat.

4. The staff noted that, besides settlements, the applicant did not provide the maximum vertical and horizontal displacements of the structures for all/governing load combinations to ensure that there is no interaction/contact between seismic Category I structures and any other structure, system, and components (SSC).
5. The staff noted that COL 3.8(12) appeared to apply if there are site-specific conditions found at the site as indicated in the COL item, then “a site-specific evaluation will be performed.” However, details of what this evaluation entails were not provided. Therefore, the applicant was requested to describe in sufficient detail the site-specific evaluation which should include evaluation of the basemat and superstructure design, settlement evaluations, soil bearing calculation versus demand, and stability evaluation for all/governing load combinations.

In its revised response to RAI 255-8285, Question 03.08.05-7 (ML17362A154), the applicant provided the following:

1. The applicant responded that both soil profiles, S1 and S8, are considered for the construction sequence. The applicant further provided figures showing the moment diagrams for soil cases, S1 and S8, under abnormal/extreme cases at three sections of the NI basemat that are considered in the design of the NI basemat. The staff finds the response acceptable because the applicant considered both S1 and S8 soil profiles for the construction sequence.
2. The applicant provided a new revised COL 3.8(18) [this COL item was originally identified as COL 3.8(11) in the applicant’s response (ML16222A402)] to: (1) refer to DCD Tier 2, Section 3.8.5.4.2 “Analysis of Settlement during Construction,” which describes the construction sequence analysis model and analysis for NI common basemat and superstructures (AB, IS and RCB) with various soil profiles, and (2) identify the two types of settlement (Maximum Allowable Differential Settlement inside Building and Maximum Allowable Differential Settlement between Buildings) criteria tabulated in DCD Tier 2 Table 2.0-1, that the COL applicant shall satisfy. The staff finds the response acceptable because the applicant addressed the construction sequence analysis model and analysis throughout the life of the plant, and four types of settlement criteria in accordance with SRP Section 3.8.5.II.4.
3. The applicant also described the four types of settlement consisting of: (1) the maximum vertical settlement, (2) tilt settlement, (3) differential settlement between adjacent structures, and (4) angular distortion, in DCD Tier 2 Section 3.8.5.4.2.2, “Various Settlements.” The applicant furthermore tabulated and provided figures of the maximum settlements values under construction sequence and post-construction condition for soil profiles of S1 and S8. The staff finds the response acceptable because the applicant provided the description of the analyses performed for construction sequence and

settlement, and described the four types of settlements in DCD Tier 2 Section 3.8.5.4.2.2, "Various Settlements."

4. The applicant tabulated the maximum vertical differential settlements for construction and post-construction for soil profiles of S1 and S8 for NI, EDG and DFOT buildings, which are presented in DCD Tier 2 Table 3.8-14. The applicant also provided markups for DCD Sections 3.8.5.8, 3.9A.1, and 3.9A.2, which provide the analysis approach for evaluating settlements and seismic anchor movements for SSCs spanning between structures. The staff finds the response acceptable because the applicant provided the maximum vertical differential settlement criteria for construction and post-construction for the NI, EDG and DFOT buildings in DCD Tier 2 Table 3.8-14, and provided the analysis approach for design of SSCs subjected to differential settlements and seismic anchor movements.
5. The applicant provided a new revised COL 3.8(19) [this COL item was originally identified as COL 3.8(12) in the response dated August 2, 2016 (ML16222A402)]. The revised COL item indicates: (1) The site-specific soil profiles shall be developed; (2) A list is provided identifying the potential differences between the site surveyed soil characteristics and the DCD; (3) The differential settlement of the basemat and soil bearing pressure shall be checked against the acceptance criteria in DCD Tier 2 Table 2.0-1; (4) The seismic Category I structures will be built in accordance with the construction sequence used in the site-specific construction sequence analysis (described in COL 3.8(18)); (5) If a site-specific evaluation is required, the COL applicant should perform a construction sequence analysis to ensure the acceptance criteria in DCD Tier 2 Table 2.0-1, is met; and (6) The effects of construction sequence shall be considered in the design of seismic Category I structures. The staff finds the response acceptable because the applicant provides all the necessary items to be considered for the COL applicant in order to meet the construction sequence and settlements that were used in the design of the plant described in the DCD. This approach is consistent with the criteria in SRP Section 3.8.5.II.K.i and 3.8.5.III.8.

Furthermore, in its response, the applicant provided markups to DCD Tier 1, Tier 2, Chapter 2.0, Section 3.8.5, and APR1400-E-S-NR14006, Revision 3, to incorporate detailed explanations of the construction sequence and settlement requirements. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-7, is resolved and closed.

The staff reviewed Section 5.0, "Construction Sequence Analysis," of APR1400-E-S-NR-14006, Revision 1, that describes the construction sequence analyses performed for the NI basemat. The staff reviewed this section and noted that additional information is needed in order to perform its safety review of the DCD application with regard to the analysis approach for constructions sequence and settlement. Therefore, the staff issued RAI 255-8285, Question 03.08.05-18 (ML15293A569), requesting the applicant to address the following items:

1. In APR1400-E-S-NR-14006, Revision 1, Section 5.0, the applicant describes the construction sequence analyses performed for the NI basemat, and indicates that Sites S1 and S8 were used for the calculations. Figure 2-1, "Shear Wave Velocity of Generic Site Categories," shows that site S2 is softer than Site S1 in the top 100' of the profile and this would be expected to lead to larger construction settlements and structural

demands. Therefore, the staff requested the applicant to provide the basis for using the site profile S1 rather than S2. The staff also requested the applicant address if any site considered for the construction of the APR1400 design has soil conditions that lead to settlements greater than those computed for S1 and S8 in the DCD and technical report, explain how that will be addressed.

2. The staff was not able to identify where the considerations of: (1) sand profiles were evaluated for the settlements which occur quickly as the loads are applied during construction, and (2) fine-grained soil where the settlements are delayed due to potential time-consolidation effects. Therefore, the staff requested the applicant to address how settlement and construction sequences during the short term condition of the basemat and superstructure, as well as long term condition were considered in the analysis studies and in the design of the basemat and superstructures.
3. Based on the staff's review it is not clear how a differential displacement of 0.5 in. per 50 ft. can be used by the COL applicant to confirm the design adequacy of the basemat and superstructure. Usually, displacement of basemat results in bending distortion between adjacent points, not simply differential displacements. Therefore, the staff requested the applicant to explain how the COL applicant is supposed to check for settlements, and revise the technical report, applicable sections of the DCD, and COL item(s) accordingly.

In its response to RAI 255-8285, Question 03.08.05-18 (ML16222A402), the applicant provided the following.

1. In its response, the applicant chose the soil profile S1 as the representative soil profile; even though, soil profile S2 is softer than S1 at some depths. The applicant calculated the subgrade moduli using the methodology described in APR1400-E-S-NR-14006, Revision 1, Section 2.2.1, "Elastic Modulus of Soil Sites." The results show that subgrade modulus of S1 (35.66 kcf) is less than S2 (49.73 kcf); therefore, the subgrade modulus of S1 was used for the construction sequence analyses performed for the NI basemat. The applicant further described that if the site specific soil information identified by the COL applicant, as a result of performing the actions required by COL 3.8(10), is not enveloped by soil profiles S1 through S9, and the soil condition leads to greater settlement, the COL applicant shall perform the analysis required by COL 3.8(11). The applicant also referred to the response of RAI 255-8285, Question 03.08.05-7, for determining the acceptability of the site specific settlements.
2. The applicant described the soil profiles in DCD Tier 2 Table 3.7A-1, "Soil Layers and Profiles (S1)," as sand, soft rock and rock, and that the settlement of APR1400 basemat will be controlled by the instantaneous settlement of sand. The applicant added that, in the actual site, the site-specific soil parameters are determined based on COL 3.8(10). The elastic soil moduli are recalculated based on elastic shear modulus provided in accordance with COL 3.8(10). The applicant described that, in the DCD phase, the static elastic moduli considered in the basemat analysis of seismic Category I was determined with a low reduction factor of 0.1153, as described in the response to RAI 255-8285, Question 03.08.05-16. Therefore, the applicant concluded that the results of settlement from analysis in the DCD phase include sufficient margin for long-term settlement in sand and rock profiles. The applicant further described that if

site-specific parameters are different from DCD Tier 2, soil parameters, the COL applicant shall evaluate this based on COL 3.8(12) of RAI 255-8285, Question 03.08.05-7.

3. The applicant referred to RAI 255-8285, Question 03.08.05-7, for the details about settlement and construction sequence.

The staff reviewed the applicant's response to RAI 255-8285, Question 03.08.05-18, and finds it acceptable because the applicant described that the modulus for the S1 profile leads to a reduced modulus as compared to the S2 profile, and thus S1 leads to a softer soil spring. In addition, the applicant considered three soil cases of S1, S4, and S8 (soft, medium, and stiff) soil profiles in the various ANSYS structural analyses. The applicant also described that if a COL applicant determines that the site-specific conditions are different than those used in the DCD stage, then the COL applicant is to perform a site-specific evaluation per COL 3.8(12) of RAI 255-8285, Question 03.08.05-7. Furthermore, the applicant addressed the question related to the settlements and bending distortion considerations in the related RAI 255-8285, Questions 03.08.05-7, -9 and -16. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-18, is resolved and closed.

The staff reviewed DCD Tier 2, Section 3.8.5.4, "Design and Analysis Procedures," which states, "The analysis of the foundation mat is performed by a three-dimensional finite element structure model, and the forces and moments determined in the analysis are input to the structural design." However, it is not clear to the staff how seismic and other loads are determined and applied to the various structures within the scope of the APR1400 design. Therefore, the staff issued RAI 255-8285, Question 03.08.05-8 (ML15293A569), requesting the applicant to:

- a. Identify and describe the method of analysis used, whether it was response spectra analysis method, equivalent static method of analysis, or forces from the SSI/SSSI analyses were used.
- b. Provide a description how the response spectra, equivalent static accelerations, or forces from the SSI/SSSI analyses were developed and then applied to the FEM design model.
- c. Provide the response spectra analysis (RSA) curves used in the analysis.
- d. Explain how the static accelerations from the seismic SSI/SSSI analyses were transferred to the separate FEM design model since the two models have different nodes and elements.

In its revised response to RAI 255-8285, Question 03.08.05-8 (ML17255A942), the applicant provided the following:

- a. The applicant described that the equivalent static analysis method is used to consider seismic loads in the NI common basemat analysis. The applicant described that the enveloped results of the linear case (SRSS combination method) and the nonlinear case (100-40-40 combination method) are used in the design of the NI basemat. The applicant performed the nonlinear analysis for

seismic loads because some uplift occurs in the NI basemat. The applicant provided markups to APR1400-E-S-NR14006 to incorporate a detailed explanation of the NI common basemat analysis. The staff finds the response acceptable because the applicant used the equivalent static analysis methodology for the design of the NI basemat consistent with the guidance provided in RG 1.92 and SRP Section 3.8.5.

- b. The applicant described that the enveloped seismic equivalent accelerations from SSI analysis are used in the NI common basemat design. The NI common basemat analysis considered three foundation models corresponding to soil profiles S01 (soft), S04 (medium), and S08 (stiff). For each of the three soil profile analyses, the envelope of the seismic accelerations from SASSI SSI analyses for the full range of the soil profiles are used. The applicant used the enveloped member forces from the three soil profiles (S01, S04, and S08) and the nonlinear cases for the design of the NI basemat. The staff finds the response acceptable and conservative because for each of the three soil profile analyses, the applicant used accelerations from the SSI analyses based on the entire range of soil profiles, and for the design of member forces the applicant enveloped the three soil profile analyses, and also enveloped the linear and the nonlinear analyses results.
- c. The applicant provided the response spectra analysis figures in the E-W, N-S and vertical directions at elevation 78'-0" for RCB Shell and Dome, at 5 percent damping, RCB Internal Structures, at 7 percent damping, and RCB Internal Structures, at 7 percent damping (applicable to the reactor coolant systems). The applicant used these response spectra for the analysis and design of the containment and internal structures, while the equivalent static analysis was used for the auxiliary building. The staff finds the use of these spectra curves are acceptable because they correspond to support points of the containment and internal structures, and the damping values are in accordance the values identified in DCD Tier 2 Table 3.7-7.
- d. The applicant described that the equivalent accelerations are computed at the slab elevations; therefore, the different nodes and elements of two models (SSI vs. FE) do not have any effect. The staff finds this approach is acceptable because the predominant mass of the actual structure occurs at each slab level.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-8, is resolved and closed.

The staff reviewed DCD Tier 2, Section 3.8A.2.4.1, "Basemat," which describes the analysis and design methods for the AB basemat. The staff noted that additional information is needed in order to perform its safety review of the DCD application. Therefore, the staff issued RAI 255-8285, Question 03.08.05-11 (ML15293A569), requesting the applicant to address the following items that are needed to ensure that the analysis and design methods are acceptable:

- a. The applicant performed an equivalent static analyses for the AB and EDG buildings. SRP Section 3.7.2 II.1.B indicates that when using an equivalent static analysis method, justification should be provided to show that the system can be

realistically represented by a simple model and the method produces conservative results in terms of responses. Therefore, the staff requested the applicant to provide justification that the use of the equivalent static method of analysis is appropriate for the AB and the EDG buildings.

- b. In DCD Tier 2, Appendix 3.8A, "Structural Design Summary," Section 3.8A.2.4.1, "Basemat," the applicant described how the connections between walls of the superstructure and basemat were simulated in the analysis model of the NI common basemat structure. The applicant's approach regarding this and other aspects of the analysis was not clear to the staff. Therefore, the staff requested the applicant to explain the analysis model, boundary conditions, soil springs, how loads were applied, what accelerations are applied. The applicant was also requested to explain whether the seismic analysis of the AB basemat was performed separately, or was it considered in the same NI concrete basemat model and analysis described in DCD Tier 2 Section 3.8A.1.4.2, used to obtain the member forces.

In its response to RAI 255-8285, Question 03.08.05-11 (ML16224A304), the applicant provided the following:

- a. In its response, the applicant summarized the results of a comparison made between the SSI analysis and the equivalent static method for the AB, EDGB and DFOT. The applicant concluded that the equivalent static method results are more conservative than the SSI analysis, and thus the use of equivalent static analysis is appropriate.

Based on the review of the comparison of the forces and moments at different elevations between the SSI analysis and the equivalent static method for the AB, EDGB and DFOT, the staff confirmed that the equivalent static method results are more conservative than that the SSI analyses. Therefore, the applicant provided adequate justification for the use of the equivalent static method of analysis.

- b. In its response, the applicant described the analysis models, element types (brick or shell), boundary conditions, seismic analysis methodologies used for the individual superstructure analyses of the RCB shell and dome, RCB internal structures and AB, and also provided references to the figures of the structural FEA analyses models that are presented in DCD Tier 2, Sections 3.8 and 3.8A.

The applicant described how the reaction forces from the superstructure and seismic loads were applied to the NI, basemat model. The applicant included a Figure 1, "Analysis Procedure for NI Basemat," in the RAI response depicting two types of analytical approaches (previous and new NI common basemat procedure). This figure describes how the reaction forces (translational forces and rotational moments) from the superstructure are applied to the basemat. The new analysis was performed to simplify the application of reaction forces from the superstructures onto the basemat in a direct fashion. The response indicated that, in addition to the superstructure reaction forces applied to the basemat, the seismic accelerations of $X = 0.27g$, $Y = 0.31g$, and $Z = 0.31g$, from elevations

68'-0" to 78'-0" of the AB, were applied to the basemat to consider the seismic inertial effects of seismic loading on the basemat.

Based on the staff's review it was concluded that the applicant's models and approach described above are consistent with industry practices and the analysis methods described in SRP Sections 3.8.1, 3.8.3, 3.8.4, and 3.8.5. Therefore, the staff finds the applicant's response acceptable.

Based on the above discussion, the staff considers RAI 255-8285, Question 03.08.05-11, resolved. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-18 11, is resolved and closed.

The staff reviewed TR APR1400-E-S-NR-14006, Revision 1, Section 3.2.5, "Applied Loads," that states, "The reactions from seismic analyses of the RCB shell and dome, RCB internal structure, and AB are applied as the seismic loads in the basemat model. The response spectrum analysis is used for the RCB shell and dome and RCB internal structure and the equivalent static analysis is used for the AB for seismic analyses of superstructures." The staff noted additional information is needed in order to perform its safety review of the DCD application. Therefore, the staff issued RAI 255-8285, Question 03.08.05-12 (ML15293A569), requesting the applicant to address the following items that are needed to ensure that the analysis and design methods are acceptable:

- a. Provide a justification for using the two different methods, the response spectrum analysis and the equivalent static methods, for the seismic design of RCB shell and dome, and the RCB internal structures.
- b. It was not clear to the staff whether these two different methods of analysis were done only for stability check or for all aspects of design: developing member forces for design, stability evaluation (sliding and overturning), up-lift evaluation analysis, basemat soil bearing pressure calculation, settlement analysis, and lateral soil pressure on foundation walls. Therefore, wherever these two methods of analysis were used, they should be justified.
- c. Section 3.2.5, "Applied Loads," of the technical report states, "In the response spectrum analysis, the maximum values of individual modes occur simultaneously; hence, the combined effect is obtained by using algebraic (considering signs) summation of the individual modal responses." This is not consistent with combining modes as described in RG 1.92. Therefore, the staff requested the applicant to justify this approach.

In its revised response to RAI 255-8285, Question 03.08.05-12 (ML17251A158), the applicant provided the following:

- a. For the design of the NI basemat, the applicant described that the equivalent static analysis method is used to determine the loads of the RCB shell and dome, RCB internal structures, and AB. Linear analyses with no uplift and nonlinear analysis with uplift were performed using the equivalent static analysis method. More detailed description of the seismic loads and load combinations of the NI common basemat are provided in the response to RAI 255-8285, Question 03.08.05-8, Revision 1. Furthermore, the applicant concluded in the response to

RAI 255-8285, Question 03.08.05-11, that the equivalent static analysis is more conservative than the SSI analysis. Based on the review, the staff finds the response acceptable because the applicant used the equivalent static method of analysis for all NI superstructures and basemat, and this analysis method was demonstrated to be conservative when compared to the seismic SSI analysis.

- b. The applicant provided responses to address what types of analyses were performed for all of the cases as follows:
1. The applicant described that member forces for design of the NI basemat were developed using equivalent static seismic analysis method for linear and nonlinear dynamic cases. The staff finds this item acceptable because the applicant used one type of analysis to determine the maximum member forces for design of the NI basemat.
 2. The applicant described that the seismic analysis results from SASSI were used for determining the forces for the stability evaluations. The staff finds this item acceptable because the applicant took the seismic forces from the SASSI analysis, which was found to be acceptable as discussed in the staff's evaluation for DCD Tier 2, Section 3.7.
 3. The applicant described that the settlement evaluation was not performed for seismic loading. The staff finds this item acceptable because settlement analysis is applicable to gravity loads (dead load and live load), not for seismic loadings.
 4. The applicant described that the maximum soil bearing pressure, was calculated for static, nonlinear, linear and SASSI analysis cases. Because the peak dynamic soil bearing pressure was localized at the corner of the NI basemat, redistribution of the peak pressures in this localized region was considered over a reasonable range of distances from the corner. Following this approach, the applicant tabulated the maximum soil bearing pressure for all load combinations, and determined that they are lower than the allowable static and dynamic bearing pressure capacities as specified in DCD Tier 2 Table 2.0-1, and DCD Tier 1 Table 2.1-1. The approach used to determine the maximum dynamic soil bearing pressure and the redistribution of this peak localized calculated value are found to be acceptable because it enveloped the pressures from the linear and SASSI analysis cases with the nonlinear equivalent static analysis method.
 5. The applicant described that the reaction loads from the auxiliary building structural analysis, due to the lateral soil pressure loads (static and dynamic earth pressures) acting on the embedded walls of the auxiliary building, are applied to the NI basemat model. The staff finds this item acceptable because the applicant appropriately applied the lateral soil pressure loads on the embedded walls for the design of the NI basemat.

- c. The applicant referred to item “a,” of this response that the analysis approach was revised to use the equivalent static analyses method, and thus, the question related to the modal combination method is no longer applicable. The staff finds this response acceptable because the applicant used the equivalent static analysis method and not the response spectra analysis.

Therefore, the staff finds the response to RAI 255-8285, Question 03.08.05-12, acceptable since the markups for the DCD and technical report APR14006-E-S-NR-14006 to address the above issues are provided in RAI 255-8285, Questions 03.08.05-16 and 03.08.05-8, respectively. Based on the review of the DCD and technical report APR14006-E-S-NR-14006, Revision 4, the staff confirmed incorporation of the changes in RAI 255-8285, Questions 03.08.05-16 and 03.08.05-8 to resolve RAI 255-8285, Question 03.08.05-12. Therefore, RAI 255-8285, Question 03.08.05-12, is resolved and closed.

In APR14006-E-S-NR-14006, Revision 1, Section 4.2.2, “Sliding Check,” the applicant indicates that the resistance forces against sliding of the common basemat are checked for the driving shear forces from the seismic load. The basemat friction force is considered to resist the sliding of the common basemat. The applicant further describes that the coefficient of friction (CoF) for the sliding check is 0.7 corresponding to the internal friction angle of 35 degrees. The applicant’s approach for evaluating the sliding analyses of the Category I structures is not clear to the staff. Therefore, the staff issued RAI 255-8285, Question 03.08.05-14 (ML15293A569), requesting the applicant to provide a detail description of the method used to determine the sliding check of the seismic Category I structures, and to justify that the CoF of 0.7 represents the minimum CoF considering the various sliding interfaces including concrete to soil, waterproofing to soil, and concrete basemat to concrete mudmat.

In its response to RAI 255-8285, Question 03.08.05-14 (ML16217A410), the applicant stated that the stability check against sliding of seismic Category I structures was based on the factor of safety (FoS) specified in DCD Tier 2 Table 3.8-10, “Acceptance Criteria for Overturning, Sliding and Flotation.” The applicant stated that the maximum shear forces induced by the seismic load are greater than those induced by the wind load. Therefore, the applicant did not consider the wind load in the calculation for the sliding evaluation. The applicant calculated the FoS against each time step based on a linear time history analysis for each soil case. The applicant determined that the minimum calculated FoS against sliding for the various soil cases was greater than the acceptance criterion of 1.1 in accordance with SRP Section 3.8.5.II.5 and DCD Tier 2, Table 3.8-10, “Acceptance Criteria for Overturning, Sliding, and Flotation.”

In the sliding stability analyses, the governing (minimum) value of 0.55 is used for the CoF considering all potential sliding interfaces. This value corresponds to the potential sliding interface between the lean concrete and the waterproofing membrane installed between the upper lean concrete layer and the lower lean concrete layer. The minimum CoF is ensured by the COL 3.8(13) and COL 3.8(14). For the sliding interface between the basemat concrete and lean concrete, the applicant referred to ACI 349, Section 11.7.4.3, where it indicates that the CoF shall be taken as 1.0 for concrete placed against hardened concrete with surface intentionally roughened. For the sliding interface between the lean concrete and the supporting soil or rock, the applicant referred to the Design Manual 7.02 of Naval Facility Engineering Command (1986) which demonstrates that the CoF of 0.55 is appropriate.

For the applied seismic load, the applicant described that the maximum horizontal driving force was calculated by taking the SRSS of seismic horizontal forces in the E-W and N-S directions at each time step of the time history. The vertical seismic force obtained from the THA is also considered and is algebraically summed at each time step, along with the dead load and uplift load from buoyancy effects of the groundwater.

The applicant determined that the minimum FoS is 1.25, for sliding during the entire time period and for all soil cases, which is greater than the 1.1 acceptance criterion. The applicant also determined the FoS for the overturning stability evaluation using a static analysis approach which conservatively used 100 percent of the maximum driving moments and 100 percent of the maximum vertical uplift force, which still exceeds the acceptance criterion of 1.1 in DCD Tier 2 Table 3.8-10.

The staff finds the use of 0.55 for the CoF is acceptable based on the technical justifications provided above. All potential sliding interfaces were considered, the concrete interface between the basemat and the lean concrete will be roughened, and the new COL items will ensure that the COL applicant verifies the minimum CoF value of 0.55 at the site. The applicant also described the sliding evaluation methodology and provided markups in DCD Tier 2 Section 3.8.5.5.2, "Sliding Acceptance Criteria," and APR1400-E-S-NR-14006, Revision 1, Sections 4.2, "Stability Check of the NI Common Basemat," 4.2.1 "Overturning Check," and 4.2.2 "Sliding Check." However, the staff determined several items that should be addressed as described below:

1. In its response, the applicant stated, "The maximum shear forces induced by the SSE are greater than those induced by the wind load," and the applicant described only the seismic sliding stability evaluation. This implies that the sliding stability evaluation was not performed for wind. However, the staff notes that the required factor of safety for wind is 1.5 versus 1.1 required for seismic. Therefore, the applicant should provide an adequate basis for not considering wind in the stability evaluations for sliding and overturning.
2. The applicant should also include the results for all load combinations for stability evaluations that include seismic, wind, tornado, and buoyancy for the NI, EDGB, and DFOT in the DCD, or provide justification for not considering any of these in the DCD.
3. The applicant should confirm that the various analyses summarized in APR1400-E-S-NR-14006, Revision 1, for the NI and that the updates based on the various RAI responses have also been performed for the EDGB and DFOT. These should include sliding and overturning stability, soil bearing pressures, seismic basemat uplift (80 percent) criterion, and settlement.

In its response to RAI 255-8285, Question 03.08.05-14 (ML17009A400), for item 1, the applicant determined that the seismic load (SSE) governs over the wind load for the stability check for the NI. The staff found that the load combinations (LC2) that includes the wind is much greater than the corresponding minimum factors of safety in SRP Section 3.8.5-51.1.5; therefore, the staff considers the response to item 1, acceptable.

In its response for item 2, the applicant tabulated that the basemats stability evaluations in DCD Tier 2, Table 3.8A-15 for NI common basemat and Table 3.8A-38 for EDGB and DFOT

basemats showing that they are all over the corresponding minimum factors of safety in SRP Section 3.8.5-51.1.5, for all the load combinations; therefore, the staff considers item 2, acceptable.

Regarding item 3 above, the applicant indicated that APR1400-E-S-NR-14006, Revision 1, will be updated to incorporate the responses including sliding and overturning stability, soil bearing pressure, seismic basemat uplift and settlement for NI, EDG and DFOT. The applicant also stated that the methodology used for the EDG and DFOT is the same methodology used for the NI except for one item. The sliding evaluation of the NI due to seismic forces was performed using the time history method while the static method was used for the EDGB and DFOT. The staff finds this acceptable because the methodology is consistent with the criteria in SRP Section 3.8.5, for sliding stability evaluation. The staff noted that the markups provided in RAI 255-8285, Question 03.08.05-14 (ML17009A400), were provided for the NI but not for the EDGB and DFOT. However, since the methodology used for the EDGB and the DFOT is essentially the same as for the NI, the staff considers the responses to items 1 and 2, above acceptable. Based on the review of the DCD and APR14006-E-S-NR-14006, Revision 4, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-14, is resolved and closed.

The staff reviewed Section 2, "Site Profiles for the APR1400 Nuclear Island Common Basemat," of APR1400-E-S-NR-14006, Revision 1, which describes the generic site profiles and the analysis and design methods for the APR1400 NI common basemat. The staff reviewed this section and noted that additional information is needed in order to perform its safety review of the DCD application. Therefore, the staff issued RAI 255-8285, Question 03.08.05-16 (ML15293A569), requesting the applicant to provide additional information to ensure that the analysis and design methods for the foundation are acceptable. Section 2.2.1, "Elastic Modulus of Soil Sites," of the technical report describes the approach used to develop the static elastic modulus E_{static} and the dynamic elastic modulus $E_{dynamic}$ used in the finite element models. The staff requested the applicant to address the following items:

1. The approach for E_{static} is based on the relationship between E_{static} and the standard penetration test (STP) blow count. For the type of large structures in the APR1400 design, E_{static} is not normally generated using relationships based on STP blow counts. Therefore, the applicant is requested to use accepted industry methods for development of E_{static} .
2. The uncertainty in the relationships presented in APR1400-E-S-NR-14006, Revision 1, Section 2.2.1, between SPT blow count (N) and shear wave velocity (V_s) is very high. These SPT relationships are not normally considered acceptable for use in defining the soil properties for use in the analysis and design. The soil properties for the seismic and gravity loads are typically based on the shear wave velocity profiles assumed for the analysis of the plant structures. The applicant was requested to adequately address the uncertainty between the STB blow count and the shear wave velocity.
3. The approach used to develop $E_{dynamic}$ is based on the elastic modulus. From the information provided, it is not clear how this formulation was used to capture the effects of soil confinement when representing the soil by compression only truss elements in the model. The applicant was requested to provide a detail description regarding its approach for determining the $E_{dynamic}$.

4. In APR1400-E-S-NR-14006, Revision1, Section 2.2.1, "Shear Wave Velocities of APR1400 Sites," the applicant indicated that the ratio between E_{static} and $E_{dynamic}$ at the soil site is 0.1153. This ratio appears to be extremely low. The applicant was requested to update the approach to calculate the ratio $E_{static}/E_{dynamic}$ and confirm the adequacy of the resulting ratio based on other sources of information and industry practice.

In its response to RAI 255-8285, Question 03.08.05-16 (ML16237A373), the applicant provided information as discussed below, followed by the staff's evaluation for each item.

1. The applicant used empirical correlations of shear wave velocity with SPT blow counts as defined in the IBC Building Code along with other referenced papers and reports. In addition, the applicant incorporated reduction in effective modulus due to potential seismic strains induced by site ground motion effects. The result of this computation leads to a reduction in effective modulus with respect to the low strain elastic dynamic modulus. The ratio of static to dynamic modulus resulting from these assumptions is 0.1153.

The staff notes that this ratio is much lower than typically assumed in seismic evaluations where the static to dynamic ratio of elastic moduli is typically taken as about 0.5. Therefore, the staff concluded that the modulus E_{static} is a conservative estimate for determining the effective site subgrade modulus because it would overestimate the computed settlements.

The response further described that the COL applicant shall perform a site-specific evaluation of NI stability using the site-specific measured E_{static} , the APR1400 basemat model, and the methodology described in DCD Tier 2, Section 3.8.5. DCD Tier 2, Section 3.8.6 will be revised to include COL 3.8(13) [later revised to COL 3.8(20)], requiring the COL applicant to perform a site-specific evaluation of NI stability.

Therefore, the staff considers the response to item 1, acceptable; however, based on the revised response, item 1, is discussed further below.

2. The applicant responded that based on the uncertainty of the relationship between shear wave velocity and STP blow counts, the COL applicant shall perform a site-specific evaluation if the applicant site is found to have a shear wave velocity of less than 305 m/sec (1,000 ft/s). The applicant stated that a site-specific evaluation (differential settlement, soil bearing pressure and sliding evaluation [if needed]), and 3D FEM global analysis for basemat design of seismic Category I structures using the site-specific measured E_{static} , and methodology, as described in Subsection 3.8.5 of DCD Tier 2, and TR APR1400-E-S-NR-14006 shall be performed.

After its initial review, the staff determined that the following items still needed to be addressed:

- a. Based on additional information in the response, the maximum shear wave velocity for soil profile S1 used in the foundation media model varies and the maximum value equals 549 m/s (1,800 ft/s). Furthermore, the shear wave velocity for S1 at the surface (based on DCD Tier 2 Table 3.7A-1) is 358 m/s (1,173 ft/s). Thus, it would not be adequate for the COL applicant to perform a site-specific evaluation if the site is found to have a shear wave velocity less than 1,000 ft/s. This is inadequate because both the shear wave velocity at the surface and throughout the depth are greater than 305 m/s (1,000 ft/s). Therefore, the COL applicant should perform a site-specific evaluation if the site is found to have a shear wave velocity profile that is less than the shear wave velocity profile used in the various basemat evaluations.
- b. Based on the applicant's statement in its response, "using the site-specific measured E_{static} ," it can be interpreted that the site-specific analysis, if required, would only be performed for the static load cases. The applicant should explain why the COL applicant does not need to perform a site-specific evaluation for dynamic load cases as well if the site is found to have a shear wave velocity profile that is less than the shear wave velocity profile used in the various dynamic basemat evaluations. Alternatively, the applicant shall revise the COL 3.8(13) [later revised to COL 3.8(20)] to include static and dynamic load cases.
- c. The RAI response stated that the site-specific analyses would be needed for "(differential settlement, soil bearing pressure and sliding evaluation [if needed]) and 3D FEM global analysis for basemat design..." The applicant was requested to expand the term "differential settlement" to include "maximum vertical settlement, maximum tilt settlement, maximum differential settlement between structures and angular distortion," as described in the NRC's evaluation of RAI 255-8285, Question 03.08.05-7. The applicant should also explain what is meant by the phrase "[if needed]," whether it applies to "sliding evaluation" only, or it would apply to all of the loading evaluations.

Based on the revised response, item 2, is discussed further below.

3. The applicant responded that the 3D FEM foundation media model was used to compute the subgrade modulus for static loading cases. In order to represent the soil characteristics, the applicant used a soil spring model for the static loading case and used a foundation media model for dynamic loading case. The elastic modulus was not increased due to the soil confinement effects. However, the results (e.g., displacement and stress, etc.) from the 3D FEM foundation model reflects the effects due to confinement by the finite elements in 3D FEM foundation media. The applicant described that the nonlinear soil spring was developed for stability evaluation (differential settlement, bearing pressure) and structural design member forces of the basemat. The applicant calculated the subgrade modulus of the vertical soil spring based on the vertical displacement of each basemat node to capture the soil Boussinesq effect, and tabulated the range of vertical subgrade modulus (k_v) for soil profiles of S1, S4 and S8.

The applicant developed a foundation media model for the seismic loading combination, and the applicant used the strain-compactable shear wave velocity as described in DCD Tier 2 Table 3.7A-1, "Soil Layer and Properties (S1)," to calculate the dynamic elastic modulus for soil stiffness in the foundation media model based on the following equation:

$$E_{\text{dynamic}} = \rho V_s^2 \times [2 \times (1 + \mu)]$$

The staff reviewed the applicant's response and found it to be acceptable because, regarding the question on confinement effects, the applicant explained that the FEM foundation model does reflect soil confinement effects due to the confining effect of the finite elements in the 3D FEM foundation media, which was used in the dynamic load case analyses. The applicant also explained that for static load cases, soil springs are used where the confining effect is included because the spring constants were determined from the vertical displacement of the soil which was based on the same foundation media model. The staff also notes that the applicant stated that the soil profiles S1, S4, and S8 were used for the static load cases and dynamic load cases, which cover the range of soil profiles of soft, medium and stiff subgrade conditions. Therefore, the staff considers the response to item 3, acceptable.

4. The applicant described that the ratio of $E_{\text{static}}/E_{\text{dynamic}}$ equal to 0.1153 is extremely low, and this value was used for the basemat analysis in order to generate large settlements conservatively.

The staff agreed that the process used by the applicant to estimate settlements would generally result in conservative results. Furthermore, the applicant's response is also acceptable because a wide range of soil profiles S1, S4, and S8 are considered. Therefore, the staff considers the response to item 4, acceptable.

The staff reviewed the applicant's revised response to RAI 255-8285, Question 03.08.05-16, (ML17256A180), and concluded the following:

1. Regarding Item 1 in the RAI question, the staff confirmed that the applicant provided markups for DCD 3.8.5 and TR APR1400_E-S-NR-14006, Revision 3 regarding the calculation of E_{static} and E_{dynamic} , and revised COL 3.8(20) for performing site-specific evaluations for the NI stability.
2. For Item 2 in the RAI question, the staff concluded the following.
 - a. Based on the staff's review of the markup for DCD Tier 2, COL 3.8(20) was revised to state that the COL applicant shall perform site-specific evaluations if the shear wave velocity is less than the shear wave velocity profile used in the various basemat evaluations for DC. The staff finds this revision acceptable because it addresses the staff's concern regarding the shear wave velocity criterion discussed above.
 - b. Based on the staff's review of the markup for DCD Tier 2, COL 3.8(20) was revised to indicate that E_{static} and E_{dynamic} shall be used for the site-specific evaluations. This revision is acceptable because it addresses the staff's concern regarding the evaluation for both E_{static} and E_{dynamic} discussed above.

- c. Based on the staff's review of the markup for DCD Tier 2, COL 3.8(20) was revised to indicate that the site-specific evaluation shall be performed for settlement which consists of maximum vertical displacement, tilt, differential settlement between structures, and angular distortion. The COL was revised to delete the phrase, "if needed." In addition, the COL was revised to identify the various sit-specific analyses needed. The staff finds the revisions acceptable because it addresses the staff's concern regarding the types of settlements and types of site-specific analyses needed, and also removed the qualifying phrase, "if needed."

The staff finds the responses to items 3 and 4 acceptable and confirm the staff's evaluation of the applicant's response (ML16237A373), discussed previously.

Based on the above discussions, the staff considers the response to RAI 255-8285, Question 03.08.05-16, acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-16, is resolved and closed.

In Section 4.1.2, "Differential Displacement," of APR1400-E-S-NR-14006, Revision 1, the applicant described the approach used to develop the differential displacements within the NI and between the NI and the adjacent TGB. For seismic loading, the relative displacements were determined at only two specific time steps where the maximum average and minimum average of displacements over the entire time history were determined. The staff also noted that Section 4.1.2, indicates that the differential settlement for seismic loading was calculated based on the maximum and minimum displacements of the basemat, and it is not based on the differential settlements per 15 m (50 ft.).

The staff needed additional information in order to perform its safety review of the DCD application. Therefore, the staff issued RAI 255-8285, Question 03.08.05-17 (ML15293A569), requesting the applicant to describe in greater detail the approach used for differential displacement. The staff also requested the applicant to explain why the differential displacements were not considered for all time steps, which might lead to a higher differential displacement. Additionally, the staff noted that the applicant provided differential settlements between NI Basemat and TGB Basemat for the static loading case in Section 4.1.2. The staff noted that the differential settlement for S4 (moderate soil stiffness) is much larger than the differential settlements for S1 (soft soil) and S8 (stiff soil) properties. Therefore, the staff requested the applicant to address this inconsistency.

In its revised response to RAI 255-8285, Question 03.08.05-17 (ML17241A142), the applicant referred to RAI 255-8285, Question 03.08.05-7 (ML15293A569), for the detailed explanation and analysis of the effects from construction sequence on design and the various types of settlements during the construction sequence and post-construction phases of the NI. As a result, the markups for the DCD and APR1400-E-S-NR-14006, Revision 3, are provided in RAI 255-8285, Question 03.08.05-7. Therefore, the staff finds RAI 255-8285, Question 03.08.05-17, acceptable. Based on the review of the DCD and APR14006-E-S-NR-14006, Revision 4, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-17 is resolved and closed.

3.8.5.4.5 *Structural Acceptance Criteria*

The staff reviewed the structural acceptance criteria used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.5.

In DCD Tier 2, Section 3.8.5.5, "Structural Acceptance Criteria," the applicant described the structural acceptance criteria for the RCB and other seismic Category I structures. The applicant referred to the structural acceptance criteria in Sections 3.8.1.5, "Structural Acceptance Criteria," for the foundation of RCB and Section 3.8.4.5, "Structural Acceptance Criteria," for the foundations of AB and EDG building. For the stability evaluation of overturning, sliding, and flotation, the applicant referred to the acceptance criteria presented in DCD Tier 2 Table 3.8-10. The applicant also provided APR1400-E-S-NR-14006, Revision 1, which describes the stability evaluation and the construction sequence analysis of the NI common basemat, EDGB basemat and DFOT basemat.

DCD Tier 2, Section 3.8.5.5, "Structural Acceptance Criteria," also identified that the COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1, "Site Parameters," are met or exceeded, as described in COL 3.8(6). These design criteria include parameters of maximum settlement, maximum soil angle of internal friction, and allowable soil bearing pressure. Even though, the applicant identified the maximum differential settlement of foundations, it is not clear to the staff whether the scope (types of settlements) and maximum values for settlement are appropriate as discussed in SER Section 3.8.5.4.4. The issues and staff evaluation related to the settlement criteria were captured in RAI 255-8285, Question 03.08.05-7. The staff determined that the maximum value for the soil angle of internal friction of 35 degrees is acceptable because that results in a coefficient of friction of 0.70 which is larger than the value of 0.55 used in the sliding stability evaluation. The value of 0.70 would result in a larger resisting force to prevent sliding. Regarding allowable soil bearing pressure and building settlement values (maximum vertical settlement, tilt settlement, differential settlement between buildings and angular distortion), the adequacy of the acceptance criteria are captured under RAIs 255-8285, Questions 03.08.05-7, 03.08.05-9, 03.08.05-12, 03.08.05-14, 03.08.05-16, and 03.08.05-17, discussed in SER Sections 3.8.5.4.3, "Loads and Load Combinations," and 3.8.5.4.4, "Design and Analysis Procedures."

Regarding the acceptance criteria used for the various stability evaluations of sliding, overturning, and flotation presented in DCD Tier 2 Table 3.8-10, the staff found that the load combinations and corresponding minimum factors of safety are acceptable because they are in accordance with SRP Section 3.8.5-5I.I.5.

The staff reviewed the structural acceptance criteria given in the DCD Tier 2 Section 3.8.5.5, as to their application to the foundations of RCB and seismic Category I structures. The applicant described the structural acceptance criteria, RGs per the SRP guidance that are applicable for the structural acceptance criteria of the APR1400 foundations for the RCB and other seismic Category I structures. The staff found the use of these structural acceptance criteria in the design and construction of the foundations of the RCB and other seismic Category I structures to be in accordance with the guidance given in SRP Section 3.8.5.II.5 and RGs.

3.8.5.4.6 *Materials, Quality Control, and Special Construction Techniques*

The staff reviewed the material, quality control and special construction techniques used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.6.

In DCD Tier 2, Section 3.8.5.6, “Materials, Quality Control, and Special Construction Techniques,” the applicant referred to DCD Tier 2, Section 3.8.1, “Concrete Containment,” Section 3.8.4, “Other Seismic Category I Structures,” and Appendix 3.8A, “Structural Design Summary.” The applicant specified that the COL applicant that refers to the APR1400 DCD shall confirm that uneven settlement due to construction sequence of the NI basemat fall in the values specified in DCD Tier 2 Table 2.0-1. This information is identified as COL 3.8(7).

The staff reviewed the material, quality control and special construction techniques given in the DCD Tier 2, Sections 3.8.1.6 and 3.8.4.6, as to their application to the foundations of the RCB and other seismic Category I structures. The applicant described that the seismic Category I structures are poured-in-place reinforced concrete structures with the major materials used in the construction consisting of concrete, reinforcing bars and structural steel. The applicant further described the concrete ingredients (cement, aggregates, mixing water, admixtures, concrete mix design and concrete compressive strength), reinforcing bars and splices. The applicant referred, in DCD Tier 2, Sections 3.8.1.6, and 3.8.4.6, to the provisions of industrial codes and standards that the materials and quality control shall satisfy, and also referred to the provisions specified in ASME Code, Section III, Division 2; ACI 349, and ASTM.

The staff found that the use of these material, quality control and special construction techniques in the design and construction of the foundations of the RCB and other seismic Category I structures to be in accordance with the guidance given in SRP Section 3.8.5.6. On this basis, the staff concluded that the material, quality control and special construction techniques provided in DCD Tier 2 Section 3.8.5.6, are acceptable.

3.8.5.4.7 *Testing and Inservice Surveillance Requirements*

The staff reviewed the testing and inservice surveillance requirements used for the foundations to ensure that they meet the applicable requirements in 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5, and are in accordance with the guidance provided in SRP Section 3.8.5.II.7.

DCD Tier 2 Section 3.8.5.7, “Testing and Inservice Inspection Requirements,” indicates that testing and inservice surveillance in DCD Tier 2, Sections 3.8.1.7 and 3.8.4.7, are performed to meet the intended safety function of the seismic Category I foundations. The DCD indicates that the COL applicant that refers to the APR1400 DCD shall provide the necessary measures for foundation settlement monitoring of the site-specific conditions. This COL action item was identified as COL 3.8(8). The DCD Tier 2, indicates that the COL applicant that refers to the APR1400 DCD shall provide testing and inservice inspection programs to examine inaccessible areas of concrete structures for degradation and monitoring of ground water chemistry. This COL 3.8(9).

DCD Tier 2 Section 3.8.5.7, also identifies that the COL applicant that refers to the DCD APR1400, shall provide the following soil information for the APR1400 site:

1. Elastic shear modulus and Poisson's ratio of the subsurface soil layers,
2. Consolidation properties including data from one dimensional consolidation tests and time-versus-consolidation plots,
3. Moisture content, Atterberg limits, grain size analyses, and soil classification,
4. Construction sequence and loading history, and
5. Excavation and dewatering programs. This is identified as COL 3.8(10).

The staff reviewed the Sections 3.8.1.7 and 3.8.4.7, to verify that the testing, monitoring and maintenance of structures is performed in accordance with 10 CFR 50.55a and ASME Section XI for the RCB foundation and 10 CFR 50.65 and RG 1.160, for other seismic Category I structures. Maintenance of seismic Category I structures is supposed to be performed to ensure that design assumptions and margins in the original design basis are maintained, and are not degraded unacceptably. The adequacy of the testing, monitoring and maintenance of the RCB foundation in accordance with 10 CFR 50.55a and ASME Section XI is captured in SER Section 3.8.1. The adequacy of testing, monitoring and maintenance of the foundations for other seismic Category I structures, in accordance with 10 CFR 50.65 and RG 1.160, is captured under SER Section 3.8.4.

Based on ASME Section III, Division 2, CC-6000, the leak-tightness integrity of the as-built containment is verified by the structural integrity test prior to operation. The structural integrity test of the as-built containment was also listed in the ITAAC for the NI structures as item 2.c, in DCD Tier 1, Table 2.2.1-2, "Nuclear Island Structural ITAAC."

In DCD Tier 2, Figure 1.2-1, "Typical APR1400 Site Arrangement Plan," the applicant provided a diagonally lined pattern legend that identified the structures within the scope of the APR1400 DCD. These structures included the NI, EDGB block (EDGB and DFOT), compound building, essential service water/component cooling water heat exchanger (ESW/CCW HX) buildings, and turbine building. In DCD Tier 2 Table 3.2-1, the applicant identified which of these structures are seismic Category I structures. They include the NI, EDGB block, and ESW/CCW HX buildings.

In DCD Tier 1 Section 2.2.2, the applicant described that the EDGB block is located adjacent to the east side of the NI with a seismic isolation gap, and comprises two buildings, one that houses additional two generators EDGB and the other for the DFOT building. Furthermore, in DCD Tier 1 Table 2.2.2-1, the applicant tabulated the key dimensions of the EDGB and DFOT building. ITAAC are provided for the EDGB; however, the applicant did not provided any ITAAC items for the DFOT building.

In DCD Tier 1 Table 2.2.1-3, the applicant identified the ESW/CCW HX buildings as seismic Category I structures. However, DCD Tier 2, Sections 3.7.2 and 3.8.4, indicate that these are not considered as part of the APR1400 plant design, and COL 3.7(3) and COL 3.8(1) are identified to require the COL applicant to provide the seismic analysis and design of these structures. In DCD Tier 2, Section 3.8.6, "Combine License Information," COL 3.8(1) indicates

that the COL applicant is to provide the design of site-specific seismic Category I structures, which includes the ESW/CCW HX buildings. However, the applicant did not describe for the COL applicant the requirements of ITAAC items associated with the ESW/CCW HX buildings.

Based on the above, the staff issued RAI 255-8285, Question 03.08.05-6 (ML15293A569), requesting the applicant address the following:

1. The applicant is requested to provide the ITAAC items, associated figures, and related information for the DFOT building in DCD Tier 1, Section 2.2.2, "Emergency Diesel Generator Building."
2. The applicant is requested to describe for the COL applicant the ITAAC items associated with the ESW/CCW HX buildings in COL 3.8(1) in DCD Tier 2, Section 3.8.6, "Combine License Information."

In its response to RAI 255-8285, Question 03.08.05-6 (ML16036A129), item 1, the applicant described that the DCD Tier 1, Section 2.2.2.1, "Design Description," describes that the EDGB block includes the EDGB and the DFOT building. DCD Tier 1 Table 2.2.2-2, provides the ITAAC items for the EDG building block. The applicant committed to revise DCD Tier 1 Table 2.2.2-2, to clarify that the DFOT building is included in the EDG building block.

The staff finds the response to item 1, acceptable because the applicant clarifies that the DFOT building is part of the EDG block and thus, the ITAAC items identified in DCD Tier 1 Section 2.2.2, apply to the DFOT also, and the response complies with SRP Section 3.8.5.1.8.

In its response to item 2, the applicant described that ITAAC items (Tables 2.2.8-1 and 2.2.9-1) of the ESW/CCW HX buildings were provided in RAI 88-8046, Question 03.05.02-6. The applicant further described that the response includes the requirement to verify the buildings are designed and constructed to withstand the structural design basis loads, as noted in COL 3.8(1).

The staff finds the response to item 2, acceptable because the applicant's response to RAI 88-8046, Question 03.05.02-6, provides the ITAAC items for the ESW/CCW HX buildings, and are consistent with ITAAC items for other seismic Category I structures, and the response is consistent with SRP Section 3.8.5.1.8.

Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 255-8285, Question 03.08.05-6, is resolved and closed.

3.8.5.5 Combined License Information Items

DCD Tier 2, Section 3.8.5, contains the following COL information items. Based on the discussion above, the staff concludes that these COL information items are acceptable.

Table 3.8.5 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.8(11)	The COL applicant is to verify that the coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55.	3.8.5.1
COL 3.8(12)	The COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1 are met or exceeded.	3.8.5.5
COL 3.8(13)	The COL applicant is to verify that the coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55. In order to meet this requirement, the COL applicant is to determine the specific undulation pattern in Figure 3.8-27 for two perpendicular horizontal directions.	3.8.5.5.2
COL 3.8(14)	The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.	3.8.5.6
COL 3.8(15)	The COL applicant is to provide a site-specific monitoring program and to monitor maximum vertical settlement, differential settlement, tilt, and angular distortion to ensure that they are less than the criteria in Table 2.0-1, Table 3.8-12 through Table 3.8-14, and section 3.8.5.4.2.2.d during construction and plant operation.	3.8.5.7
COL 3.8(16)	The COL applicant is to provide testing and inservice inspection programs to examine inaccessible areas of concrete structures for degradation and to monitor groundwater chemistry.	3.8.5.7
COL 3.8(17)	The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.	3.8.5.7
COL 3.8(18)	A detailed construction sequence analysis to determine the resulting construction settlements, including the various standard soils profiles (S01-S04, S06-S09) and sequencing of concrete pours for the NI common basemat (RCB and Auxiliary Building), and superstructure model (Auxiliary Building, internal structures, and Shell & Dome), is presented in Section 3.8.5.4.2. A comparison of the four types of construction settlements (i.e. maximum vertical settlement, tilting settlement, maximum differential settlement between structures, and angular distortion) to the maximum criteria is summarized in Tables 3.8-12 through 3.8-14, and section 3.8.5.4.2.2.d.	3.8.6

Item No.	Description	Section
	<p>The COL applicant should use the construction sequence settlement analysis given in Section 3.8.5.4.2, substituting site-specific soil layer conditions, to ensure that the four types of settlement criteria described in Table 3.8-12 thru Table 3.8-14, and section 3.8.5.4.2.2.d are satisfied. An alternative construction sequence and settlement analysis may be performed by the COL applicant in response to 1) the inability to meet the settlement criteria described in Table 3.8-12 thru Table 3.8-14, and section 3.8.5.4.2.2.d using the DCD approach discussed in Section 3.8.5.4.2 or 2) Other site specific factors that may require a different construction plan and foundation sequence. However, in either case the COL applicant shall satisfy four types of settlement criteria described in Table 3.8-12 thru Table 3.8-14, and section 3.8.5.4.2.2.d.</p>	
COL 3.8(19)	<p>The following items need to be considered by the COL applicant.</p> <ol style="list-style-type: none"> 1) The surveyed soil profiles will be developed. 2) Based on the surveyed soil characteristics, differences from the DCD soil profiles may exist. These differences may include: <ol style="list-style-type: none"> a. Stiff or soft soil areas; b. Different soil types (e.g, cohesive); c. Potential for loss of cement in the mudmat; d. Non-uniformity of soil layers, or e. Other differences in the soil profile from the properties assumed in design certification. <p>If any of these items or conditions are identified, then a site-specific evaluation shall be performed and the item or condition shall be checked for adequacy.</p> 3) The time (i.e., short term and long term), instantaneous settlement and time-consolidation effects shall be evaluated in accordance with surveyed soil profiles regardless if a site-specific evaluation is needed under Item 2) above. The bearing pressure shall be checked to demonstrate acceptability with the acceptance criteria in DCD Table 2.0-1. Settlements shall be checked in Table 3.8-12 thru Table 3.8-14, and section 3.8.5.4.2.2.d. 4) The COL applicant will build the seismic Category I structure according to the construction sequence used in the site-specific construction sequence analysis. 5) If a site-specific evaluation is required, the COL applicant should perform a construction sequence analysis based on the site-specific parameters. If the settlement, including results of construction sequence analysis, exceeds the acceptance criteria described in Table 3.8-12 through Table 3.8-14, and section 3.8.5.4.2.2.d, the construction sequence will be modified to meet the acceptance criteria described in Table 3.8-12 through Table 3.8-14, and section 3.8.5.4.2.2.d, by the COL applicant.. 	3.8.6

Item No.	Description	Section
	6) The effect on the design for seismic Category I structures due to construction sequence analysis shall be accounted for by the COL applicant.	
COL 3.8(20)	The COL applicant shall perform site-specific evaluations if the shear wave velocity is less than the shear wave velocity profile used in the various basemat evaluations for design certification. The site-specific evaluations ([settlement (maximum vertical displacement, tilt, differential settlement between structures, angular distortion), soil bearing pressure (static and dynamic loading cases), overturning, and sliding]) and 3D FEM global analysis for basemat design of seismic Category I structures shall be performed using the site-specific parameters (measured Estatic, Edynamic consistent with soil strain assumed in SSI anlysis) and the methodology described in DCD Tier 2, Subsection 3.8.5 and Technical Report, APR1400-E-S-NR-14006, Subsection 4.	3.8.6
COL 3.8(21)	The COL applicant is to confirm that the parking position of the crane and trolley when the crane is not being used is: location of polar crane: Az.280°, trolley location: 12 ft 7 in away from end of east part. The COL applicant is to confirm that this requirement is included in the technical specification of the COL application for the use of the polar crane.	3.8.1.3.2

The staff finds the above list complete and adequately describes actions necessary for the COL applicant. The staff considers COL 3.8(8) and COL 3.8(11) through COL 3.8(21), acceptable.

3.8.5.6 Conclusion

The staff reviewed DCD Tier 2, Section 3.8.5, to determine whether the design, fabrication, construction, testing, and ISI of seismic Category I foundations comply with 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5. The staff concludes that the applicant meets the relevant requirements of 10 CFR 50.55a; 10 CFR Part 50, Appendix B; and GDC 1, GDC 2, GDC 4, and GDC 5. The basis for this conclusion is the following:

1. The applicant meets the requirements of 10 CFR 50.55a and GDC 1, to ensure that the seismic Category I foundations are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed, by meeting the applicable codes, standards, and specifications in DCD Tier 2 Section 3.8.5, which refers to the documents identified in DCD Tier 2, Sections 3.8.1.2 and 3.8.4.2.
2. The applicant meets the requirements of GDC 2 to ensure that the seismic Category I foundations are able to withstand the most severe natural phenomena, by analyzing and designing these foundations to withstand the most severe earthquake, wind, tornado, and external flood loads that have been established for the APR1400 certified design.

3. The applicant meets the requirements of GDC 4 to ensure that the seismic Category I foundations are appropriately protected against other dynamic effects, by analyzing and designing these structures, where applicable, to withstand the dynamic effects due to pipe whipping, missiles, and discharging fluids associated with the LOCA.
4. The applicant meets the requirements of GDC 5 to ensure that SSCs are not shared between units or that sharing will not impair their ability to perform their intended safety functions, since this DC is for only one unit.
5. The applicant meets the requirements of 10 CFR Part 50, Appendix B, to provide a quality assurance program for the design, construction, and operation of SSCs, by meeting the applicable codes, standards, and specifications in SRP Section 3.8.5, which refers to the documents identified in DCD Tier 2, Sections 3.8.1.2 and 3.8.4.2.

The use of these criteria, as defined by applicable codes, standards, and guides; loads and loading combinations; design and analysis procedures; structural acceptance criteria; materials, quality control programs, and special construction techniques; and testing and in-service surveillance requirements provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes and various postulated accidents occurring within and outside the seismic Category I foundations, the seismic Category I foundations will withstand the specified conditions without impairment of their structural integrities or safety functions.

3.9 Mechanical Systems and Components

3.9.1 Special Topics for Mechanical Components

3.9.1.1 Introduction

This section provides the staff's evaluation of the applicant's description of certain special topics for mechanical components, defined in SRP Section 3.9.1. The staff's evaluation considered whether the submitted information complies with or conforms to the requirements, codes and standards, and the regulatory guidance on the methods of analysis for seismic Category I components and supports, including both those designated as ASME BPV Code, Section III, Class 1, 2, 3, or core support (CS), and those not covered by the ASME Code. This section also describes design transients for Code Class 1 and core support components and supports.

3.9.1.2 Summary of Application

The applicant has provided a DCD Tier 2 description in Section 3.9.1, "Special Topics for Mechanical Components," summarized, in part, below.

DCD Tier 2, Section 3.9.1.1, "Design Transients," describes the design transients for each of five service or test conditions defined in ASME BPV Code Section III and the frequencies (number of cycles) for each transient assumed in the Code design and fatigue analyses of RCS Class 1 components, auxiliary Class 1 components, RCS component supports, and reactor internals. The number of cycles assumed for each design transient was based on a 60-year design life.

DCD Tier 2, Section 3.9.1.2, "Computer Programs Used in Analyses," identifies the computer programs that are used for static, dynamic, and hydraulic transient analyses of mechanical system components.

DCD Tier 2, Section 3.9.1.3, "Experimental Stress Analysis," states that experimental stress analysis is not used for the APR1400 design.

DCD Tier 2, Section 3.9.1.4, "Considerations for the Evaluation for the Faulted Condition," identifies seismic Category I RCS Items and the faulted condition for non-code items. The faulted condition (Level D loading) is used in the design-basis pipe breaks described in Section 3.6.2. The resultant component and support reactions are specified, in combination with the appropriate normal operating and seismic reactions, for design verification by the methods described below and in Subsection 3.9.3. Inelastic methods defined in the ASME BPV Code Section III, such as plastic instability or limit analysis methods are not used.

3.9.1.3 *Regulatory Basis*

The relevant requirements of the Commission's regulations for this area of review, and the associated acceptance criteria, are given in SRP Section 3.9.1, Revision 3, and are summarized below. Review interfaces with other SRP sections also can be found in SRP Section 3.9.1.

The relevant requirements of the Commission's regulations for this area are also found in Federal Regulations 10 CFR Part 52.

- Part 50 of 10 CFR, Appendix A, GDC 1, requires, in part, that components important to safety be designed, fabricated, erected, and, tested to quality standards commensurate with the importance of the safety functions to be performed.
- GDC 2, states in part, components important to safety be designed to withstand seismic events without loss of capability to perform their safety functions.
- GDC 14, states that the RCPB be designed, fabricated, erected and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.
- GDC 15, states that the reactor coolant system and associated auxiliary, control and protection systems be designed with sufficient margin to assure that the design conditions of the RCPB are not exceeded during any condition of normal operation, including AOOs.
- Section 52.47(a)(19) of 10 CFR, requires an application to include a description of the quality assurance program applied to the design of the SSCs of the facility. Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," sets forth the requirements for nuclear power plants. The program for a nuclear power plant shall include a discussion of how the applicable requirements of Appendix B to 10 CFR Part 50, were satisfied.
- Section III of Appendix B to 10 CFR Part 50, addresses design control requirements for Quality Assurance Criteria.

- Section 52.47(a) of 10 CFR, in part, requires an application to include the information necessary to demonstrate that the standard plant complies with the earthquake engineering criteria in 10 CFR Part 50, appendix S.
- Section IV(a)(ii) of Appendix S to 10 CFR Part 50, requires an application, in part, to demonstrate the suitability of the plant design bases for mechanical components in consideration of site seismic characteristics.

Specific SRP acceptance criteria acceptable to meet the relevant requirements identified above are summarized below.

- As described in Section II 1 of SRP Section 3.9.1, to meet the requirements of GDC 1, 2, 14, 15, and 10 CFR Part 50, Appendix S, the applicant should provide a complete list of transients to be used in the design and fatigue analysis of all ASME BPV Code Class 1 and core support components, supports, and reactor internals within the RCPB. The number of events for each transient and the number of load and stress cycles per event and for events in combination should be included.
- To meet the requirements of 10 CFR Part 50, Appendix B, and GDC 1, a list of computer programs to be used in dynamic and static analyses to determine the structural and functional integrity of seismic Category I ASME BPV Code and non-Code items and the analyses to determine stresses should be provided. The staff reviews computer programs that are used for static, dynamic, and hydraulic transient analyses as they relate to plant design, and determines to establish the acceptability of these computer programs.
- To meet the requirements of GDC 1, 14, and 15, if experimental stress analysis methods are used in lieu of analytical methods for any seismic Category I ASME BPV Code or non ASME BPV Code items, the section of the SAR addressing the experimental stress analysis methods is acceptable if the information meets the provisions of Appendix II to ASME BPV Code, Section III, Division 1, and, as in the case of analytical methods, if the information is sufficiently detailed to show that the design meets the provisions of the ASME BPV Code required "Design Specifications." The staff reviews the experimental methods to determine if they are meeting the ASME BPV Code requirements.
- To meet the requirements of GDC 1, 14, and 15 when Service Level D limits (ASME stress allowable of plant faulty condition) are specified by the applicant for ASME BPV Code Class 1 and core support components and for supports, reactor internals, and other non ASME BPV Code items, the methods of analysis to calculate the stresses and deformations should conform to the methods outlined in Appendix F to ASME BPV Code, Section III, Division 1. The staff reviews these methods of analysis that are subjected to the conditions addressed in SRP Section 3.9.1.III.4.

3.9.1.4 *Technical Evaluation*

The staff reviewed the information in DCD Tier 2 Section 3.9.1, relative to the design transients and methods of analysis used for all seismic Category I components, component supports, core support structures, and reactor internals designated as Class 1, 2, 3, and CS under ASME BPV Code, Section III, and those components not covered by the code. The staff

reviewed DCD Tier 2 Section 3.9.1, to ensure information on design transients for Code Class 1 and core support components and supports was provided. The staff's review included the following topics:

- transients used in the design and fatigue analyses of all Code Class 1 and core support components, supports, and reactor internals
- description and verification of all computer programs to be used in analyses of seismic Category I Code and non-Code items
- descriptions of the analysis methods to be used if the applicant elects to use elastic-plastic stress analysis methods in the design of any components

The experimental stress analysis technique mentioned in SRP Section 3.9.1, is not used in the APR1400 design and is not evaluated further in this section.

The environmental conditions to which all safety-related components will be exposed over the life of the plant, as mentioned in SRP Section 3.9.1, are addressed through multiple SER Sections, including SER Section 3.11 (on environmental qualification), SER Section 3.12 (which includes discussion of environmentally assisted fatigue), and SER Section 6.2.1 (on materials).

3.9.1.4.1 *Design Transients*

This section evaluates the acceptability of the transients (including the number of cycles and events expected over the service lifetime of the plant) used in the design and fatigue analysis of ASME BPV Code Class 1 and CS components, supports, and reactor internals within the RCPB. The number of events for each transient and the number of load and stress cycles per event and for events in combination is evaluated.

The staff reviewed the design transients specified in DCD Tier 2 Section 3.9.1, and other sections that used the design transients in the design and fatigue analysis of ASME BPV Code components for the plant design life. The applicant makes the following design commitments in other sections of the DCD that relate to this review area:

- In DCD Tier 2 Subsection 3.9.3.1.1, the applicant specifies that the design transients for ASME BPV Code, Section III, Class 1 components, core supports and piping are provided in DCD Tier 2, Table 3.9-1.
- In DCD Tier 2 Section 3.9.3.1.3, the applicant specifies that the ASME Class 2 and 3 components that are subject to thermal or dynamic cyclic loads are evaluated for their fatigue sustainability using the ASME BPV Code Section III NC-3219.2. Fatigue analyses for ASME Class 2 and 3 components are also performed in accordance with NC-3200 for the components that do not meet the NC 3219.2 criteria.
- In DCD Tier 2 Section 3.9.3.1.2, the applicant specifies that the design transients for reactor internals are identified in Subsection 3.9.1.1.
- In DCD Tier 2 Section 3.12.5.2, the applicant specifies that the RCS design transients used for the design and fatigue analysis of ASME Class 1 piping systems and support components are addressed in Table 3.9-1.

The staff's evaluation of several topics related to DCD Tier 2 Section 3.9.1, is presented in other sections of this report. In addition to the design transients listed in DCD Tier 2 Table 3.9-1, the loadings produced by seismic events are also applied in the design of components and support structures of the RCS. The number of cycles pertaining to fatigue effects of cyclic motion associated with the seismic events is provided in SER Section 3.7.3. Design loading combinations for ASME BPV Code Class 1, 2, and 3 components are addressed in SER Section 3.9.3. The thermal stratification of piping is addressed in SER Section 3.12.

In DCD Tier 2 Section 3.9.1.1.3, the staff found that no transient events were classified as Service Level C conditions. In a letter dated June 1, 2015 (ML15152A248), the applicant clarified that the same events have been addressed, but were generally re-categorized in a conservative fashion. Based on the recent nuclear power plant industry data, the frequencies of events traditionally categorized as a Service Level C condition are conservatively modified to be classified as a Service Level B condition for design purposes. The DCD will be updated to clarify differences from previous NRC guidance on Service Level C conditions, and proposed revisions were provided to the staff as an enclosure to the letter. The staff finds that the changes meet the staff's guidance on the Service Level C condition and ANSI/ANS-51.1 provisions. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

The staff also noted, that DCD Tier 2 Table 3.9-1, includes the design transient of steam generator tube rupture (SGTR) as a Service Level D condition. In ANSI/ANS-51.1, SGTR is classified as a plant condition 3 event, which appears to be equivalent to the severity of Level B or C events in the APR1400 design. The staff issued RAI 73-8025, Question 03.09.01-3 (ML15196A599), requesting that the applicant justify why the SGTR is included as a Level D event. In its response to RAI 73-8025, Question 03.09.01-3, (ML15239B449), the applicant provided justification for the classification of the SGTR event. Specifically, the applicant stated that SGTR is classified as a Level D event in the System 80+ design. Classification of the APR1400 SGTR event is also based on the Korean OPR1000 design practice, in which a SGTR is also classified as a Level D event. Based on this information, which is consistent with design transients previously certified by the NRC for the System 80+ design, the staff concludes that the classification of the SGTR event provides adequate margin for the design of the RCPB. The staff considers the response to RAI 73-8028, Question 03.09.01-3, acceptable because the applicant stated that SGTR is classified as the same Level D event in the certified System 80+ design. Therefore, RAI 73-8028, Question 03.09.01-3, is resolved and closed.

DCD Tier 2 Table 3.9-1, presents the APR1400 design basis initiating events and frequencies used in the stress analysis of ASME BPV Code Class 1 and Class CS components of the primary system. The staff noted that the number of event occurrences listed in this table is either higher or lower than the number of event occurrences for similar events listed in NUREG-1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," dated August 1994 (ML003711752), Section 3.9.1. SRP Section 3.9.1.III.1, states that the list of transients, the number of events estimated for each transient presented in the application, and the method for determining this number are compared to the same information on similar and previously licensed applications and to the acceptance criteria outlined in Subsection II of this SRP section. Any deviations from previously accepted practice are to be noted and the applicant should justify them. The staff noted that DCD Tier 2 Table 3.9-1, has significantly different values for number of design transient occurrences compared to the design

transients of a similar certified design application. Therefore, the staff issued RAI 73-8025, Question 03.09.01-1 (ML15196A599), requesting the applicant to provide, in accordance with the SRP Section 3.9.1.III.1, the bases for these variations (higher/lower cycles), as compared to previously licensed or certified applications.

In its response to RAI 73-8025, Question 03.09.01-1 (ML15239B449), the applicant stated that event frequencies for the APR1400 are based on those of the OPR1000, which has adopted the System 80+ design and was a reference design for the APR1400 development. Event frequencies of the OPR1000 are similar to those of the System 80+, which was previously certified by the NRC. The response presented a detailed comparison table of the APR1400 and System 80+ event frequencies. The design life of the OPR1000 is 40 years, whereas the APR1400 design generally assumes a 60-year design life (as was the case for the System 80+ design).

The response also included the applicant's general guidelines for determining the APR1400 event frequencies, which the staff agrees are conservative for designing plant equipment. The majority of the design basis events and frequencies are greater than or equal to the given System 80+ events. The staff finds these to be consistent with previously accepted practice and therefore to provide reasonable assurance of appropriate design margin. The applicant provided additional justification for those frequencies that were lower than those previously established and accepted for the System 80+ design, as follows. For each item presented in the RAI response, the staff found the applicant's justification to be reasonable and consistent with previously approved practice. Therefore, the staff considers RAI 73-8025, Question 03.09.01-1, resolved and closed. Additional evaluation of the transients and number of expected cycles is presented in SER Chapter 15.

- Low power operation: The applicant evaluated the expected number of low-power occurrences considering the relatively short period of plant startup and operation at low power (below 15 percent). The assumed number of cycles represents low power operation (including increases and decreases of power) as it occurs on an approximate monthly basis for 60 years, which the staff views as conservative based on current operating plant experience, even though the 1600 events noted is less than the 2000 events assumed for System 80+. This low-power event includes turbine power steps and ramps to increase and decrease power between 5 and 15 percent, as well as manual control below 5 percent power.
- Heatup and cooldown: The applicant estimated 250 heatup and cooldown cycles for refueling and unplanned maintenance outages over the 60-year design life. This value corresponds to two outages per year during most of plant life and 30 outages during the initial startup test period, plus an additional 100 cycles added for conservatism to address other potential upset events. Although the System 80+ design assumed 300 cycles, the value of 250 is viewed as conservative by the staff based on current operating plant experience. The heatup and cooldown transient also includes manual operation of the auxiliary spray system and operation of the shutdown cooling system. Similarly, the frequency of reactor coolant pump startup and coastdown is adjusted to match the same 250 cycles for 4 pumps (1000 cycles), with an additional 1000 cycles added for margin, resulting in 2,000 cycles. Again, although this is less than the value for System 80+ (4,000 cycles), the staff views this number of cycles to be conservative based on current operating experience.

- Additional operating experience: The applicant also reduced the number of cycles for several events (natural circulation cooldown, control element assembly withdrawal, and CVCS malfunction) compared to the System 80+ design. For these events, the applicant referenced operating experience documented in NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995," and NUREG/CR-6928, "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," issued February 2007, and clarified how additional margin was provided above the observed number of cycles. The staff found these justifications to be reasonable based on current operating experience.
- Check valve operability tests: The applicant adjusted the number of safety injection and shutdown cooling system check valve tests to 120 (rather than 500 estimated for System 80+) because the test plans indicate they are conducted during refueling outages, which are expected to occur at most once per year during the life of the plant. The staff considered this justification to be reasonable and appropriately conservative.

In DCD Tier 2 Table 3.9-1, note (1), the applicant stated that the design life for RCS main components and Class 1 piping is 60 years, and the design life for Class 2 and 3 piping and other components except RCS main components is 40 years. Similar to the question above, to support the staff's finding associated with SRP Section 3.9.1.III.1, the staff issued RAI 73-8025, Question 03.09.01-2 (ML15196A599), requesting the applicant to provide the basis for designing Class 1 piping and components for 60 years and Class 2 and 3 piping and components for 40 years, as well as to provide the basis for the number of transient cycles in DCD Tier 2 Table 3.9-1, when the 40 year and 60-year columns are identical.

In its response to RAI 73-8025, Question 03.09.01-2 (ML15239B449), the applicant clarified in its response to RAI 73-8025, Question 03.09.01-2, that certain replaceable SSCs in the Class 2 and 3 systems have a 40-year design life, after which an evaluation can be conducted to assess acceptable continued operation and repair or replacement can be conducted if required. Given that the duration for a potential combined license referencing the APR1400 design would be 40 years (regardless of any design analysis for a longer design life), with reevaluation by the NRC for any potential license extension, this approach is acceptable to the staff. In addition, the applicant presented information on the number of cycles for opening of the economizer feedwater control valve and certain leak tests, which are considered to be the same for a 40-year and 60-year design life. Similar to other transients discussed above, the values selected are based on conservative estimates for the number of startup cycles and refueling outages, and are viewed by the staff as appropriate for either design life. Therefore, the staff finds that the applicant's RAI response with regard to the design life for Class 1, 2, and 3 piping and components acceptable, since the applicant provided the acceptable conservative design transients for designing Class 1 piping and components. Therefore, RAI 73-8025, Question 03.09.01-2 is resolved and closed.

In DCD Tier 2, Chapter 16, Subsection 5.5.5 "APR1400 Technical Specifications," the applicant describes the program of technical specifications. This program provides the controls to track the cyclic and transient occurrences to ensure that components are maintained within the design limits. Additional evaluations of generic technical specifications are detailed in SER Chapter 16.

In DCD, Tier 2 Table 3.9-1, note (2), the applicant stated that although APR1400 will be operated as a base load plant, the effects of daily load follow operation are accounted for in the structural design and analysis of ASME Code Class 1 components, reactor internals, and component supports. In its response to RAI 293-8332 Question 04-03-4 (ML17107A407), the applicant stated that the APR1400 is a base load plant but it has the load change capability for normal power maneuvers and unexpected load transients. The applicant clarified that the APR1400 license is requested to be certified for a base load plant. The staff found the applicant's clarification acceptable, since note (2) states that the applicant seeks certification of the APR1400 as a base load plant.

3.9.1.4.2 *Computer Programs Used in Analyses*

This section evaluates the applicant's use of computer programs for analysis and design of seismic Category I structures, components, and equipment to verify that these computer codes meet the requirements of 10 CFR Part 50, Appendix B, and GDC 1, as described in SRP Section 3.9.1.II.2.

To support the staff's review of the information in the DCD, the staff conducted an audit in June and July 2015 of the detailed supporting documents associated with the computer programs used for static, dynamic, and hydraulic transient analyses in the APR1400 design. In particular, the staff audited the verification and validation (V&V) documents of the computer programs. In general, the staff found that KHNP's V&V methodologies for the computer programs are acceptable and consistent with relevant industry standards. Audit reports (ML15219A289 and ML15219A687), document the staff's observations and the applicant's responses. Specifically, the follow-up audit confirmed that the staff's observations from the initial audit were incorporated into the V&V reports and sensitivity analyses. In this follow-up audit, the staff observed a remaining inconsistency in the referenced material for the steam generator tubesheet. The staff confirmed that the materials used for the steam generator tubesheet as specified in the sensitivity analyses were acceptable, because the materials conform to the ASME Section II requirements as incorporated by reference in 10 CFR 50.55a. The staff finds that all of the technical issues raised during the audits have been addressed. DCD Tier 2, Subsection 3.9.1.2.1, "Code Class Systems, Components, and Supports" provides a list of computer programs used for analysis. The descriptions provided are consistent with the use of these codes described elsewhere in the DCD, as well as with the staff's recent experience with computer codes used for DC. The list is also complete with the exception of one computer code identified by the staff. During an audit related to DCD Tier 2 Section 3.9.2, the staff observed that one of the audited reports indicated that the computer code "DPVIB" was used in the design of the NSSS. However, DCD Tier 2 Section 3.9.1, has no description of this computer code. Therefore, the staff issued RAI 73-8025, Question 03.09.01-4 (ML15196A599), requesting the applicant to describe the computer code. In its response to RAI 73-8025, Question 03.09.01-4 (ML15239B449), the applicant clarified that the DPVIB program is not used to analyze stresses in determining the structural or functional integrity of the reactor internals. As such, the applicant stated that the program does not generate sufficiently significant information such that it should be listed in the DCD. The applicant also noted that other operating nuclear units that are prototypes for the APR1400 reactor internals have not included a description of the DPVIB computer code in their applications.

Subsequently, the staff audited the DPVIB computer program according to the audit plan (ML16137A187) of Sections 3.9.1 and 3.9.2. During the audit, the staff reviewed the V&V

reports of the DPVIB computer programs, V&V methodologies and benchmarks in order to determine the acceptability of DPVIB. The summary of this audit is detailed in staff's report (ML17101A449). As a result of the audit, the staff concluded that the output of the DPVIB is consistent with the test data and shows slight conservatism. Therefore, the staff found the output of DPVIB acceptable. During the audit, the applicant provided the DCD markups that included the description of DPVIB computer program and the staff found the DCD markup acceptable. Subsequently, the staff confirmed incorporation of the changes that included the description of DPVIB computer program in DCD Tier 2.

3.9.1.4.3 *Considerations for the Evaluation of Faulted Conditions*

In DCD Tier 2 Section 3.9.1.1, the applicant states that the methods of analysis to calculate the stresses and deformations for faulted conditions will conform to the methods in ASME BPV Code Section III, Division 1, Appendix F. The staff reviewed this DCD section and other applicable portions of DCD Tier 2, such as Sections 3.9.3 and 3.9.5, to confirm that Appendix F is referenced when Service Level D limits are specified for Code Class 1 and core support components, as well as for supports, reactor internals, and other non-code items.

Based on its review of the information in the DCD, the staff finds that the evaluation of faulted conditions conforms to ASME BPV Code Section III, Appendix F, as referenced in SRP Acceptance Criterion 4 of SRP Section 3.9.1, and is, therefore, acceptable.

In DCD Tier 2 Section 3.9.1.3, the applicant states that the experimental stress analysis is not used for the APR1400. The staff finds this design information acceptable because the experimental stress analysis is not used for the APR1400 design.

In DCD Tier 2 Section 3.12.5.10, the applicant states that the structural evaluations are performed using elastic and/or simplified elastic-plastic analyses in accordance with the ASME BPV Code. The staff finds that the methodologies of stress analysis are acceptable because these are performed in accordance with the ASME BPV Code, consistent with SRP Section 3.9.3. Additional evaluations of stress analysis are detailed in SER Sections 3.12 and 3.9.3.

The applicant uses RG 1.207, "Guideline for Evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components Due to the Effects of the Light-Water Reactor Environment," for the design of the piping and components that are subjected to the design transients and environment assisted fatigue. Additional evaluations of piping and components that are subjected to the environment assisted fatigue are detailed in SER Sections 3.12 and 3.9.3, respectively. Additional detailed evaluations of the environmental conditions to which all safety-related components that exposed over the life of the plant are evaluated in SER Section 6.1.1.

3.9.1.5 *Combined License Information Items*

There are no COL items related to DCD Tier 2 Section 3.9.1.

3.9.1.6 *Conclusion*

Based on the evaluation presented above, the staff concludes the following:

- The applicant has met the relevant requirements of 10 CFR Part 50, Appendix B, and GDC 1 by demonstrating the applicability and validity of the design methods and computer programs used for the design and analysis of seismic Category I SSCs, consistent with industry standards for V&V of computer programs.
- The applicant has met the relevant requirements of GDC 2 and 10 CFR Part 50, Appendix S, by including design transients and seismic events as part of the design basis for withstanding the effects of natural phenomena. Additional staff evaluation of the use of seismic cycles in the fatigue evaluation for APR1400 is presented in SER Sections 3.7.3, 3.9.3, and 3.12.
- The applicant has met the relevant requirements of GDC 14 and GDC 15 by demonstrating that the design transients and consequent loads and load combinations (as discussed further in SER Section 3.9.3) provide appropriate design and service limits for design of the RCPB for all conditions and events expected over the service lifetime of the plant.

3.9.2 Dynamic Testing and Analysis of Systems, Components, and Equipment

3.9.2.1 Introduction

This section of the DCD provides the analytical methodologies, testing procedures, and dynamic analyses employed by the applicant to ensure the structural and functional integrity of piping systems, mechanical equipment, reactor internals, certain components, and their supports under vibratory loadings, including those due to fluid flow and postulated seismic events.

This section addresses six main areas of review:

- piping vibration, thermal expansion, and dynamic effects testing
- seismic analysis and qualification of seismic Category I mechanical equipment
- dynamic response analysis for reactor internals under operational flow transients and steady-state conditions
- preoperational flow-induced vibration testing of reactor internals
- dynamic system analysis of the reactor internals under faulted conditions
- correlations of reactor internals vibration tests with the analytical results

Each of these areas of review is addressed in more detail below. This discussion includes a summary of the application and the regulatory basis.

3.9.2.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Section 2.4.1, "Reactor System," related to reactor internals flow induced vibration (FIV) tests, and DCD Tier 1, Section 2.14, "Initial Test Program," which provides a non-system based description of the APR1400 initial test program (ITP).

DCD Tier 2: The applicant provided a DCD Tier 2 discussion in Section 3.9.2, supplemented by the technical reports listed below. This section provides the criteria, testing procedures, and dynamic analyses employed to assure that equipment maintains its structural and functional integrity for normal, off-normal, and postulated loads/events in accordance with the acceptance criteria to meet the regulatory criteria described in Section 3.9.2.3 below. In accordance with the provision of RG 1.20, regulatory position C.1.4, the applicant classifies the APR1400 reactor internals as non-prototype Category I, with the Palo Verde Nuclear Generating Station (PVNGS) Unit 1, Westinghouse System 80 reactor vessel internals (RVI) as the valid prototype.

ITAAC: The ITAAC associated with DCD Tier 2 Section 3.9.2, are given in DCD Tier 1, Sections 2.4.1 and 2.14.

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

Technical Reports: The technical reports supporting the information presented in DCD Tier 2 Section 3.9.2, are as follows:

- APR1400-Z-M-NR-14009, Revision 1, "Comprehensive Vibration Assessment Program for the Reactor Vessel Internals," February 2017 (Proprietary)
- APR1400-Z-M-NR-14010, Revision 0, "Structural Analysis of Fuel Assemblies for Seismic and Loss of Coolant Accident Loading," November 2014 (Proprietary)
- APR1400-E-S-NR-14004, Revision 0, "Evaluation of Effects of HRHF [Hard Rock High Frequency] Response Spectra on SSCs," November 2014 (Proprietary)
- APR1400-E-S-NR-14001, Revision 0, "Seismic Design Bases," November 2014 (Proprietary)

3.9.2.3 *Regulatory Basis*

The relevant requirements and the associated acceptance criteria are given in SRP Section 3.9.2, and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 3.9.2.

- The requirements in 10 CFR 50.55a, as it relates to the design, fabrication, erection, and testing of SSCs in accordance with quality standards commensurate with the importance of the safety function to be performed.
- 10 CFR Part 50, Appendix A, GDC 1, as it relates to the design, fabrication, erection, and testing of SSCs in accordance with quality standards commensurate with the importance of the safety function to be performed.
- GDC 2, as it relates to the ability of SSCs, without loss of capability to perform their safety function, to withstand the effects of natural phenomena, such as earthquakes, tornadoes, floods.
- Part 50 of 10 CFR, Appendix S, Section IV(a)(ii), as it relates to certain SSCs that must be designed to remain functional for a SSE.

- GDC 4, as it relates to the protection of SSCs 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.
- GDC 14, as it relates to designing SSCs of the RCPB to have an extremely low probability of rapidly propagating failure and gross rupture.
- GDC 15, as it relates to designing the reactor coolant system (RCS) with sufficient margin to assure that the RCPB is not exceeded during normal operating conditions, including AOOs.
- Part 50 of 10 CFR, Appendix B, Section II Quality Control Program, as it relates to the quality assurance criteria for the dynamic testing and analysis of SSCs.
- Section 52.47(b)(1) of 10 CFR, which requires that a DC 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, 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 and the NRC's regulations.

Acceptance criteria to meet the above requirements can be found in:

- RG 1.20, Revision 3, as it relates to the reactor internals vibration analysis and testing methodologies,
- RG 1.61, Revision 1, as it relates to the damping values used for dynamic analysis,
- RG 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants," as it relates to the initial test programs for piping and reactor internals,
- RG 1.92, Revision 2, as it relates to response combination methods,
- Guidance for test specifications, as provided in ASME OM-S/G-1990, "Standards and Guides for Operation of Nuclear Power Plants," Part 3, "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems," and Part 7, "Requirements for Thermal Expansion Testing of Nuclear Power Plant Piping Systems," and
- ASME Boiler and Pressure Vessel (BPV) Code (or, the Code), Section III, as incorporated by reference in 10 CFR 50.55a.

3.9.2.4 *Technical Evaluation*

There are six main areas of review in this section. Because of the distinctive character for each area of review, the technical evaluation provides additional details on the summary of the application and identifies the regulatory basis. The DCD Tier 1 information associated with reactor internals initial tests is found in DCD Tier 1 Section 2.4.1, which is evaluated in SER Section 14.2.

3.9.2.4.1 *Piping Vibration, Thermal Expansion, and Dynamic Effects Testing*

The specific areas of review for testing in the application include the systems that are monitored, test program details, acceptance criteria, and possible corrective actions when excessive vibration or indications of thermal motion restraint occur. SRP Section 3.9.2, states that piping vibration, safety relief valve vibration, thermal expansion, and dynamic effects testing for specific high- and moderate-energy piping and their supports and restraints should be conducted during startup functional testing to demonstrate that the systems meet the relevant requirements of GDC 1 that relates to the design, fabrication, erection, and testing of SSCs in accordance with quality standards commensurate with the importance of the safety function to be performed; GDC 14 that relates to designing SSCs of the RCPB to have an extremely low probability of rapidly propagating failure and of gross rupture; and GDC 15 that relates to designing the RCS with sufficient margin to assure that the RCPB is not exceeded during normal operating conditions, including AOOs. The systems to be monitored should include: (1) all ASME Class 1, 2, and 3 piping systems, (2) high-energy piping systems inside seismic Category I structures, (3) high-energy portions of systems whose failure could reduce the functioning of seismic Category I plant features to an unacceptable safety level, and (4) seismic Category I portions of moderate-energy piping systems located outside the containment. The purpose of these tests is to confirm that these piping systems, restraints, components, and supports have been adequately designed to withstand the dynamic loadings and operational transient conditions encountered during service as required by the Code, and to confirm that normal thermal motion is not restrained.

In DCD Tier 2 Subsection 3.9.2.1, the applicant states that the testing of piping vibration, thermal expansion, and dynamic effects are tested during the ITP as delineated in DCD Tier 2 Section 14.2. The ITP is implemented to demonstrate that these piping systems, restraints, components, and supports have been designed to withstand flow-induced dynamic loading under the steady-state and operational transient conditions anticipated during service, to confirm that proper allowance for thermal contraction and expansion is provided, and to demonstrate that piping vibrations are within the acceptable level such as those caused by an in-line component trip. The DCD further states that the supports and restraints necessary for operation during the life of the plant are considered to be parts of the piping system. Therefore, the staff issued RAI 151-8078, Question 03.09.02-1 (ML15234A007), requesting the applicant to justify the applicability of the stress limits in the referenced guidance of ASME OM-S/G during steady state vibration throughout the 40-year licensing period.

In its response to RAI 151-8078, Question 03.09.02-1 (ML15335A026), the applicant stated that the APR1400 design used the criteria that the stress limit for steady-state vibration is the endurance limit of the piping material, consistent with ASME OM-S/G-1990, Part 3. The allowable endurance stress values for the plant life are the stress values of the ASME Code Section III, Division 1, Appendix I, design fatigue curve (S-N Curve) at 10^{11} stress cycles. The applicant also indicated that a detailed evaluation will be performed if the steady state vibration is over 10^{11} stress cycles. Because the stress limits for vibration follow the Code, the staff concludes that the applicant's evaluation using the endurance stress limits for steady state vibration is adequate and acceptable for the design life of the piping system. Therefore, RAI 151-8078, Question 03.09.02-1, is resolved and closed.

The staff reviewed DCD Tier 2, Sections 3.9.2 and 14.2.12.1, which state that the ITP of piping systems is applicable to the ASME BPV Code Section III, Class 1, 2, and 3 piping systems. The

applicant did not, however, identify testing applicable to other piping systems not designed to meet the ASME BPV Code Section III requirements. In accordance with SRP Section 3.9.2.I.1.D, the staff issued RAI 51-8078, Question 03.09.02-2 (ML15234A007), requesting the applicant to provide a list of seismic Category I portions of moderate energy piping systems located outside containment, and confirm inclusion of these piping systems in the scope of the ITP, similar to the ASME BPV Code Section III piping.

In its response to RAI 151-8078, Question 03.09.02-2 (ML16008A987), the applicant stated that a complete list of seismic Category I portions of moderate energy piping systems located outside containment will be provided at the detailed design phase by the COL applicant since not all of the applicable systems are within the scope of the design. As such, the applicant stated that DCD Tier 2 Subsection 3.9.2.1, will be revised to state that the piping systems recommended in SRP Section 3.9.2, Section I.(1), A, B, C, and D, are to be included in the test procedure, as shown in the provided mark ups. Because the systems will be the responsibility of the COL applicant and tested as part of the ITP, the staff concludes the response to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-2, is resolved and closed.

The applicant further stated in the DCD that when applicable, the ITP includes a list of systems, flow modes, and selected locations for visual inspections and other measurements, as well as the acceptance criteria and possible corrective actions if excessive vibration or indications of thermal motion restraint occur. The applicant further stated that the list of snubbers on systems that are subjected to sufficient thermal movements from cold to hot position is provided as part of the ITP to measure snubber travel. The staff reviewed DCD Tier 2, Section 3.9.2.1 and Section 14.2.12.1, but did not find where the applicant identified which specific systems are included in the testing program, and whether, as stated in SRP Section 3.9.2, testing is conducted on all ASME Class 1, 2, and 3 piping systems. The staff issued RAI 151-8078, Question 03.09.02-3 (ML 16008A987), requesting the applicant to: (a) provide a listing of the high- and moderate-energy piping systems inside containment that are covered by the vibration, thermal expansion, and dynamic effects testing program, (b) verify that the systems to be monitored include all ASME Class 1, 2, and 3 piping systems, and (c) provide the list of snubbers on systems that are subjected to sufficient thermal movements from cold to hot position.

In its response to RAI 151-8078, Question 03.09.02-3 (ML16084A991), the applicant provided the following information.

- The applicant committed to provide a listing of the high- and moderate-energy piping systems inside containment that are covered by the vibration, thermal expansion, and dynamic effects testing program at the detailed design phase after the piping physical layout is designed. The applicant noted that a listing of these piping systems will be included in the test procedure, which is the responsibility of the COL applicant. As such, DCD Tier 2, Subsection 3.9.2.1, which defines the test scope and criteria, will be revised as shown in the DCD mark-up to state these piping systems recommended in SRP Section 3.9.2, Section I.(1), A, B, C, and D, will be in the test procedure.
- DCD Tier 2 Section 3.9.2.1.a, contains all ASME Class 1, 2, and 3 piping systems for the APR1400, as recommended by SRP Section 3.9.2, Section I, (1), A. To clarify the

scope of ASME Class 1, 2, and 3 piping systems, DCD Tier 2 Section 3.9.2.1, will be revised as identified by SRP Section 3.9.2, as shown in the mark-up attached to the response.

- The applicant also stated that a list of snubbers on systems that are subjected to sufficient thermal movements from cold to hot position will be provided at the detailed design phase after the piping analyses and supports design are completed. The list of snubbers will be included in the test procedure, which is the responsibility of the COL applicant. DCD Tier 2 Subsection 3.9.2.1, will be changed as shown in the DCD mark-up to indicate that the list of snubbers on systems which experience sufficient thermal movement to measure snubber travel from cold to hot position will be provided as part of the test procedure.

Because the listing of the systems will be the responsibility of the COL applicant, and will be tested as part of the ITP, the staff concludes the applicant's response is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-3, is resolved and closed.

In its review of DCD Tier 2 Section 14.2, the staff was not initially clear whether the vibration, thermal expansion, and dynamic effects testing program simulates actual operating modes. SRP Section 3.9.2, states that an acceptable test program to confirm the adequacy of the design should include a list of the flow modes of operation and transients such as pump trips, valve closures, etc., to which the components will be subjected during the test. Therefore, the staff issued RAI 151-8078, Question 03.09.02-4 (ML 16008A987), requesting the applicant to provide a listing of the different flow modes to which the systems will be subjected during the vibration, thermal expansion, and dynamic effects testing program to confirm that the piping systems, restraints, components, and supports have been adequately designed to withstand flow-induced dynamic loadings under the steady-state and operational transient conditions anticipated during service.

In its response to RAI 151-8078, Question 03.09.02-4 (ML16084A991), the applicant indicated that a listing of the different flow modes will be provided at the detailed design phase since the flow modes and their result on the piping systems are determined after the piping analyses are completed. However, to ensure the elements of an acceptable startup test-program are incorporated, as identified by SRP Section 3.9.2, the applicant committed to adding different flow modes of operation and transients to which the systems will be subjected during startup function testing of the specified piping systems in DCD Tier 2 Section 3.9.2.1. Because the listing of the flow modes will be the responsibility of the COL applicant, and tested as part of the ITP, the staff concludes the applicant's response is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-4, is resolved and closed.

In DCD Tier 2 Subsection 3.9.2.1.1, the applicant stated that for steady-state vibrations, the alternating stress amplitudes, Salt, are determined from the maximum amplitudes measured during the initial operation and stress intensity levels based on the guidance of ASME OM S/G 2007. DCD Tier 2, Sections 3.9.2.1.1 and 3.9.2.1.2, list the ASME BPV Code, Section III, acceptable limits for maximum alternating stress for ASME Class 1 piping systems, and ASME Class 2 and 3 piping, respectively. SRP Section 3.9.2, acceptance criterion 7, recommends the use of ASME OM-S/G-1990, Part 3, for vibration testing. The staff issued RAI

151-8078, Question 03.09.02-16 (ML 16008A987), requesting the applicant to clarify the edition of ASME OM-S/G used for the APR1400 design throughout DCD Tier 2 (referenced as the 2007 Edition in some locations) and to justify any differences from the guidance in SRP Section 3.9.2. In addition, the reference to, "OM Part 7," (as well as other similar references to other parts) should be clarified in the DCD to give the complete reference (e.g., OM-S/G-2007, Part 7).

In its response to RAI 151-8078, Question 03.09.02-16 (ML15335A025), the applicant stated that the DCD will be revised to reflect that the piping system tests will be performed in accordance with ASME OM-S/G-1990. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-16, is resolved and closed.

The applicant's vibration criteria are based on ASME OM S/G-2007, Part 3, paragraph 3.2.1.2. For austenitic stainless steels, the stress limits are obtained from Figures I-9.2.1 and I-9.2.2, of the Mandatory Appendix I to Section III of the ASME BPV Code. In addition, the DCD Tier 2, states that the allowable stress reduction factor provides reasonable assurance that the alternating stress S_{alt} is based on the number of cycles during the design life. The staff issued RAI 151-8078, Question 03.09.02-5 (ML 16008A987), requesting the applicant to provide a justification whether the fatigue strength at 10^6 cycles with the reduction factor would be conservative.

In its response to RAI 151-8078, Question 03.09.02-5 (ML15335A026), the applicant stated that for APR1400 design, the allowable stress limits are obtained at 10^{11} cycles in accordance with ASME Section III, Mandatory Appendix I, design fatigue curve. The staff considers the APR1400 design to be adequate and consistent with ASME OM-S/G-1990, Part 3, consistent with SRP Section 3.9.2, acceptance criterion 7. Therefore, RAI 151-8078, Question 03.09.02-5, is resolved and closed.

In DCD Tier 2 Section 3.9.2, the applicant stated that the dynamic transient vibrations are usually induced by rapid start or trip of a pump or turbine, or the quick closing or opening of valves such as turbine-stop valves and various types of control valves. The dynamic transients also occur as a result of rapid actuation of safety/relief valve (SRV) opening or as a result of unexpected events. The staff reviewed DCD Tier 2 Section 14.2, and did not find any ITP element that tested the dynamic transient conditions stated above. Therefore, the staff issued RAI 151-8078, Question 03.09.02-6 (ML153234A007), requesting the applicant to provide appropriate ITP test programs for each of the transient vibration conditions in accordance with the guidance of RG 1.68, and ASME OM-S/G-2007, Part 3, such that APR1400 would meet GDC 14 and GDC 15.

In its response to RAI 151-8078, Question 03.09.02-6 (ML16084A991), the applicant stated that each piping transient test will be performed in connection with the system test during the Power Ascension Test. ITP 14.2.12.1.118, "Balance-of-Plant Piping Vibration Measurement Test," includes testing of the systems to withstand flow induced dynamic loadings under the steady state and operational transient conditions and references DCD Tier 2 Section 3.9. The associated test procedures will include the detailed test specifications in accordance with the general requirements of RG 1.68, and the specific vibration testing requirements of ASME OM Part 3. To ensure that the requirements of RG 1.68, and ASME OM are included, DCD Tier 2 Subsection 3.9.2.1, will be updated to specify that these specific provisions are addressed as part of the test program. Because the transient conditions will be tested as part of the ITP, the

staff concludes the applicant's response is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-6, is resolved and closed.

In DCD Tier 2 Section 3.9.2.1.3, the applicant indicates that the thermal expansion tests are developed in accordance with the guidance of ASME OM-S/G-2007, Part 7. In addition, SRP Section 3.9.2, states that an acceptable thermal expansion program to confirm the adequacy of the design should include a description of the thermal-motion monitoring program. However, the applicant did not provide a description of the test in the DCD. The staff issued RAI 151-8078, Question 03.09.02-7 (ML 16008A987), requesting the applicant to provide a description of the thermal motion monitoring program for verification of snubber movement, adequate clearances and gaps, the acceptance criteria, and the method regarding how motion will be measured.

In its response to RAI 151-8078, Question 03.09.02-7 (ML16084A991), the applicant stated that DCD Tier 2 Subsection 3.9.2.1.3, will be changed to clarify that the detailed description of the thermal motion monitoring program will be included as part of the test procedure completed by the COL applicant. Because the detailed description of the thermal motion monitoring program will be the responsibility of the COL applicant, the staff concludes the applicant's response is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-7, is resolved and closed.

3.9.2.4.2 Seismic Analysis and Qualification of Seismic Category I Mechanical Equipment

The staff reviewed DCD Tier 2, Section 3.9.2.2, "Seismic Analysis and Qualification of Seismic Category I Mechanical Equipment," areas relating to SRP Section 3.9.2. The review was conducted in accordance with SRP Section 3.9.2 and SRP Section 3.7.3, for the analysis methodology and the acceptance criteria. Both SRP sections are related to the seismic analysis of the subsystems as substructures that are not included in the main structural systems which directly connect to the basemat.

Seismic Qualification Testing

The evaluation of the qualification of seismic Category I mechanical equipment is documented in SER Section 3.10.

Seismic System Analysis Methods

The seismic system analysis method is evaluated in SER Section 3.7.2.

Determination of Number of Earthquake Cycles

The determination of the number of earthquake cycles is evaluated in SER Sections 3.7.3 and 3.10.

Basis for Selection of Frequencies

The applicant stated in DCD Tier 2 Section 3.9.2.2.4, that the stiffness of restraints and supports is designed such that they have a fundamental frequency greater than that of the zero-period acceleration (ZPA). The seismic responses of equipment and subsystems are maintained within the established limits. SRP Section 3.9.2, acceptance criterion II.2B, states that to avoid resonance, the fundamental frequencies of components and equipment selected preferably should be less than $\frac{1}{2}$ or more than twice the dominant frequencies of the support structure. The staff noted that the criteria or procedures were set forth to separate fundamental frequencies of components and equipment away from the excitation of the support structure and seismic motion to avoid amplification and resonance. As such, the staff concludes that the basis for selection of fundamental frequency of the support to be higher than seismic ZPA cutoff frequency is acceptable such that the support will not be subjected to detrimental amplification as the resonance frequency will be above the excitation frequency.

Three Components of Earthquake Motion

In DCD Tier 2 Section 3.9.2, the applicant includes the procedures by which the three components of earthquake motion should be applied in determining the seismic response of systems, and components. The applicant indicates in DCD Tier 2, Section 3.9.2.2.5, "Three Components of Earthquake Motion," that the combination of three directional components of earthquake motion is in accordance with RG 1.92 as described in DCD Tier 2, Sections 3.7.2.6 and 3.12.3.2. The staff reviewed DCD Tier 2 Section 3.7.2.6, where the applicant stated that for dynamic analyses of the seismic Category I structures, three statistically independent orthogonal components of earthquake motion, two horizontal and one vertical, are applied to the structural models as separate loading cases. For the time-history analysis, the total response can be obtained by algebraically summing the response parameters. For the response spectrum analysis, the total response of the structure due to the three input seismic motions is obtained by combining the directional responses using the square root sum of the square (SRSS) method. The directional responses at a certain structural location is obtained based on a combination of modal responses, in accordance with RG 1.92 for each of applied seismic motion of acceleration response spectra. The staff finds the procedures by which the three components of earthquake motion are determined acceptable for the response spectrum and time history analysis methods because they are consistent with SRP Section 3.9.2, acceptance criterion II.2D, for applying the three components of earthquake motion.

Combination of Modal Responses

In DCD Tier 2, Sections 3.9.2.2.6 and 3.7.3.7, the applicant states that the combination of modal responses is applicable when the response spectrum method of analysis is used, because the phase relationship between various modes is not identified and only the maximum responses for each mode are determined. Modal responses are combined by the methods described in DCD Tier 2 Section 3.7.2.7, for the mechanical equipment. DCD Tier 2 Section 3.9.2.2.6, states that for the response spectrum method of analysis: (1) the SRSS method of combination is used for separated modes, and (2) the RG 1.92 method of combination is used for closely spaced modes and complete quadratic combination with the Gupta method. The staff finds that these provisions are in accordance with the criteria of SRP Section 3.7.3, Item II.7, and are acceptable for use in the context of DCD Tier 2 Section 3.9.2.

Analytical Procedures for Piping

The evaluation of piping for seismic effects is documented in SER Section 3.12.

Multiple-Supported Equipment Components with Distinct Inputs

In DCD Tier 2 Section 3.9.2.2.8, the applicant states that when the equipment or component is supported at points with different elevations within a building and between buildings, either the envelope of these elevation response spectra or multiple supports excitation is used for the seismic qualification of the equipment. For analyzing the piping systems supported at multiple locations within a single structure or multiple structures, the method used is described in DCD Tier 2 Section 3.12.3.2.

The staff noted that in SRP Section 3.7.3.II.9, an acceptable approach to the staff for analyzing equipment items supported at two or more locations is to define a URS that envelopes all of the individual response spectra at the various support locations. The staff further noted that the URS method described above can result in considerable overestimation of seismic responses. In the case of multiple-supported equipment in a single structure and/or spanning between structures, an alternate method that can be used is the independent support motion (ISM) approach consistent with guidance given in Section 2 of NUREG-1061, Volume 4. If the ISM method is utilized, all of the criteria presented in NUREG-1061, related to the ISM method should be followed. Therefore, in RAI 151-8078, Question 03.09.02-8, the staff requested the applicant to specify in DCD Tier 2 Section 3.9.2, that multiple-support excitation methods should be implemented in accordance with the staff's recommendations on response combinations given in NUREG-1061, Volume 4, Section 2, consistent with SRP Section 3.7.3 in combining the final structural response from each ISM.

In its response to RAI 151-8078, Question 03.09.02-8 (ML15335A026), the applicant stated that DCD Tier 2 Section 3.9.2.2.8, will be revised such that KHNP will follow the guidance provided in NUREG-1061, Volume 4, Section 2, for instances when the independent support motion is used as an alternate method for the multiple supported excitation cases as shown in the marked up copy included in the response. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 151-8078, Question 03.09.02-8, is resolved and closed.

Use of Constant Vertical Static Factors

In DCD Tier 2 Section 3.9.2.2.9, the applicant states that a constant static factor is not used for the seismic design of seismic Category I SSCs specified in DCD Tier 2, Sections 3.7.2.9 and 3.7.3.6. The staff considers it acceptable that the constant vertical static factor will not be used in the APR1400 seismic design because the vertical seismic response is considered to occur simultaneously with the two horizontal components and is consistently coupled with the horizontal components of the seismic motion, as described in DCD Tier 2 Section 3.7.2.9.

Torsional Effects of Eccentric Masses

In DCD Tier 2 Section 3.9.2.2.10, the applicant indicates that the torsional effects and loads are accounted for in the seismic analysis when all eccentric masses such as valves and valve operators are included properly in the analysis mode. The applicant also states that consideration of the torsional effects of eccentric masses should not be limited to piping systems only, but should be considered for all subsystems. The methods used to account for the torsional effects of valves and other eccentric masses such as valve operators in the seismic subsystem analyses are to be as follows:

- When valves and other eccentric masses are considered rigid, the masses of the operator and valve body or other eccentric mass are located at the center of gravity. The eccentric components (that is, yoke and valve body) are modeled as rigid members.
- When valves and other eccentric masses are not considered rigid, the dynamic models are simulated by the lumped masses in discrete locations (that is, center of gravity of valve body and valve operator), coupled by elastic members with properties of the eccentric components.

In DCD Tier 2 Section 3.12.4.2, the applicant states that the torsional effects of an eccentric mass, such as a valve operator, that may affect the piping design are included in the dynamic analysis. This modeling of the torsional effects of eccentric masses is acceptable because it is consistent with SRP Section 3.9.2, acceptance criterion II.2.I.

Buried Seismic Category I Piping Conduits, and Tunnels

The evaluation of buried seismic piping is documented in SER Section 3.7.3.

Interaction of Other Piping with Seismic Category I Piping

The evaluation of the piping interaction is provided in SER Section 3.12.

Analysis Procedure for Damping

The evaluation of the analysis procedure for damping is provided in SER Section 3.7.3.

Seismic Analysis of Mechanical Tanks

The staff issued RAI 267-8301, Question 03.07.03-1 (ML 16008A987), requesting the applicant to provide justification for the consideration of only the larger of two horizontal input motions in its seismic analysis of tanks described in Section 3.7.3.9, that may not be cylindrical or tanks

mounted on a structure. In its response to RAI 267-8301, Question 03.07.03-1 (ML16165A512), the applicant revised DCD Tier 2 by adding Section 3.9.2.2.14, "Seismic Analysis of Mechanical Tanks," in the DCD mark-up attached to the response. In accordance with 10 CFR Part 50 Appendix S, the staff reviewed the adequacy of methods for seismic analysis for the structural integrity of mechanical tanks such as the fire water tank, fuel tanks for the emergency diesel generator, and other mechanical tanks that are classified as seismic Category I, as described in DCD Tier 2 Section 3.9.2.2.14.

In DCD Section 3.9.2.2.14, the applicant stated that the seismic analyses of the mechanical tanks are performed using a separate (decoupled) finite element model to determine their natural frequencies and mode shape. The applicant further stated that seismic loads are calculated, depending on the natural frequency results from the FEA, either by using the equivalent static method or dynamic method if the tanks are considered flexible (i.e., frequency less than 33 Hz). The staff issued RAI 533-8718, Question 03-09-02-17 (ML16357A029), requesting the applicant to: (1) provide the basis for using 33 Hz while ZPA frequency is 50 Hz at APR1400 plants, and (2) confirm whether and how the fluid (i.e., water, fuel, etc.) was considered in the finite element model for tanks to be fully or partially liquid filled, including the effects of fluid-structure interaction and the sloshing effects in the calculation of natural frequency and stresses during a seismic event. In its response to RAI 533-8718, Question 03-09-02-17 (ML17062A925), the applicant stated that in accordance with the CSDRS in DCD Tier 2, Figures 3.7-1 and 3.7-2, the APR1400 ZPA frequency will be revised to be 50 Hz as in the DCD mark-up. The applicant also stated that the seismic analysis of liquid storage tanks accounts for the hydrodynamic forces exerted by the fluid on the tank walls. The response also noted that evaluation of the hydrodynamic forces requires suitable modeling and dynamic analysis of the tank-liquid system, to support the complex nature of the system. For APR1400 plants, the applicant stated that the COL applicant will be responsible reviewing the detailed analysis of the mechanical tank structural integrity. To ensure that the tank seismic analysis is adequately performed, the applicant added a COL 3.9(7) to DCD Tier 2 Section 3.9.2.2.14, as shown in the DCD.

With respect to whether the fluid was considered in the finite element model for tanks to be fully or partially liquid filled, the staff finds the applicant's response acceptable because the COL applicant will be responsible for the integrity of mechanical tanks. With respect to the APR1400 ZPA frequency concern, the staff finds the applicant's proposed change to be acceptable because it substitutes the appropriate value of 50 Hz. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 533-8718, Question 03-09-02-17, is resolved and closed.

Test and Analysis Results

DCD Tier 2 Section 3.9.2.2.15, references DCD Tier 2 Section 3.10, for seismic test and analysis results. The staff's evaluation of this subject is provided in SER Section 3.10.

3.9.2.4.3 *Dynamic Response Analysis of Reactor Internals under Operational Flow Transients and Steady-State Conditions*

SRP Section 3.9.2, acceptance criterion II.3, indicates analytical solutions to predict vibrations of reactor internals are needed only for prototype plants to demonstrate compliance with GDC 1 and 4. This may not be necessary for the APR1400 design since in DCD Tier 2 Section 3.9.2.4,

the applicant classified the APR1400 reactor internals to be a non-prototype Category I, consistent with RG 1.20, and with PVNGS Unit 1, a Westinghouse System 80 reactor, as the valid prototype.

To address the potential for adverse flow effects, DCD Tier 2 Section 3.9.2.3, describes the flow-induced vibration forcing functions of the reactor internal components during normal operating conditions. Both deterministic (periodic and transient) and random forcing functions due to pressure fluctuations in the coolant are considered. In DCD Tier 2 Section 3.9.2.3.1.1, the applicant states that an analysis based on a hydrodynamic model is used to obtain the relationship between RCP pulsations in the inlet nozzles and the core support barrel. The application also states that data from the System 80 preoperational test is used to determine the magnitude of these pulsations at the pump rotor and blade passing frequencies and their harmonics. The staff audited detailed information associated with this hydrodynamic model between June 30, 2015, and July 15, 2015, as documented in an audit report dated November 12, 2015 (ML15300A164).

The computer code DPVIB used for the hydrodynamic analysis was not initially included in the DCD. Resolution of this issue, which was identified in RAI 73-8025, Question 03.09.01-4, is discussed in SER Section 3.9.1. In addition, as a result of the audit, the staff identified detailed information that should be docketed to support the staff's safety finding associated with this section because Tier 2 Section 3.9.2.3.1, did not describe the hydrodynamic model or the method of calculating the forcing functions. The staff issued RAI 151-8078, Question 03.09.02-9 (ML15234A007), requesting the applicant to: (1) describe how, within the hydrodynamic model, pump pulsation pressure fluctuation was translated to loads on RVI components; and (2) clarify whether measured test data from one or four pumps were used and justify that the assumption of in-phase pressure fluctuation from four pumps operating is conservative.

In its response to RAI 151-8078, Question 03.09.02-9 (ML15296A568), the applicant indicated that the model uses measured data for all available conditions from the valid prototype CVAP using the following steps:

1. All available data are taken from test conditions which consist of one, two, three, or four operating pumps.
2. One-pump basis values are obtained by dividing the measured values by the number of operating pumps for each condition.
3. Maximum values are selected to get the representative values for one-pump basis values at the design temperature.
4. All-pump basis values are obtained by multiplying the one-pump maximum representative values by four.

The staff determined that the procedure is consistent with RG 1.20, because the pressure fluctuation is obtained in a conservative manner for the condition in which four pumps are operating. The applicant also stated that the reactor vessel inlet nozzle location data is used as an input in solving the wave equation to calculate pressure loads on the core support barrel (CSB). The staff considers this is acceptable since the inlet nozzle location data as measured are the vibration source of pump pressure pulsation.

In its response to RAI 151-8078, Question 03.09.02-9 (ML16032A600), the applicant provided the specific methodology which references the Penzes paper (1974) (Penzes, L.E., Theory of Pump-Induced Pulsating Coolant Pressure in Pressurized Water Reactors, Nuclear Engineering and Design, Vol. 27, pp.176-188, 1974). This reference contains complex mathematical calculations involving fluid mode frequencies, the pressure distribution, and Fourier coefficients that result in the loads on the CSB support. The calculation of loads is achieved using the computer program DPVIB, which is described and documented in DCD Tier 2 Section 3.9.1.2.2.5. The staff concluded that in performing calculations using DPVIB, the applicant demonstrated the pump pulsating pressure is translated to loads on RIV components. Therefore, RAI 151- 8078, Question 03.09.02-9, is resolved and closed.

In DCD Tier 2 Section 3.9.2.3.1.1, the applicant stated that the random hydraulic forcing function is developed by experimental methods and the forcing function is modified to reflect the flow rate and density differences based on an analytical expression found in the Penzes paper. However, the staff did not find an expression that is physically suitable to modify the random turbulent flow loadings represented by power spectrum density. The staff issued RAI 151-8078, Question 03.09.02-10 (ML15234A007), requesting the applicant to provide a description of the experimental methods and the analytical expression that modified the random forcing functions.

In its response to RAI 151-8078, Question 03.09.02-10 (ML15296A568), the applicant stated that the wording used in the DCD Tier 2 Section 3.9.2.3.1.2, was intended to indicate that the random hydraulic forcing function is developed based on the System 80 CVAP preoperational testing data and proposed an associated DCD revision. In the response, the applicant also provided the expressions used to modify the forcing function when necessary to reflect the flow rate (velocity) or density differences between the testing data and the design.

In its revised response to RAI 151-8078, Question 03.09.02-10 (ML116274A418), the applicant indicated that equations the Penzes paper were used to develop the power spectrum curve based on the measured data in the corresponding frequency domain. The staff evaluated the information provided by the applicant and finds that the power spectrum curves obtained for APR1400 are acceptable considering the conservatism of the resulting power spectrum curves which envelop the measured spectrum data. Therefore, RAI 151-8078, Question 03.09.02-10, is resolved and closed.

The applicant performed finite element analyses for each of the reactor internals components using mathematical models. The core support barrel (CSB) assembly is modeled with axisymmetric shell element using the ASHSD computer code. The ANSYS library elements are used for other CSB assembly components such as the lower support structure (LSS), in-core instrument (ICI) support system, core shroud, and the upper guide structure (UGS) support barrel assembly, which consists of the UGS support barrel, fuel alignment plate, UGS support plate, and control element assembly (CEA) guide tubes. The mathematical model is used to determine the static and dynamic characteristics as well as periodic and random response analyses using ANSYS computer code. The applicant stated that the ANSYS code computes the root mean square (RMS) displacements, loads, and stresses in a multi-degree-of-freedom linear-elastic structural model subjected to stationary random dynamic loadings. The DCD also states that a value of three times the RMS is used for considering peak responses to random loading. Considering that the use of the value three times the RMS is common design practice in the industry and that APR1400 used an absolute sum for the combination of pump pulsation, vortex shedding and turbulent loads in calculating stresses and fatigue usage factors of

ASME BPV Code Section III components and reactor internals, the staff concludes that the methodologies in calculating the random responses are acceptable.

3.9.2.4.4 *Preoperational Flow-Induced Vibration Testing of Reactor Internals*

In DCD Tier 2 Section 3.9.2.4, the applicant states that the APR1400 is classified as a non-prototype Category I design, consistent with RG 1.20, and that the PVNGS Unit 1, System 80 reactor is the valid prototype. The applicant also stated that its evaluation of the PVNGS CVAP report, "A Comprehensive Vibration Assessment Program for PVNGS Unit 1 (System 80 Prototype)," CEN-263(V), Revision 1, dated January 1985, for analytical predictions, test measurements, and visual inspection results leads to the conclusion that the System 80 prototype reactor internals are structurally adequate and acceptable for long-term operation. The staff reviewed the data comparison provided in DCD Tier 2, Tables 3.9-15, 3.9-16, and 3.9-17, and found that the PVNGS Unit 1, design and the APR1400 design are substantially the same with regard to arrangement, design, size, and operating conditions. Consistent with the guidance in RG 1.20, the applicant provided a CVAP report (APR1400-Z-M-NR-14009) for the APR1400 reactor internals, as well as steam generator internals and the RCS piping and piping attached to the RCS, to support the designation of PVNGS Unit 1, as the prototype for APR1400. In addition, the APR1400 CVAP discussed in detail the slight differences of the designs and the RVI parameters and concluded that the design differences will not substantially alter the behavior of the flow transients, and the response of the reactor internals. Therefore, based on a review of the above-referenced information, the staff concludes that the applicant provided adequate demonstration for APR1400 to be classified as non-prototype seismic Category I reactor internals, with the PVNGS Unit 1, System 80 reactor being the designated prototype reactor.

In DCD Tier 2 Section 3.9.2.4, the applicant states that evaluation of steam generator internals is included in Appendix A of the CVAP report, APR1400-Z-M-14009, Revision 0. The staff reviewed Appendix A of this technical report and found that it presents an analysis based on the turbulent loading that concludes the stresses in the critical locations are small and acceptable. The analysis, however, does not address the fluid-structural interaction or flow-induced vibration due to cross flow conditions. In light of the recent operating experience with steam generator tube degradation at San Onofre Nuclear Generating Station, the staff issued RAI 151-8078, Question 03.09.02-11 (ML15234A007), requesting the applicant to demonstrate that the APR1400 steam generator tube bundle design will prevent such degradation by: (1) discussing the dynamic characteristics of the U-bend assembly including frequencies and mode shapes and describing the U-bend support configuration, or (2) providing the comparison between the APR1400 steam generators and similar steam generators (such as PVNGS Unit 1 replacement steam generators) that have operated without such adverse flow effects.

In its response to RAI 151-8078, Question 03.09.02-11 (ML15296A568), the applicant provided the fluid induced vibration (FIV) assessment of the APR1400 steam generator tube bundle including the modal analysis results, as well as a comparison of the APR1400 steam generator to similar operating nuclear plant steam generator tube bundle designs. The staff reviewed the applicant's presentation of the ANSYS finite element model for the tube modal analysis, which includes straight and U-bend tubes supported by various features. The applicant evaluated both fluid elastic instability and random turbulence excitation for the tubes. For fluid elastic instability, the stability ratio is determined by dividing the effective velocity by the critical velocity. The staff considered the applicant's calculation results to demonstrate conservative stability

ratios with sufficient safety margin. For random turbulence excitation, the applicant's calculations showed that the maximum root-mean-square displacements are within the allowable limits such that the stress is less than the allowable limits. Based on the evaluation of the applicant's response, the staff concludes that the applicant provided adequate analytical information to demonstrate the APR1400 design will operate below the critical flow limit with sufficient margin for FIV effects on the steam generator tubes. Therefore, RAI 151-8078, Question 03.09.02-11, is resolved and closed.

In APR1400-Z-M-14009, Appendix B, "Vibration Assessment for the Reactor Coolant System Piping and the Piping Attached to the Steam Generator," the applicant states that the vibration assessment program consists of a vibration and stress analysis program and a flow-excited acoustic resonance measuring and inspection program. This program is performed in conformance with RG 1.20, and SRP Section 3.9.2, for the following system piping: (1) reactor coolant system (RCS) piping, (2) main steam system (MS) piping, (3) feedwater system (FW) piping, and (4) condensate system (CD) piping. The staff issued RAI 151-8078, Question 03.09.02-12 (ML 15234A007), requesting the applicant to justify not including vibration assessment for the shutdown cooling and other emergency core cooling system (ECCS) lines, given operating experience at the similar PVNGS plant where a flow-excited acoustic resonance was experienced in the shutdown cooling system (SCS), resulting in leaking and failure of an isolation valve.

In its response to RAI 151-8078, Question 03.09.02-12 (ML15296A568), the applicant provided additional information on how the PVNGS licensee had resolved the operating experience issue identified in the RAI. Specifically, the licensee moved the SCS suction line isolation valve SI-V651, closer to the RCS hot leg, approximately 3.4 m (11 ft), from the RCS nozzle compared to the original location approximately 16 m (52.5 ft), from the nozzle. No excessive vibration in the SCS suction line has been reported at PVNGS since the modification was made. The SCS suction line design of the APR1400 is similar to the redesigned version of the PVNGS plant SCS suction line. In addition, the SCS suction line diameters (16 in.) and hot leg diameters (42 in.) of the APR1400 are the same as those of the PVNGS plant. As such, the staff concludes that the APR1400 design in this respect is acceptable based on the similar design configuration to PVNGS and its favorable plant operating experience following the modification that is included in the APR1400 design. Based on the consideration of operating experience in the plant design, RAI 151-8078, Question 03.09.02-12, is resolved and closed.

In DCD Tier 2 Section 3.9.2.4, the applicant stated that the CVAP for the APR1400 RVI consists of an analysis program and an inspection program. The vibration analysis provides the theoretical evidence of the structural integrity of the RVI and serves as the basis for the inspection program. The vibration analysis is divided into three parts: (1) calculation of hydraulic loads or forcing functions, (2) construction of appropriate analysis model to determine the modal characteristics, and (3) calculation of the responses. In APR1400-Z-M-14009, the applicant presents the analysis methodologies for calculating the dynamic responses of the RVI to the flow-induced hydraulic loads. The inspection program consists of inspection of the RVI both before and after hot functional testing. The applicant also stated that the duration of the hot functional test is established to provide reasonable assurance that 10^6 cycles of vibration occur before the follow-up inspection. A detailed inspection is performed of major bearing surfaces, contact surfaces, welds, and maximum stress locations identified in the analysis program. The two visual inspections are compared to provide reasonable assurance that there is no sign of abnormal wear or contact for any of the RVI. The combination of tests, predictive

analysis, and inspection provides adequate assurance that the reactor internals will, during their service lifetime, withstand the flow-induced vibrations of reactor operation without loss of structural integrity. The staff concludes that the APR1400 DCD provides sufficient information to address the regulatory positions of RG 1.20, for inclusion of a preoperational vibration program for the reactor internals that provides an acceptable basis for verifying the design adequacy of the internals under test loading conditions comparable to those that will be experienced during operation.

3.9.2.4.5 *Dynamic System Analysis of the Reactor Internals under Faulted Conditions*

SRP Section 3.9.2, review area I.5, states that dynamic system analyses should confirm the structural design adequacy and ability, with no loss of function, of the reactor internals and unbroken loops of the reactor coolant piping to withstand the loads from a LOCA in combination with a SSE. The staff's review covered the methods of analysis, the representation of mathematical models, the applicable forcing functions, the calculation scheme, the acceptance criteria, and the interpretation of analytical results.

In DCD Tier 2 Section 3.9.2.5.1, the applicant states that the seismic dynamic analysis of the reactor internals including the core is performed separately for the horizontal and vertical directions. The nonlinear horizontal model, as shown in DCD Tier 2 Figure 3.9-16, was constructed to consider gaps between internal components (between core and core shroud, and between core support barrel and reactor vessel) and the large relative displacements that may occur during the SSE event. The vertical non-linear model (DCD Tier 2 Figure 3.9-18) was constructed considering the possibility of the core assembly lifting off the support plate. The applicant further stated that the mathematical model also includes hydrodynamic effects. However, the DCD did not provide information regarding fluid-structural interactions for the models shown in DCD Tier 2, Figures 3.9-16 and 3.9-18. SRP Section 3.9.2, acceptance criterion II.5.D, states that the effects of flow upon the mass and flexibility properties of the system should be addressed. Therefore, in RAI 151-8078, Question 03.09.02-13, the staff requested that the applicant provide information as to how fluid-structural interaction effects are accounted for in the mass and flexibilities of reactor internals as part of the dynamic modeling.

In its response dated October 23, 2015 (ML15296A568), the applicant stated that the effect of fluid-structure interaction between reactor internals structures is characterized by a hydrodynamic mass matrix. The hydrodynamic mass matrix consists of off-diagonal hydrodynamic coupling terms and diagonal hydrodynamic added mass terms. The hydrodynamic mass theory is incorporated into the CESHOCK computer program, which accounts for the interaction between two adjacent structures separated by a fluid-filled gap by applying a hydrodynamic mass matrix to evaluate the fluid forces on the motion of structures. The V&V of the CESHOCK computer program was previously audited by the staff and found acceptable, as documented in SER Section 3.9.1. The use of this methodology to account for fluid-structure interaction effects between RVI uses a technically justified and validated computer program. Therefore, RAI 151-8078, Question 03.09.02-13, is resolved and closed.

In DCD Tier 2 Section 3.9.2.5.1, the applicant states that the input excitation to the internals model is the response time-history of the reactor vessel at the internals support determined from the RCS analysis. Coupling effects between the internals and reactor vessel are accounted for by including a simplified representation of the internals with the RCS model. In addition, the applicant stated that the nonlinear seismic response and impact forces for the internals and fuel

are determined using the CESHOCK computer program, which is described in DCD Tier 2 Section 3.9.1. The procedures used to account for damping in the analysis of the reactor internals and core are provided in DCD Tier 2 Section 3.7.2.14. The staff issued RAI 151-8078, Question 03.09.02-14 (ML 15234A007), requesting that the applicant provide justification for using the procedures for analysis of damping provided in DCD Tier 2 Section 3.7.2.14, which are for the modal analysis of a linear structural system or the proportional viscous damping using direct integration method for a linear system, and for the non-linear dynamic analysis described in DCD Tier 2 Section 3.9.2.5.

In its response to RAI151-8078, Question 03.09.02-14 (ML15296A568), the applicant stated that RVI and core seismic analyses are performed with a nonlinear time history analysis using the CESHOCK computer program, which solves the differential equation of motion for a multi-degree-of-freedom system using a direct integration method. The evaluation of CESHOCK computer program is documented in SER Section 3.9.1, and the evaluation of damping methods is provided in SER Section 3.7.2. The applicant provided additional information to justify its approach to determining natural frequencies using modal analyses and selecting conservative bounding frequencies. The resulting damping values were demonstrated to be less than four percent, the value in RG 1.61, for the relevant frequency range. The use of the composite damping described in SRP Section 3.7.2, as confined between the lower and upper bound frequencies is considered conservative. The damping matrix is also applicable to the non-linear analysis as the direct integration method is used and the system frequencies are maintained within the lower and upper bound for each instance time point. Based on this information, the staff concludes that the nonlinear analysis is technically justified for purposes of the RVI evaluation. Therefore, RAI 151-8078, Question 03.09.02-14, is resolved and closed.

In DCD Tier 2 Section 3.9.2.5.2.1, the applicant stated that according to the application of the leak-before-break (LBB) approved by the NRC, the RCS design of the APR1400 excludes the postulated pipe ruptures of the main loop piping and their dynamic effects. Therefore, the RCS and RVI are evaluated only for breaks of piping systems to which the LBB is not applied. These pipe ruptures can be divided into primary side pipe ruptures and secondary side pipe ruptures. The primary side pipe ruptures, including the ruptures of branch lines connected to the RCS main loop piping and pressurizer, cause a blowdown load within the reactor vessel as well as vibration of the reactor vessel. The blowdown loads consist of transient pressure, flow rate, and density distributions throughout the primary RCS. The secondary side pipe ruptures, the ruptures of secondary nozzles and pipes attached to the steam generators, cause only vibration of the reactor vessel. The secondary side breaks, which cause vibratory motion to the reactor internals, do not cause blowdown loads within the reactor vessel.

The RVI pipe rupture analysis for both horizontal and vertical direction uses the same model used in seismic analysis. The input excitation for the primary side pipe ruptures consists of the reactor vessel motion and blowdown load, while the input excitation for the secondary side pipe ruptures is only the reactor vessel motion. The critical damping value of 4 percent is used for the RVI components. The above RVI pipe rupture analysis method is acceptable to the staff because the damping value is consistent with RG 1.61. Further, there is added conservatism in the analysis due to the additional damping caused by the submerged condition of the RVI.

In DCD Tier 2 Section 3.9.2.5, the applicant states that the analytical models and the procedures of the reactor internals and core for IRWST discharge loads are the same as those used in the seismic analyses. The input excitation to the reactor internals and core model is the

acceleration time histories of reactor vessel flange and snubbers determined from the RCS IRWST analysis. The maximum stresses resulting from IRWST discharge, pipe break, and SSE are combined using the SRSS method to obtain the total stress intensities. The use of the SRSS method to combine the loads described above is evaluated in SER Section 3.9.3.

The detailed dynamic analysis and design for the fuel assembly for Service Level D for seismic and LOCA loading are evaluated in SER Section 4.2.

Based on the evaluation of the applicant's information, the staff concludes that the appropriate dynamic system analyses have been performed and confirm that the structural design of the reactor internals is able to withstand the dynamic loadings of the most severe LOCA in combination with the SSE, with no loss of function. The staff also concludes that the methods and procedures for dynamic systems analyses, the considerations in defining the mathematical models, the descriptions of the forcing functions and the acceptance criteria, and the interpretation of the analytical results are in compliance with the relevant requirements of 10 CFR Part 50, Appendix A, GDC 2, as it relates to the ability of SSCs, without loss of capability to perform their safety function, to withstand the effects of natural phenomena, such as earthquakes, tornadoes, floods. The analysis also satisfies GDC 4 in relation to the protection of SSCs 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.

3.9.2.4.6 *Correlations of Reactor Internals Vibration Tests with the Analytical Results*

The purpose of this section is to evaluate whether the RVI model is representative of the APR1400 design, such that it can be used to obtain loads for design of reactor vessel internals resulting from normal operation, transients, and postulated accidents including SSE and LOCA.

The regulations in 10 CFR Part 50, Appendix A, GDC 1, states, in part, "Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed." To enable the staff to make a conclusion as to the APR1400 design's compliance with GDC 1, specific to the appropriate correlation of tests and analyses of reactor internals, the staff issued RAI 151-8078, Question 03.09.02-15 (ML15234A007), requesting the applicant to provide the following information:

- Comparison of the measured response frequencies with the analytically obtained natural frequencies of the reactor internals for validation of the mathematical models used in the analysis
- Comparison of the analytically obtained mode shapes with the shape of measured motion for identification of the modal combination or verification of a specific mode
- Comparison of the response amplitude time variation and the frequency content from test and analysis for verification of the postulated forcing function
- Comparison of the maximum responses from test and analysis for verification of stress levels

- Comparison of the mathematical model for dynamic system analysis under operational flow transients and under combined LOCA and SSE loadings between APR1400 and the valid prototype plant
- Comparison of measurements and predictions of any adverse flow phenomena (e.g., flow excited acoustic and/or structural resonances) for validation of the model(s) predicting the loading induced by the phenomena

In its response to RAI 151-8078, Question 03.09.02-15 (ML15296A568), the applicant provided a comparison of the results of the APR1400 finite element model and measured data from the prototype PVNGS Unit 1, including natural frequencies and the mode shapes for specific locations in the RVI. The staff reviewed this information and determined that the comparison of the results were within an acceptable range because the CSB predicted frequency is 7.3 Hz, versus the measured 7.6 Hz, and a value within 10 percent is considered acceptable. The applicant also provided a comparison of the full-power pump-pulsation pressures between the measured data at PVNGS and the analytical APR1400 results for additional locations. The APR1400 analysis uses approximately twice the measured pressure data as input data for the forcing functions. The staff considers the use of twice the measured pressure to be conservative, and the dynamic characteristics of the structures are nearly the same when comparing the natural frequencies and the mode shapes. A comparison of peak stresses for the analyzed locations shows APR1400 analysis results to be much higher than the measured stresses. The prediction includes the variations of forcing frequencies accounting for the uncertainties of the mathematical models and loadings including adverse flow phenomena. The staff considers the use of higher stresses for the analytical evaluation to be conservative and acceptable for APR1400 design. Therefore, RAI 151-8078, Question 03.09.02-15, is resolved and closed.

3.9.2.5 Combined License Information Items

DCD Tier 2, Section 3.9.2, contains the following COL information items. Based on the discussion above, these COL items are consistent with the mechanical tanks and the CVAP approach described above and are therefore acceptable. The staff concludes that no additional COL information items are needed.

Table 3.9.2 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.9(1)	The COL applicant is to provide inspection results to demonstrate an acceptable CVAP through acceptable inspection results for the APR1400 reactor internals classified as non-prototype Category I in accordance with RG 1.20.	3.9.2.4
COL 3.9(7)	The COL applicant is to review the detailed analysis of mechanical tanks, including the effects of fluid sloshing.	3.9.2.2.14

3.9.2.6 Conclusion

The staff concludes that the information provided in the DCD meets GDC 14 and 15, for the design and testing of the RCPB to ensure a low probability of rapidly propagating failure and of gross rupture by ensuring that design conditions are not exceeded during normal operation, including AOOs. The DCD includes an acceptable vibration, thermal expansion, and dynamic effects test program to be conducted during startup and initial operation on specified high- and moderate-energy piping and its systems, restraints, and supports. The tests provide adequate assurance that the piping and piping restraints of the system are designed to withstand vibrational dynamic effects of valve closures, pump trips, and other operating modes of design-basis flow conditions. In addition, the tests provide assurance of adequate clearances and free movement of snubbers for unrestrained thermal movement of piping and supports during normal system heat-up and cool-down operations. The planned tests will develop loads similar to those experienced during reactor operation.

The application meets the relevant requirements of GDC 2, and 10 CFR Part 50, Appendix S, for demonstrating design adequacy of all Category I systems, components, equipment, and their supports to withstand earthquakes by meeting the acceptance criteria of SRP Section 3.7.2, SRP Section 3.7.3, and the applicable regulatory positions of RGs 1.61 and 1.92; and by providing acceptable seismic systems analysis procedures and criteria. The scope of review of the seismic system analysis included the seismic analysis methods of all Category I systems, components, equipment and their supports, procedures for modeling, inclusion of torsional effects, seismic analysis of Category I piping systems, seismic analysis of multiply-supported equipment and components with distinct inputs, and determination of composite damping. The review has included design criteria and procedures for evaluation of the interaction of non-Category I with Category I piping. The review has also included criteria and seismic analysis procedures for reactor internals and Category I buried piping outside containment.

The system analyses are performed by the applicant on an elastic basis. Modal response spectrum, multi-degree of freedom, and time history methods form the bases for the analyses of all major Category I systems, components, equipment, and their supports. Modal response parameters are combined in accordance with the appropriate acceptable methods described in SRP Section 3.7.2, and RG 1.92. The square root of the sum of the squares of the maximum co-directional responses is used in accounting for three components of the earthquake motion for both the time history and response spectrum methods. Floor spectra inputs to be used for design and test verifications of systems, components, equipment, and their supports are generated from the time history method, taking into account variation of parameters by peak widening.

The DCD meets the requirements of Appendix B to 10 CFR Part 50, 50.55a, GDC 1 and 4, for the design and testing of reactor internals to quality standards commensurate with the importance of the safety functions performed with appropriate protection against dynamic effects. The DCD also meets the regulatory positions of RG 1.20, for preoperational vibration tests by developing a preoperational vibration program planned for the reactor internals and providing an acceptable basis for design adequacy of these internals under test loading conditions comparable to those experienced during operation. The combination of planned tests, predictive analysis, and post-test inspection and acceptance criteria provide adequate assurance that the reactor internals will, during their service lifetime, withstand the flow-induced vibrations of reactor operation without loss of structural integrity. The integrity of the reactor

internals in service is essential to proper positioning of reactor fuel assemblies and unimpaired operation of the control rod assemblies for safe reactor operation and shutdown.

The DCD meets the relevant requirements of GDC 2 and 4, for design of systems and components important to safety to withstand the effects of earthquakes and appropriate combinations of the effects of normal and postulated accident conditions. The analysis provides adequate assurance that the combined stresses and strains in the components of the reactor coolant system and reactor internals will not exceed the allowable design stress and strain limits for the materials of construction. The applicant's evaluation for the design life of piping systems using the endurance stress limits is adequate and acceptable since the cumulative usage factor (CUF) is zero while the stress level is less than the endurance limits. The methods for component analysis have been found compatible with those for the systems analysis. The proposed combinations of component and system analyses are, therefore, acceptable. The assurance of structural integrity of the reactor internals under LOCA conditions for the most adverse postulated loading event adds confidence that the design will withstand a spectrum of lesser pipe breaks and seismic loading events.

The DCD meets the relevant requirements of GDC 1, for design and testing of systems and components to quality standards commensurate with the importance of the safety functions performed by the proposed program to correlate the test measurements with the analysis results. The program provides an acceptable basis for demonstrating the compatibility of the results from tests and analyses, the consistency between mathematical models used for different loadings, and the validity of the interpretation of the test and analysis results. In addition, as discussed in SER Section 3.9.2.2, ITAAC is not applicable for DCD Tier 2 Section 3.9.2 as it relates to the methodology, dynamic effects and testing of ASME Class 1, 2, 3, and CS structures, systems and components.

3.9.3 ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures

3.9.3.1 Introduction

This section discusses the requirements for maintaining the structural and pressure boundary integrity of safety-related, pressure-retaining components, core support structures, and component supports, which are designed to the criteria specified in the ASME BPV Code.

3.9.3.2 Summary of Application

DCD Tier 1: There is no DCD Tier 1 information associated with this section.

DCD Tier 2: The applicant has provided a DCD Tier 2 description in Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Class CS Core Support Structures." This section addresses several areas of review including: loading combinations, system operating transients, and stress limits for component design; the design and installation of pressure-relief devices; pump and valve functional capability; and the design of component supports.

Technical Reports: Technical reports associated with DCD Tier 2 Section 3.9.3 are as follows:

- APR1400-E-S-NR-14004, "Evaluation of Effects of HRHF Response Spectra on SSCs," Revision 1, dated February 2015.
- APR1400-E-N-NR-14001, "Design Features to Address GSI-191," Revision 0, dated December 2014.

3.9.3.3 *Regulatory Basis*

The relevant Commission regulations for this area of review and the associated acceptance criteria are given in SRP Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures," Revision 3, issued April 2014, and are summarized below. Review interfaces with other SRP sections can also be found in SRP Section 3.9.3.

- Section 50.55a of 10 CFR, and GDC 1 of Appendix A to Part 50, as they relate to the design, fabrication, erection, and testing of SSCs in accordance with quality standards commensurate with the importance of the safety function to be performed.
- GDC 2, and 10 CFR Part 50, Appendix S, as they relate to the ability of SSCs to withstand the effects of natural phenomena, such as earthquakes, tornadoes, floods, and the appropriate combination of all loads without loss of capability to perform their safety function.
- GDC 4, as it relates to the protection of SSCs 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.
- GDC 14, as it relates to designing SSCs of the RCPB to have an extremely low probability of rapidly propagating failure and of gross rupture.
- GDC 15, as it relates to designing the RCS with sufficient margin to assure that the RCPB is not exceeded during normal operating conditions, including AOOs.
- Section 52.47 of 10 CFR, as it relates to DC applicants providing for audit information normally contained in certain procurement specifications and construction and installation specifications.
- Section 52.47(b)(1) of 10 CFR, which requires that a DC 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, 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, and the NRC's regulations.

Acceptance criteria adequate to meet the above requirements include:

- RG 1.124, "Service Limits and Loading Combinations for Class 1 Linear-Type Supports," Revision 3, issued July 2013.
- RG 1.130, "Service Limits and Loading Combinations for Class 1 Plate-and-Shell-Type Component Supports," Revision 3, issued July 2013.

- ASME BPV Code, Section III, Paragraph NCA-3250, which requires that a design specification be prepared for Class 1, 2, and 3 components such as pumps, valves, and piping systems.

3.9.3.4 *Technical Evaluation*

The requirements of GDC 1, 2, and 4, and 10 CFR 50.55a, applicable to this section require that structures and components important to safety be constructed and tested to quality standards commensurate with the importance of the safety functions to be performed, and designed with appropriate margins to withstand effects of anticipated normal plant occurrences, natural phenomena such as earthquakes, and postulated accidents, including LOCA. In addition, GDC 14 and 15, require that the RCPB design limits will not be exceeded.

The staff's review, guided by SRP Section 3.9.3, concerns the structural integrity and functional capability of pressure retaining components and their supports, as well as core-support structures that are designed in accordance with the ASME BPV Code, Section III, Division 1. The staff reviewed loading combinations and their respective stress limits, the design and installation of pressure-relief devices, and the design and structural integrity of ASME Code Class 1, 2 and 3, components and component supports, as well as core support and core support structures.

3.9.3.4.1 *Loading Combinations, System Operating Transients, and Stress Limits*

As part of the staff's evaluation of the applicant's compliance with the requirements of GDC 1, 2, 4, 14, and 15, 10 CFR 50.55a, and 10 CFR Part 50, Appendix S, this section evaluates the acceptability of the loads and loading combinations, system operating transients and stress limits used in the design of ASME BPV Code Class 1, 2 and 3 components, component supports and core support structures. The loads and load combinations, system operating transients, and component stress limits are evaluated to determine whether they conform to SRP Section 3.9.3.II.1.

In DCD Tier 2, Section 3.9.3.1, "Loading Combinations, Design Transients, and Stress Limits," the applicant establishes the criteria for the design limits and loading combinations associated with normal operation, postulated accidents, and specified seismic and other transient events for the design of ASME BPV Code, Section III components. DCD Tier 2 Table 3.9-2, provides further information on the design, Level A, Level B, Level C, and Level D, conditions loading combinations for the design ASME Code Class 1, 2, and 3, components and component supports.

DCD Tier 2 Table 3.9-2, indicates that the load combination for Service Level C includes dynamic system loadings associated with the emergency condition. However, DCD Tier 2 Section 3.9.1, states that there are no transient events for the emergency condition. These two sections initially appeared to be inconsistent. Therefore, the staff issued RAI 319-8360, Question 03.09.03-2 (ML15328A033), requesting the applicant to describe the specific dynamic system loads that are included in the load combination for Service Level C, and add a clarification note in DCD Tier 2 Table 3.9-2, as applicable.

In its response to RAI 319-8360, Question 03.09.03-2 (ML16188A413), the applicant proposed that the load combination of Service Level C be deleted in DCD Tier 2, Section 3.9.3-3.9.5,

Table 3.9-2, Table 3.9-6, Table 3.9-7, Table 3.9-10, Table 3.9-11, Table 3.9-12, Table 3.12-1 and Table 3.12-2. As the applicant indicated in the DCD Tier 2 Section 3.9.1.1.3, there is no plant emergency condition specified for Service Level C. The loads that resulted from the plant emergency condition are specified conservatively in the plant upset condition of Service Level B. The staff finds that loadings from Service Level C have been considered in load combinations of Service Level B, as the applicant responded in the RAI response. As a result, the load combinations of Service Level C have been conservatively accounted for and have been added to load combinations of Service Level B, therefore, load combinations of Service Level C would not be necessary to be identified in DCD Tier 2 sections. The staff also noted that components designed to these load combinations of Service Level B should have conservative ASME allowable stress limits. Therefore, the proposed deletion of the load combination of Service Level C is acceptable and the updated information is consistent with the other DCD Tier 2 sections.

In addition, the applicant proposed that IRWST loads be added to the load combinations of Service Level D of DCD Tier 2, Tables 3.9-10, 3.12-1, and 3.12-2. The staff finds the added IRWST load to the load combination of Service Level D conforms to the SRP Section 3.9.3, and is acceptable.

As discussed in the RAI response, the wind and tornado loads are deleted from the load combinations of Service Level D of DCD Tier 2, Tables 3.9-6, 3.9-7, 3.9-10, and 3.12-2. The staff noted that the applicant designs ASME Class 1, 2, and 3 components and component supports without wind and tornado loads because the components and component supports are designed within wind/tornado protected structures and are not directly exposed to wind or tornado loads. Therefore, the staff finds the applicant's response regarding the deletion of wind and tornado loads acceptable.

In its response to RAI 319-8360, Question 03.09.03-2 (ML15328A033), the applicant stated that the make-up flow can compensate for the loss of coolant from a break with a 5.56 mm (7/32 in.) diameter, and postulated breaks in one-inch nominal diameter piping and smaller piping, do not require the analysis of the dynamic system loadings from a ruptured pipe on components, component supports or core support structures. The staff noted that pipes with greater than one-inch nominal diameter should also have postulated breaks. As a result of these postulated breaks, the jet impingement and pipe whip loads (resulting from these postulated breaks) are imposed on the components and component supports. In its revised response to RAI 319-8360, Question 03.09.03-2 (ML16232A613), the applicant stated that the note, "pipe break loads include loads due to LOCA," will be added to the associated tables. This provides the inclusion of jet impingement and pipe whip loads in the load combination of Service Level D. The term, "dynamic system loads," in Service Level C is deleted in the related DCD Tier 2, Sections 3.9.3.1, 3.9.4.3, 3.9.5.2; and Section 3.9.5.2.4, Tables 3.9-2, 3.9-6, 3.9-7, 3.9-10 through -12, 3.12-1, and 3.12-2 are revised.

The staff evaluated the proposed DCD changes and confirmed that they conform to SRP Section 3.9.3, and therefore, are acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 319-8360, Question 03.09.03-2, is resolved and closed.

In DCD Tier 2 Table 3.9-2, Service Level D has the "DF" load included in the load combination. In the legend note (2), the applicant defined DF loads as dynamic system loadings associated

with pipe breaks (not eliminated by a leak-before-break analysis). Note (2) was not initially clear whether the DF load includes loadings associated with relief valve opening and closure in a closed system. Therefore, the staff issued RAI 319-8360, Question 03.09.03-3 (ML15328A033), requesting the applicant to describe how these loads are included in the analysis and the extent that these valve operations are expected following the pipe break referenced in this load combination.

In its response to RAI 319-8360, Question 03.09.03-3 (ML1613A277), the applicant stated that the DF loading defined in note (2) for DCD Tier 2 Table 3.9-2, is included and the DF load associated with the loadings from pipe breaks and the loadings from relief valve actuation, such as POSRV actuation. The staff noted that the term DF loads should be clearly defined as loadings from pipe breaks and loadings from relief valve actuation, such that these loads are accurately assigned into the Table 3.9-2 load combinations. In the RAI response, the applicant stated that the event which assumes relief valve (POSRV) actuation following a pipe break is the feedwater system pipe break. The loadings induced by the pipe break and the POSRV actuation as a result of this event are applied to the loading combinations as described in DCD Tier 2 Subsection 3.9.3.1. Therefore, DCD Tier 2 Table 3.9-2, is revised to define the DF loading explicitly and to differentiate between transient loading conditions that also include relief valve actuation loading, designated as DFL, and to add the load combination of Service Level B. The staff evaluated the changes and finds that the applicant's approach conforms to SRP Section 3.9.3, and is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 319-8360, Question 03.09.03-3, is resolved and closed.

In DCD Tier 2, Section 3.9.3.1, Section "Test Loadings," the applicant stated that ASME Code Class 1, 2, and 3, piping and components of fluid systems are designed and constructed in accordance with ASME BPV Code Section III. In addition, hydrostatic testing is performed per ASME BPV Code Section III. The applicant further stated that, "significant structural discontinuities in parts such as nozzles and flanges are considered. In addition to the design calculation required by ASME [BPV Code] Section III, stress analysis is also performed by methods outlined in the code appendices or by other methods by reference to analogous codes or other published literature." The staff discussed this broad statement about other methods with the applicant at an April 15, 2015, public meeting. Subsequently, the applicant provided a proposed revision to the DCD on June 1, 2015 (ML15152A248), to delete the following phrase in this sentence: "or by other methods by reference to analogous codes or other published literature." The staff finds the proposed sentence acceptable because it references ASME BPV Code Section III and its appendices, which have been accepted by the staff through the incorporation by reference of the Code into 10 CFR 50.55a, and eliminates ambiguous phrasing referring to other methods. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

As part of the staff's review for compliance with GDC 2, and 10 CFR Part 50, Appendix S, the staff reviews the use of seismic loads in the load combinations for ASME Class 1, 2, and 3 components and core support structures. The applicant submitted Technical Report APR1400-E-S-NR-14004, Revision 1, "Evaluation of Effects of HRHF [Hard Rock High Frequency] Response Spectra on SSCs [Structures, Systems, and Components]," (referred hereafter as the HRHF TR). This HRHF TR includes an evaluation of the HRHF spectra on certain components. The relationship of this report to the component structural analyses presented in DCD Tier 2 Section 3.9.3, was initially unclear. Therefore, the staff issued RAI

319-8360, Question 03.09.03-4 (ML15328A033), requesting the applicant to provide additional information in several areas related to this report.

The HRHF TR was initially referred to only in Appendix 3.7B of DCD Tier 2 Chapter 3, and not in other sections that use seismic inputs in their evaluation of component structural integrity and dynamic qualification (e.g., DCD Tier 2, Sections 3.9.2, 3.9.3, 3.9.4, 3.9.5, 3.10, and 3.12). Because this report is incorporated by reference into the DCD through Tier 2, Table 1.6-2, however, it appeared that the applicant intended these HRHF spectra to be part of the review of the application. The applicant was requested to describe, for each section that uses proposed certified seismic design response spectra (CSDRS) seismic inputs, how the HRHF spectra were also considered in the design, analysis, and testing of components, including piping. (A similar observation was made specific to DCD Tier 2 Section 3.12, in RAI 311-8278, Question 03.12-9, as described in SER Section 3.12.

In its response to RAI 311-8278, Question 03.12-9 (ML17174B269), the applicant provided a mark-up of DCD Tier 2 Section 3.10.1.2, to include the additional detail regarding HRHF. However, the marked-up DCD Tier 2 Section 3.10.1.2, does not reference the HRHF TR. Therefore, the staff requested that the applicant include the reference of the Technical Report APR1400 E-S-NR-14004 into the DCD Tier 2 Section 3.10.1.2. In its supplemental response to RAI 311-8278, Question 03.12-9 (ML17174B269), the applicant provided an additional mark-up of DCD Tier 2 Section 3.10.1.2, with a reference to the TR, as requested by staff. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 319-8360, Question 03.09.03-4, is resolved and closed.

In Section 6.2.2 of the HRHF TR, the applicant stated that “the RCS [reactor coolant system] component nozzles of the RV [reactor vessel], SG [steam generator], and RCP [reactor coolant pump] are included in the evaluation since a component nozzle has greater potential for failure than at other locations and the cold leg, hot leg, and crossover leg are relatively sensitive to high frequencies when compared with other components.” The HRHF TR does not provide details of how these component locations were selected from the overall population and how the evaluation was performed. The staff issued RAI 319-8360, Question 03.09.03-4 (ML16188A355), requesting the applicant to: (1) describe the screening criteria used to select components (including piping) for evaluation of the effects of HRHF spectra, (2) list the components so evaluated, and (3) compare the calculated stresses using HRHF seismic inputs to the analyses conducted using CSDRS seismic inputs in the load combinations.

In its response to RAI 319-8360, Question 03.09.03-4, (ML16188A355), the applicant stated that the components are selected for HRHF evaluation based on the screening criteria that depends on importance to safety as used for component supports, dynamic characteristics as used for CEDMs, and high stress concentration such as nozzles. As a result, the selected RCS components (reactor vessel, steam generator, reactor coolant pump, pressurizer), RCS loop piping, RCS component supports and RCS component nozzles are evaluated for HRHF effects. The staff finds that these components are evaluated with the maximum RCS component loads obtained from the HRHF seismic input and are compared with the design loads determined from the results of the CSDRS seismic input. Because the design loads from CSDRS seismic input envelope the component loads and support loads from the HRHF seismic input, a stress evaluation of the HRHF seismic inputs is not performed for these components. Therefore, the staff finds that the methodology of evaluating HRHF effects is adequate.

The applicant described stress limits for ASME Code Class 1 components, supports, and piping in DCD Tier 2 Table 3.9-3. Similarly, stress limits for ASME Code Class 2 and 3, components and supports are also described in DCD Tier 2, Tables 3.9-5 through 3.9-9. The applicant indicates that design transients for ASME Class 1, 2, and 3, components, component supports and for reactor internals are described in DCD Tier 2 Section 3.9.1.1. This information is evaluated in SER Section 3.9.1. The load combinations and stress limits specific to the reactor internals stress analysis are presented in DCD Tier 2 Section 3.9.5, and evaluated in SER Section 3.9.5.

The application includes COL 3.9(2) related to stress results for specific Class 1, 2, and 3, components. The final detailed results of these stress calculations rely on a level of detailed design beyond what is necessary at the DC application stage. The staff's review focuses on the design specifications for these components, as described below. Following discussion with the applicant in an April 15, 2015, public meeting, the staff concluded that this subject was already addressed through the ITAAC relating to final as-built ASME BPV Code design reports, which are included in the application in accordance with 10 CFR 52.80(a). The staff reviewed these ITAAC and determined that they present sufficient information to demonstrate that the as-built components will satisfy the requirements of the respective ASME design specification for each component and the applicable subsection of the ASME BPV Code. Additional information on the ITAAC review, as well as the standardization of ITAAC across applications, is presented in SER Section 14.3.3. Based on this information, the staff concluded that a COL item was unnecessary and could cause confusion at the COL application stage. As a result, the applicant provided a proposed revision to the DCD on June 1, 2015 (ML15152A248) that deleted this COL item. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In DCD Tier 2 Section 3.9.3.1.4, the applicant states that design specifications for ASME BPV Code Section III components and supports are prepared using guidelines given in ASME BPV Code Section III. The design specifications for these ASME components include the functions, boundaries, design requirements, overprotection requirements, environment conditions, code classification, material requirements, and the effective Code edition and addenda and Code Cases. As described above, in accordance with 10 CFR 52.47, the applicant is expected to make information normally included in procurement specifications and construction and installation specifications available for audit if it is necessary to support the staff's finding. At a public meeting on April 14, 2015, the staff discussed the availability of this information with the applicant. Further information on the meeting is provided in the associated meeting summary dated May 14, 2015 (ML15124A886). Based on those discussions, the applicant submitted a list of components within the scope of the audit in a letter dated June 1, 2015 (ML15152A248).

In August 2015, the staff performed a regulatory audit of the component design and procurement specifications. The purpose of the regulatory audit was to confirm that the APR1400 component design and procurement specifications (or related detailed design information) were prepared in accordance with the methodology and design criteria described in the DCD and are consistent with SRP Section 3.9.3. This includes verification by the staff that the design information described in the DCD was adequately translated into documentation for each of the components designed to ASME BPV Code Section III, Class 1, 2, and 3 requirements.

An audit report dated April 20, 2016 (ML15350A057) documents the staff's audit observations and the applicant's responses. During this audit, the staff reviewed individual design and procurement specifications for ASME Code components, including valves, pumps, component supports, dynamic restraints, equipment seismic qualifications and component classifications. The staff found that several design specifications for ASME code components and component supports in the APR1400 NSSS need to be revised to incorporate the audit findings. During this audit, the applicant provided a mark-up of COL 6.8(7), to be included in the next revision of DCD Tier 2 Table 1.8-2. The audit included staff's finding that the design specification of IRWST sump strainer incorrectly specified design loads (incorrect specified head loss of 1.5 (ft-water) in lieu of 2.0 (ft-water)), insufficient load definitions specified in the design specification for pressurizer assembly and insufficient load combinations specified in the design specification for reactor coolant pump (RCP). Additional details of staff's observations are summarized in the audit report dated April 20, 2016 (ML15350A057).

In addition, design specifications (or information typically included in specifications) for sample of safety-related pumps and valves in balance of plant (BOP) systems in the APR1400 need to be made available for a follow-up audit, such that the staff can reach a conclusion regarding the specification-related provision in 10 CFR 52.47. Subsequently, the staff performed the follow-up audit of design and procurement specifications. The staff found that the changes of design and procurement specifications addressed the staff's audit findings. However, the specifications provided as part of the follow-up audit were not formal versions of the specifications. Therefore, the staff issued RAI 550-8737, Question 03.09.03-7 (ML17195B072), requesting the applicant to provide the staff with formally signed APR1400 design and procurement specifications so that the staff can verify the completeness of these specifications. A summary of audit is provided in the follow-up audit report dated June 30, 2017 (ML17095A754).

In its response to RAI 550-8737, Question 03.09.03-7 (ML17237B993), the applicant provided the mark-ups of the DCD Tier 2 Table 3.2-1, to include, "SC-1: Seal plug," as stated in the "Heated Junction Thermocouple Probe Assembly (HJTC) Design Specification." In this markup, a COL item is added to DCD Tier 2 Table 1.8-2, stating that a COL applicant is to confirm the IRWST sump strainer head loss is less than the allowable head loss of 2 ft-water and that the final signed packages for design specifications requiring revision would be transmitted to the electronic reading room for verification by the staff. In addition, the response provided by the applicant included the plan of formal revisions of design specifications as well as several supporting documents which demonstrate the relationship between the procurement specification and design documents. The applicant also stated that the audit items and the applicant's responses have been incorporated into the relevant supporting documents that have been issued, and are transmitted to the electronic reading room for verification by the staff. The applicant further stated that a COL applicant will be responsible for plant specific procurement specification, as required by Quality Assurance Program Description for the APR1400 (APR1400-KQ-TR-11005-NP, Revision 5). The staff reviewed changes of design specifications and found they are acceptable. The staff found the RAI response acceptable, since the applicant provided the plan for the formally signed APR1400 and procurement specifications. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 550-8737, Question 03.09.03-7, is resolved and closed.

As a result of the audits, the staff found that design and procurement specifications for ASME Class 1, 2 and 3 components, component supports, and core support structures meet

the ASME BPV Code, Section III, NCA-3250, requirements and are consistent with the methodology and criteria described in the DCD.

During this audit, the staff observed that uncertainties in net positive suction head required (NPSH_r) did not appear to be clearly addressed in the portions of specifications that addressed qualification of pumps. In DCD Tier 2 Table 3.6-1, "NPSH_r for SI Pump and CS Pump," of APR1400-E-N-NR-14001, "Design Features to Address GSI-191," the applicant addresses uncertainties in NPSH_r for the SI and CS pumps. Specific values are provided for NPSH_r3 percent (provided by the pump vendor as a result of factory testing as the value of NPSH which results in a 3 percent drop in pump discharge head) and for NPSH_{r,eff} (the NPSH_r3 percent value with uncertainties in NPSH_r included). As described in SECY-11-0014, "Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents," dated January 31, 2011, which was referenced by the applicant in the notes to DCD Tier 2 Table 3.6-1, experience has shown that the uncertainty in NPSH_r of a pump installed in the field is greater than the uncertainty obtained by testing at the pump vendor's facility for several reasons. However, uncertainties in NPSH_r were not described in the audited specifications or in the TR for safety-related pumps other than the SI and CS pumps. Therefore, the staff issued RAI 319-8360, Question 03.09.03-6 (ML15328A033), requesting the applicant to describe the provisions to account for uncertainties in NPSH_r for safety-related pumps other than the SI and CS pumps and revise the technical report as appropriate, such that the application integrates this operating experience consistent with 10 CFR 52.47(a)(22).

In its response to RAI 319-8360, Question 03.09.03-6 (ML16134A597), the applicant stated that APR1400-E-N-NR-14001, addresses the uncertainties of NPSH_r for the SI and CS pumps to ensure the performance of the pumps for ECCS and CHRS functions in postulated accidents as discussed in SECY-11-0014. The applicant further explained that relevant post-accident mitigation does not rely on any other safety related pumps to perform the ECCS and CHRS functions. The staff noted that provisions to account for uncertainties are generally addressed by the pump vendors meeting the ASME QME-1 requirements. Therefore, the pump uncertainties do not need to be addressed in this technical report. The staff finds the applicant response acceptable since the pump vendors address the uncertainties by meeting the ASM QME-1 requirements. Therefore, RAI 319-8360, Question 03.09.03-6, is resolved and closed.

3.9.3.4.2 *Design and Installation of Pressure-Relief Devices*

This section evaluates the applicant's designs and installation of pressure-relief devices to meet the requirements of GDC 1, 2, 4, 14 and 15; 10 CFR 50.55a; and 10 CFR Part 50, Appendix S, and SRP Section 3.9.3.II.2.

In DCD Tier 2, Section 3.9.3.2, "Design and Installation of Pressure Relief Devices," the applicant provides the criteria for the design and installation of pressure-relief devices that complies with the requirements of ASME BPV Code, Section III, Appendix O, "Rules for Design of Safety Valve Installations." The applicant also describes the ASME BPV Code, Section III, Class 1 and 2 pressure relief devices. Pressure-relieving devices for ASME BPV Code, Section III, Class 2, systems include the main steam safety valves (MSSVs) on the steam line and the low temperature overpressure protection (LTOP) relief valves on the containment isolation portion of the normal shutdown cooling system (SCS). Where more than one valve is

installed on the same pipe run, the sequence of valve openings to be assumed in analyzing the stress at any piping location is estimated to induce the maximum instantaneous value of stress at that location. The applicable stress limits are satisfied for all components of the pipe run and connecting systems, and the pressure relief valve station, including supports. After the dynamic structural system analysis, a dynamic load factor affects the reaction forces and moments and a dynamic load factor of 2.0 is used in lieu of a dynamic analysis to determine the dynamic load factor. The staff finds the above description for the design of pressure-relief devices consistent with SRP Section 3.9.3, and is, therefore, acceptable.

3.9.3.4.3 *Pump and Valve Functionality Assurance*

This section evaluates whether the applicant's design of pumps and valves meet the requirements of GDC 1, 2, 4, 14, and 15; 10 CFR 50.55a; and 10 CFR Part 50, Appendix S and ASME Class 1, 2, and 3, pumps and valves, as described in SRP Section 3.9.3. The review documented in this section interfaces with that documented in Section 3.9.6 of this report, which also addresses the functionality of pumps and valves. The staff issued RAI 62-7995, Question 03.09.03-1 (ML15189A485), requesting the applicant to provide clarification on the provisions of ASME QME-1-2007, as accepted in RG 1.100. In its revised response to RAI 62-7995, Question 03.09.03-1 (ML17237B993), the applicant proposed changes to the DCD relevant to the discussion below.

The staff reviewed DCD Tier 2, Section 3.9.3.3, "Pump and Valve Functionality Assurance," which discusses the functional capability of safety-related pumps and valves during the life of the plant under various postulated transient conditions. Active pumps and valves are also required to function under faulted conditions. Active pumps and valves are defined as pumps and valves that perform a mechanical motion in order to shut down the plant, maintain the plant in a safe shutdown condition, or mitigate the consequences of a postulated event. The applicant states that the functional design and qualification of safety-related pumps and valves are performed in accordance with ASME QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," as accepted by the staff as adequate to meet the regulations in RG 1.100, "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants," Revision 3. The applicant provides lists of relevant components in DCD Tier 2, Table 3.9-18, "List of Active Pumps," and DCD Tier 2, Table 3.9-4, "Seismic Category I Active Valves." The staff finds the information of pump and valve functionality assurance in Section 3.9.3.3 acceptable, since the applicant provided information that conforms to RG 1.100. As mentioned above, additional staff evaluation of the functional design and qualification of pumps and valves is provided in SER Section 3.9.6. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 62-7995, Question 03.09.03-1, is resolved and closed.

In DCD Tier 2, Section 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment," the applicant describes the equipment qualifications used to assess the functional capability of the required components. These criteria and considerations include collapse and deflection limits associated with these components. The provided information in this section regarding the pump and valve seismic qualifications address the requirements in 10 Part CFR 50, Appendix S, and GDC 2, 4, 14, and 15. Additional staff evaluation of equipment seismic qualifications is discussed in SER Section 3.10.

In DCD Tier 2 Section 3.9.3.3.3, the applicant states that ASME Class 1, 2, and 3, valves are designed and analyzed according to the requirements of ASME BPV Section III, Subarticles NB -500, NC-3500, and ND-3500, respectively. Tests or a combination of test and analysis for pumps and valves are used in accordance with ASME QME-1-2007, as accepted by the staff as sufficient to meet the regulations in RG 1.100, Revision 3. The staff finds the design of Class 1, 2, and 3, valves conforms to 10 CFR 50.55a, 10 CFR Part 50, Appendix S, and GDC 1, 2, 4, 14 and 15, since the valves are designed to ASME BPV Section III, and conform to RG 1.100 Revision 3.

On the basis of the above evaluation, the staff determined that the discussion of functional capability within the scope of this review section is acceptable. The testing and analysis methods to be used in the qualification of these components are commonly used in the industry and accepted by the staff in formal guidance. The APR1400 design provides an adequate margin of safety to withstand the expected loadings. Therefore, the staff concludes that the applicant satisfies 10 CFR 50.55a, 10 CFR Part 50, Appendix S, and GDC 1, 2, 4, 14 and 15, by specifying appropriate analysis and testing methods for designing safety-related pumps and valves for the APR1400 plant.

3.9.3.4.4 *Component Supports*

This section evaluates whether the applicant's design of component supports meets the requirements of GDC 1, 2 and 4; 10 CFR 50.55a; and 10 CFR Part 50, Appendix S, and SRP Section 3.9.3.II.3.

The staff reviewed DCD Tier 2, Section 3.9.3.4, "Component Supports," in which the applicant describes the design of ASME Class 1, 2, and 3, component supports and their attachments. The applicant states that the design of ASME Class 1, 2, and 3, component supports and the attachments are in accordance with ASME BPV Code, Section III, Subsection NF, up to the interface of the building structure, with jurisdictional boundaries as defined by ASME BPV Code, Section III, Subsection NF. The stress limits are defined in accordance with ASME BPV Code, Section III, Subsection NF, and Appendix F; RG 1.124, Revision 2; and RG 1.130, Revision 2. The staff evaluated the information provided by the applicant and concluded that it is acceptable because these design provisions are consistent with the ASME BPV Code, Section III, as it is incorporated into 10 CFR 50.55a and in regulatory guidance.

Concrete expansion anchors are designed to meet the requirements of ACI-349 and IE Bulletin 79-02 with the provisions identified in DCD Tier 2 Subsection 3.8.4.5. The staff's evaluation of this material is presented in SER Section 3.8.4.

Part 50 of 10 CFR, Appendix A, GDC 2, and Appendix S, require that structures and components important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. One aspect of compliance with these requirements, as described in SRP Section 3.9.3, is the inclusion of energy-absorbing snubbers in the design. As stated in the acceptance criteria in SRP Section 3.9.3, Subsection II, the snubber end fitting clearance, mismatch of end fitting clearances, mismatch of activation and release rates, and lost motion should be minimized and should be considered when calculating snubber reaction loads and stress which are based on a linear analysis of the system or component. This provision is especially important in multiple snubber applications where mismatch of end fitting clearance has a greater effect on the load sharing of these snubbers

than does the mismatch of activation level or release rate. Equal load sharing of multiple snubber supports should not be assumed if mismatch in end fitting clearance exists.

In DCD Tier 2, Section 3.9.3.4 "Component Supports," the applicant states that where required, snubber supports are used as shock arrestors for safety-related systems and components. Snubbers are used as structural supports during a dynamic event such as an earthquake or a pipe break but during normal operation act as passive devices that accommodate normal expansions and contractions of the systems without resistance. For the APR1400, snubbers are minimized to the extent practical in the APR1400 design.

To the extent that snubbers may be used in the detailed design of the APR1400 plant, the general design should be described in DCD Tier 2 Section 3.9.3.4. The staff issued RAI 319-8360, Question 3.9.3-5 (ML15328A033), requesting the applicant to provide additional information, with a summary in the DCD, of the following snubber-related information (as well as other general information as appropriate on the snubber design):

- the snubber end fitting clearance, mismatch of end fitting clearances, mismatch of activation and release rates,
- the snubber lost motion when calculating snubber reaction loads, and
- the load sharing, release rate when multiple snubber applications are used.

In its response to RAI 319-8360, Question 03.09.03-5 (ML16029A419), the applicant stated that for large bore hydraulic snubbers used for steam generators and RCPs, the snubber end fitting clearances between clevis pins and holes are designed and manufactured to be minimized. During the installation of a pair of snubbers onto a component, a mismatch of end fitting clearances may occur. The maximum magnitude remains a tight fit that will not affect the snubber's function.

The applicant further explained that the snubber model includes a linear spring element whose spring rate is determined using test results (e.g., displacements and test loads), displacements that account for the effects of end fitting clearances, lost motion and compression of fluid. Snubber reaction loads are determined from the system analysis with the spring elements. For multiple snubber installation, the mismatch of the snubber action initiation velocities is required to be within 0.01 in/s (0.25 mm/s) of each other. The staff noted that the snubbers are certified by the manufacturer to meet the functional requirements of the snubber Design Specification, and the snubbers are included in the inservice testing (IST) program to confirm their operability and correct installation. The applicant committed to add a summary of snubber design in the mark-up of DCD Tier 2 Section 3.9.3.4, in response to staff's RAI on this topic. The staff finds the RAI response acceptable, since the applicant provided the requested snubber design information. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 319-8360, Question 03.09.03-5, is resolved and closed.

Additional information on inservice testing and inspection of dynamic restraints is provided in DCD Tier 2 Section 3.9.6.4, and is evaluated in SER Section 3.9.6. In addition, the DCD includes COL 3.9(6) for COL applicants to provide a table of safety-related components that use snubbers for their supports.

3.9.3.5 Combined License Information Items

DCD Tier 2, Section 3.9.3, contains the following COL information items.

Table 3.9.3 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.9(3)	The COL applicant is to identify the site-specific active pumps.	3.9.6
COL 3.9(6)	The COL applicant is to provide a table listing all safety-related components that use snubbers in their support systems.	3.9.6.4
COL 6.8(7)	The COL applicant is to confirm that the IRWST sump strainer has the total strainer head loss less than the allowable head loss (0.61 m (2ft)).	6.8

The staff evaluated the above COL items and concluded that the applicant appropriately lists the information that will be provided by the COL applicant for the APR1400 plant.

3.9.3.6 Conclusion

The staff concludes that the information provided in the DCD with respect to the use of codes and standards is acceptable consistent with the requirements in 10 CFR Part 50, Appendix A, GDC 2, 4, 14, and 15. With respect to the ASME code of record, the application is sufficient to support the staff's finding of compliance with the requirements of 10 CFR Part 50, Appendix A, GDC 1, and 10 CFR 50.55a, that nuclear power plant SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed because the applicant correctly identified the ASME Code of Record to apply to the APR1400 design.

3.9.4 Control Rod Drive System

3.9.4.1 Introduction

The control rod drive system (CRDS) consists of the control rods and the related mechanical components that provide the means for mechanical movement. GDC 26, 10 CFR Part 50, Appendix A, requires that the CRDS provide one of the independent reactivity control systems. The rods and the control element drive mechanisms (CEDMs) shall be capable of reliably controlling reactivity changes under conditions of normal operation, including AOOs, and under postulated accident conditions. A positive means for inserting the rods shall always be maintained to ensure appropriate margin for malfunction, such as stuck rods. The applicant's information regarding design criteria; testing programs; summary of method of operation of the CRDS; applicable design codes and standards, design loads and combinations; and operability assurance program is reviewed in this section. This information pertains to the CRDS, which is considered to extend to the coupling interface with the reactivity control elements in the reactor pressure vessel (RPV). The review in this section is limited to the CEDM portion of the CRDS.

3.9.4.2 *Summary of Application*

DCD Tier 1: The Tier 1 information associated with the CEDMs is found in Section 2.4.1.1, “Design Description,” and Table 2.4.1-2, “Reactor Coolant System Components List,” and Table 2.4.1-4, “Reactor Coolant System ITAAC.”

DCD Tier 2: The applicant provided a DCD Tier 2 system description in Section 3.9.4, “Control Element Drive Systems,” that is summarized here in part. Section 3.9.4 presents the technical information supporting the design basis for the CEDM. The APR1400 CEDM is a magnetic jack-type driving apparatus used to vertically position the control element assemblies (CEAs) as an independent reactivity control system. Each CEDM is capable of withdrawing, inserting, holding, or tripping the CEA from any point within its 3.8m stroke in response to operation signals.

The CEDMs are mounted on nozzles on the top of the RPV closure head. A CEDM consists of upper pressure housing, motor housing, motor assembly, coil stack assembly, two reed switch position transmitter (RSPT) assemblies, and an extension shaft assembly (ESA). The drive power is supplied by the coil stack assembly, which is positioned around the motor housing. Two RSPT assemblies are supported by the upper shroud, which encloses the upper pressure housing assembly.

The lifting operation consists of a series of magnetically operated step movements. Two sets of mechanical latches are used to engage an ESA. The magnetic force is obtained from the coil stack assembly mounted on the outside of the motor housing.

The CEDM control system actuates the stepping cycle and moves the CEA by a withdrawal or insertion stepping sequence. CEDM-hold is obtained by energizing a latch coil at a reduced current, while all other coils are de-energized. The CEAs are tripped upon interruption of electrical power to all coils. Each CEDM is connected to the CEAs by an ESA.

The axial position of a CEA in the core is indicated by three independent readout systems.

One system counts the CEDM steps electronically, and the other two consist of magnetically actuated reed switches located at regular intervals along the upper pressure housing.

ITAAC: The ITAAC associated with DCD Tier 2, Section 3.9.4 are given in DCD Tier 1, Table 2.4.1-4, “Reactor Coolant System ITAAC,” item 12, which indicates that tests are performed on the as-built CEDMs to confirm scram ability.

3.9.4.3 *Regulatory Basis*

The relevant requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.9.4, and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 3.9.4.

- GDC 1, and 10 CFR 50.55a, as they relate to the CRDS, require that the CRDS be designed to quality standards commensurate with the importance of the safety functions to be performed.

- GDC 2, as it relates to the CRDS, requires that the CRDS be designed to withstand the effects of an earthquake without loss of capability to perform its safety functions.
- GDC 14, as it relates to the CRDS, requires that the RCPB portion of the CRDS be designed, constructed, and tested for the extremely low probability of leakage or gross rupture.
- GDC 26, as it relates to the CRDS, requires that the CRDS be one of the independent reactivity control systems that is designed with appropriate margin to assure its reactivity control function under conditions of normal operation, including AOOs.
- GDC 27, as it relates to the CRDS, requires that the CRDS be designed with appropriate margin, and in conjunction with the ECCS, be capable of controlling reactivity and cooling the core under postulated accident conditions.
- GDC 29, as it relates to the CRDS, requires that the CRDS, in conjunction with reactor protection systems, be designed to assure an extremely high probability of accomplishing its safety functions in the event of AOOs.

Acceptance criteria to meet the above requirements include:

- The descriptive information is determined to be sufficient provided the minimum requirements for such information meet Section 3.9.4 of RG 1.29.
- SRP Section 3.9.4, lists codes and standards used by the nuclear industry for construction (as defined in NCA-1110 in Section III of the ASME BPV Code) that have been found acceptable.
- For the various design and service conditions defined in NB-3113 of Section III of the ASME BPV Code, load combination sets are as discussed in SRP Section 3.9.3.
- The stress limits applicable to pressurized and non-pressurized portions of the CRDS should be as given in SRP Section 3.9.3 for the response to each loading set.
- The operability assurance program will be acceptable provided the observed performance as to wear, functioning times, latching, and ability to overcome a stuck rod meet system design requirements.

3.9.4.4 *Technical Evaluation*

3.9.4.4.1 *Descriptive Information and Construction Codes: Compliance with GDC 1 and 10 CFR 50.55a, and Conformance with RG 1.29*

The staff reviewed DCD Tier 2 Section 3.9.4, in accordance with SRP Section 3.9.4. DCD Tier 2 Section 3.9.4, provides information on the APR1400 CEDM design describing the CEDM component and their operation; CEDM design specifications; design loads, stress limits and allowable deformations; and operability assurance program.

DCD Tier 2, Figure 3.9-7, "Control Element Drive Mechanism," was initially unclear as to which components form the pressure boundary, including the motor housing assembly. This

information is necessary to complete the area of review described in SRP Section 3.9.4.I.1, which states that “[t]he descriptive information, including design criteria, testing programs, drawings, and a summary of the method of operation of the control rod drives, is reviewed to permit an evaluation of the adequacy of the system to perform its mechanical function properly.”

The applicant submitted a letter dated July 6, 2015 (ML15187A312) that proposed modifications to DCD Tier 2 Figures 3.9.7, illustrating the pressure boundary and other parts of the CEDM for the DCD. The staff reviewed this information to determine whether it conforms to the guidance of SRP Section 3.9.4.I.1, by clearly stating the parts of the CEDM that form the pressure boundary. The staff confirmed that the information provided is consistent with the relevant guidance and is therefore acceptable. In addition, the staff confirmed that the proposed modifications were incorporated into the DCD.

DCD Tier 2, Section 3.9.4.2, “Applicable CEDM Design Specifications,” describes the classification of the CEDM components, also provided in DCD Tier 2 Table 3.2-1, stating that the components forming the pressure boundary are the motor housing assembly, upper pressure housing assembly, vent stem, and housing nut. These components are designed, constructed, and tested in accordance with ASME BPV Code Section III, Subsection NB. DCD Tier 2 Table 3.2-1, also states that the CEDM pressure housing assembly, motor assembly, extension shaft assembly, and reactor trip switchgear are classified as seismic Category I. The rod drive motor generator set is classified as seismic Category III, which is defined in DCD Tier 2 Section 3.2.1. The staff finds these classifications consistent with GDC 1, 10 CFR 50.55a, and RG 1.29, and therefore, acceptable.

However, in DCD Tier 2 Table 3.2-1, there was initially no reference to a code and standard for either the motor assembly or the extension shaft assembly, as described in DCD Tier 2 Table 3.2-1, item 11a(2) and item 11a(3). This information is necessary to complete the area of review described in SRP Section 3.9.4.I.2, which indicates that those portions that are not part of the RCPB are reviewed for compliance with other specified parts of Section III, or other sections of the ASME BPV Code.

SER Section 3.2.2, discusses and evaluates the quality group classification of components. As described in that section, the staff requested additional information for several SSCs in DCD Tier 2 Table 3.2-1, which had no information regarding codes and standards. The disposition of this issue is described in SER Section 3.2.2.

The applicant did not initially include in the DCD the design margins for non-pressure boundary components. This information is necessary for the staff to make a finding under SRP Section 3.9.4, acceptance criterion 2.C: “For non-pressurized equipment (Non-ASME BPV Code): Design margins presented for allowable stress, deformation, and fatigue should be equal to or greater than margins for other plants of similar design with successful operating experience. A justification of any decreases in design margins should be provided.” The staff discussed this issue with the applicant in a public meeting on June 23, 2015, and the applicant provided written material to support the meeting discussion, formally documented in a letter dated July 6, 2015 (ML15187A312). The staff finds the additional information sufficient to resolve its concerns because the applicant demonstrated that it met SRP Section 3.9.4, acceptance criterion 2.C, by testing the non-pressure boundary components to 1.5 times the design duty requirement.

3.9.4.4.2 *Load Combinations and Stress Limits: Compliance with GDC 2, 14, and 26*

In DCD Tier 2 Section 3.9.4, the applicant describes the function of the CEDM and specifies the necessary requirements pertaining to its materials, design, inspection, and testing prior to and during service. The loading combinations and corresponding stress limits for ASME BPV Code design are defined for the design condition, Service Levels A, B, C, and D (also known as normal, upset, emergency, and faulted conditions), and test conditions and are presented in DCD Tier 2 Table 3.9-11. The staff finds the limits presented in DCD Tier 2 Table 3.9-11, consistent with SRP Section 3.9.4, acceptance criterion 3, which states that stress limits for the CEDM pressure housings be consistent with ASME Code Section III, requirements. Therefore, the staff finds this information provided consistent with the relevant guidance and staff concludes that it is acceptable.

In DCD Tier 2 Section 3.9.4.3, "Design Loads, Stress Limits, and Allowable Deformations," the applicant establishes the CEDM pressure housings loading combinations, loading values, and the primary stresses to meet the ASME BPV Code, Section III, Division I, Subsection NB requirements.

The staff finds the loading combinations to be appropriate and that designing the CEDM pressure housings to ASME BPV Code Section III, Division I, Subsection NB conforms to SRP Section 3.9.4, acceptance criterion 2.A. Therefore, the staff finds the design criteria consistent with the relevant guidance and the staff concludes that it is acceptable. In DCD Tier 2 Section 3.9.4.3, discusses evaluation of the deformation of the CEDM under seismic conditions to verify scram ability, but the referenced DCD Tier 2 Section 3.9.2.7.3, does not provide details of the verification established by the analysis or test.

From June 30, 2015, to July 2, 2015, the staff performed an audit of the CEDM summary stress report, CEDM design specification, and CEDM scram time qualification test report to verify the scram ability of the CEDM established by analysis or test, as documented in an audit report dated November 12, 2015 (ML15300A151). The staff found that DCD Tier 2 Section 3.9.4.3, does not clearly state the differences between the APR1400 CEDM and those used in the production tests and deflection drop tests, including changes made such as seismic supports in upper portions of CEDM shroud, shroud tube wall thickness increase, and outside diameter increase of longer CEDM nozzle. Additional information was needed to clarify the exact differences between the APR1400 CEDMs, production test CEDMs, and deflection drop test CEDMs, in regard to supports, structural, material, and any other measurable differences so that the staff could determine if these tests can be used to confirm the seismic capability of the CEDM design to meet GDC 2. A comparison table and a short summary of the deflection test, along with design limits for the CEDM to ensure insertability under seismic conditions should be incorporated into the DCD. Therefore, the staff issued RAI 85-7949, Question 03.09.04-2 (ML15197A268), requesting the applicant to address this issue.

In its response to RAI 85-7949, Question 03.09.04 2 (ML15328A341), the applicant stated that DCD Tier 2, Sections 3.9.2.7.3 and 3.9.4.4, will be revised to summarize the differences between the APR1400 CEDMs and the deflection drop test CEDMs, including installation of seismic supports to restrain horizontal deflection, increased wall thickness of the CEDM shroud tube, increased outside diameter of the longer reactor vessel head nozzle, and a change in material of the reactor vessel head nozzles and motor housing lower end fittings from Alloy 600 to Alloy 690TT. The applicant also proposed a revision to the functional test summary, stating

that the scram test using a minimum drop weight was performed by applying an incremental static deflection to the CEDM. From the test, a minimum radius of curvature of 2.025 in. for the upper pressure housing was obtained as the critical criterion to ensure scram ability. Deflection of the CEDM under seismic loading, as calculated by structural dynamic analysis, was compared with the test result to verify scram ability.

The staff finds the response to RAI 85-7949, Question 03.09.04-2, acceptable because the applicant clarified the differences between the APR1400 CEDM and the production tests and deflection drop tests used, and proposed a revision to DCD Tier 2 Section 3.9.4.4, that describes the differences. Also, the applicant clarified how it will ensure insertability under seismic conditions and proposed revisions to DCD Tier 2 Section 3.9.2.7.3, with a summary of the deflection test and design limits. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 85-7949, Question 03.09.04-2, is resolved and closed.

3.9.4.4.3 *Operability Assurance: Compliance with GDC 27 and 29*

In SRP Section 3.9.4, acceptance criterion 4, states that “[t]he operability assurance program will be acceptable provided the observed performance as to wear, functioning times, latching, and ability to overcome a stuck rod meet system design requirements.” In DCD Tier 2 Section 3.9.4.1.1.2, the applicant states that clearances in the motor assembly enable the CEDM to avoid a stuck rod condition, and the clearances are verified by the tests described in DCD Tier 2 Section 3.9.4.4. However, DCD Tier 2 Section 3.9.4.4, does not explicitly state where the ability to overcome a stuck rod is verified. Additional information on the ability to overcome a stuck rod are necessary for the staff to make a finding under this SRP acceptance criterion.

The applicant submitted a letter dated July 6, 2015 (ML15187A312) that proposed modifications to DCD Tier 2, Section 3.9.4.4 and provided the description of the CEDM operability assurance program for the DCD. The staff reviewed this information to determine that it conformed to the guidance of SRP Section 3.9.4, acceptance criterion 4, by clearly stating how the life cycle and scram test provide verification that the CEDM will not experience a stuck rod condition because the stuck rod did not occur during the aforementioned tests. The staff confirmed that the information provided is consistent with the relevant guidance and is therefore acceptable. In addition, the staff confirmed that the proposed modifications were incorporated into the DCD.

In DCD Tier 2 Section 3.9.4.4, the applicant describes the CEDM operability assurance program, including the operation speeds and drive line loads during the first production tests, but does not state if these are also functional requirements for the CEDM. It was initially unclear whether the functional requirements of the APR1400 CEDM were identical to those of the first production tests (i.e., 76.2 cm/min for maximum stepping speed and 159 kg for design drive line load, as described in DCD Tier 2 Section 3.9.4.4). The applicant also states in DCD Tier 2 Section 3.9.4.1, that the design duty requirement for the CEDM is a total cumulative CEA travel of 30,480 m (100,000 ft) operation without loss of function. A basis for this design duty requirement was not initially provided. The functional requirements of the CEDM and the basis for the design duty requirement should be clearly stated in the DCD. This information is necessary to complete the area of review described in SRP Section 3.9.4.1.1, which states that “[t]he descriptive information, including design criteria, testing programs, drawings, and a summary of the method of operation of the control rod drives, is reviewed to permit an

evaluation of the adequacy of the system to perform its mechanical function properly.” Therefore, the staff issued RAI 85-7949, Question 03.09.04-1 (ML15197A268), requesting the applicant to address these issues.

In its response to RAI 85-7949, Question 03.09.04-1 (ML1528A341), the applicant stated that DCD Tier 2 Section 3.9.4.1, will be revised to include the CEDM maximum operating speed, the minimum and maximum weight of the ESA and CEA, the minimum upward force exerted by the CEDM on the CEA and ESA, and the design duty requirement of 1000 full height CEA drops. In the DCD, the applicant updated DCD Tier 2 Section 3.9.4.1, to include the CEDM maximum operating speed, the minimum and maximum weight of the ESA and CEA, the minimum upward force exerted by the CEDM on the CEA and ESA, and the design duty requirement of 1000 full height CEA drops.

The staff finds the response to RAI 85-7949, Question 03.09.04-1, acceptable because the applicant clarified functional requirements for the CEDM that are consistent with the detailed information audited by the staff and justified based on the production tests. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 85-7949, Question 03.09.04-1, is resolved and closed.

In DCD Tier 2 Section 3.9.4.4, the applicant discussed changes to the material of the motor housing lower end fitting and thickness of the upper shroud tube, but does not discuss how these changes affect the 60-year life of the CEDM, as the changes are stated to improve structural integrity (from material change) and mechanical strength (thickness change). The changing of materials and thickness may result in changes to loads such as deadweight and changes to the pressure housing that could affect its safety function as a pressure boundary. Also, in DCD Tier 2 Section 3.9.4.4, the applicant discusses operating experience as providing design verification for the APR1400 CEDM. The staff needed additional detail on how the referenced operating plants have provided design verification of the changes to the motor housing lower end fitting and upper tube shroud as mentioned above.

This issue was discussed in a public meeting on June 23, 2015, and the applicant provided written material to support the meeting discussion, formally documented in a letter dated July 6, 2015 (ML15187A312). The staff finds the additional information sufficient to resolve its concern because the structural integrity of the pressure housing was confirmed in an audit conducted on June 30, 2015, to July 2, 2015 (ML15300A149), and referenced above. The staff's evaluation on the materials for the CEDM is found in SER Section 4.5.1.

3.9.4.5 Combined License Information Items

There are no COL items related to DCD Tier 2 Section 3.9.4.

3.9.4.6 Conclusion

The staff finds that the applicant has met the requirements of GDC 1, and 10 CFR 50.55a, with respect to designing components important to safety to quality standards commensurate with the importance of the safety functions to be performed because the design procedures and criteria used for the control rod drive system conform to the requirements of the ASME BPV Code.

In addition, the staff finds that the applicant has met the requirements of GDC 2, 14, and 26, with respect to designing the control rod drive system to withstand effects of earthquakes and conditions of normal operation, including AOOs, with adequate margins to assure the system's reactivity control function and with extremely low probability of leakage or gross rupture of the reactor coolant pressure boundary. The staff evaluated the specified design transients, design and service loadings, combination of loads, and resulting stresses and deformations under such loading combinations in SER Section 3.9.3.

Lastly, the staff finds that the applicant has met the requirements of GDC 27 and 29, with respect to designing the CRDS to assure its capability of controlling reactivity and cooling the reactor core with appropriate margin in conjunction with either the ECCS or the reactor protection system. As discussed above, the staff concluded that the operability assurance program is acceptable with respect to meeting system design requirements in observed performance as to wear, functioning times, latching, and overcoming a stuck rod.

3.9.5 Reactor Pressure Vessel Internals

3.9.5.1 Introduction

This section verifies that the DCD describes the arrangement of the reactor pressure vessel internals (also referred to as reactor internals), their specific functions, the flow path through the reactor vessel, and the applicant's design criteria. The reactor internals serve several functions. They provide support and alignment for the reactor core, provide a flow path that directs and distributes the flow of reactor coolant through the nuclear fuel under all design conditions, and shields the reactor pressure vessel from neutron impingement.

The objectives of the staff's review are to confirm the following:

- The reactor internals have been designed and tested to appropriate quality standards.
- The portions of the internals that provide structural support for the core meet the applicable requirements of ASME Boiler and Pressure Vessel (BPV) Code, Section III.
- The appropriate design transients and loading combinations have been specified.
- The internals' mechanical stresses, deflections and deformations will not result in a loss of structural integrity or impairment of function.

The designation, "reactor internals," in the context of this review section includes the core support structures, internal structures and all structural and mechanical elements inside the reactor pressure vessel with the following exceptions:

- Reactor fuel elements and the reactivity control elements
- Control rod drive elements
- In-core instrumentation (ICI)

3.9.5.2 *Summary of Application*

DCD Tier 1: Tier 1 information associated with this section is provided in DCD Tier 1, Section 2.2.6, "Reactor Vessel Internals."

DCD Tier 2: Tier 2 information associated with this section is provided in DCD Tier 2, Section 3.9.5, "Reactor Pressure Vessel Internals."

DCD Tier 2 Section 3.9.5, describes the arrangement of the reactor internals and the flow path of reactor coolant through the reactor vessel, including core bypass flows, from the point where the coolant enters the vessel through the cold leg nozzles and exits through the hot leg nozzles. The reactor internals are divided into two main categories: the core support barrel assembly and the UGS assembly. The core support barrel assembly consists of the core support barrel, the lower support structure, the ICI nozzle assembly and the core shroud. Its major functions are to support the reactor core and to provide a separation of flow between the cold leg flow, which flows outside of the core support barrel, and the hot leg flow, which flows inside of the core support barrel. The UGS assembly consists of the UGS barrel assembly and the inner barrel assembly (IBA). Its major function is to provide support and alignment of the fuel assemblies and the control element assemblies (CEAs). The UGS assembly also directs the core flow exiting the reactor core to the reactor vessel outlet nozzles.

The applicant states that the reactor internals classified as core support structures are constructed in accordance with ASME BPV Code, Section III, Subsection NG. The reactor internals other than core support structures meet the guidelines of ASME BPV Code, Section III, Subsection NG-3000 and are constructed so as not to adversely affect the integrity of the core support structures.

ITAAC: The ITAAC associated with DCD Tier 2, Section 3.9.5 are given in DCD Tier 1, Section 2.2.6.2, "Inspection, Tests, Analyses, and Acceptance Criteria."

3.9.5.3 *Regulatory Basis*

The relevant requirements for this area of review and the associated acceptance criteria are given in SRP Section 3.9.5, Revision 3, issued March 2007, and are summarized below. Review interfaces with other SRP sections can be found in SRP Section 3.9.5.

- GDC 1 and 10 CFR 50.55a, require that reactor internals be designed to quality standards commensurate with the importance of the safety functions performed.
- GDC 2, requires that reactor internals be designed to withstand the effects of natural phenomena such as earthquakes without loss of capability to perform safety functions.
- GDC 4, requires that reactor internals be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operations, maintenance, testing and postulated pipe ruptures, including LOCAs. Dynamic effects associated with postulated pipe ruptures may be excluded from the design basis when analyses demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for piping.

- GDC 10, requires that reactor internals be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any conditions of normal operation, including the effects of AOOs.
- Section 52.47(b)(1) of 10 CFR, requires that a 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 DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and the NRC's regulations.

Criteria acceptable to meet the above requirements include:

- Requirements for loads, loading combinations, and limits applicable to those portions of reactor internals constructed to ASME BPV Code, Section III, Subsection NG are presented in Section 3.9.3 of this safety evaluation.
- The design and construction of the core support structures should comply with the requirements of ASME BPV Code, Section III, Subsection NG.
- ASME BPV Code, Section III, Subsection NG-3000 contains guidelines that should be met for the design criteria, loading conditions, and analyses that provide the bases for the design of core support structures. Reactor internals other than core support structures should be constructed such that the integrity of the core support structures is not adversely affected, as specified in ASME BPV Code, Section III, Subsection NG-1122 and should be consistent with the guidelines in ASME BPV Code, Section III, Subsection NG-3000.
- Deformation limits for reactor internals should be established by the applicant and presented in the safety analysis report. The basis for these limits should be included. The stresses of these displacements should not exceed the specified limits. The requirements for dynamic analysis of these components are addressed in Section 3.9.2, of this safety evaluation.
- The reactor internals should be designed to accommodate asymmetric blowdown loads from postulated pipe ruptures. The applicant's evaluation of such loads should demonstrate that they do exceed the limits imposed by the applicable codes and standards.
- Potential adverse flow effects of flow-induced vibration and acoustic resonances on reactor internals should be adequately addressed in accordance with relevant criteria specified in SRP Section 3.9.5.

3.9.5.4 *Technical Evaluation*

3.9.5.4.1 *Design Arrangement*

DCD Tier 2, Section 3.9.5.1, "Design Arrangement," states that the components of the reactor internals are divided into two major parts consisting of the core support barrel assembly and the UGS assembly.

The component classification for core support structures and internal structures is summarized below.

- Core support structures:
 - Core support barrel (part of core support barrel assembly)
 - Lower support structure (part of core support barrel assembly)
 - UGS barrel assembly (part of the UGS assembly)
- Internal structures:
 - Core shroud (part of core support barrel assembly)
 - Alignment keys
 - Hold-down ring
 - Core support barrel snubbers
 - ICI nozzle assembly (part of core support barrel assembly)
 - Core support barrel outlet nozzles
 - Inner barrel assembly (part of the UGS assembly)
 - Guide lugs
 - Heated junction thermocouple tube assembly
 - Flow skirt
 - Core stops

The applicant states that the reactor internals are designed, fabricated, erected, and tested to conform to the following requirements:

- Section 50.55a of 10 CFR, and GDC 1, require that reactor internals be designed to quality standards commensurate with the importance of the safety functions performed.
- Section 52.47(b)(1) of 10 CFR, requires that a 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 DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and the NRC's regulations.
- Section 52.80(a) of 10 CFR, requires that the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance

criteria met, the facility has been constructed and will be operated in conformity with the combined license, the provisions of the Act, and the Commission's rules and regulations.

- GDC 2, requires that reactor internals be designed to withstand the effects of natural phenomena such as earthquakes without loss of capability to perform safety functions.
- GDC 4, requires that reactor internals be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operations, maintenance, testing and postulated pipe ruptures, including LOCAs. Dynamic effects associated with postulated pipe ruptures may be excluded from the design basis when analyses demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for piping.
- GDC 10, requires that reactor internals be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any conditions of normal operation, including the effects of AOOs.

DCD Tier 2, Section 4.1, "Summary Description," provides a summary description of the general APR1400 design configuration and the fuel assembly. The APR1400 reactor is a pressurized-water reactor with two reactor coolant loops. The reactor core is composed of 241 fuel assemblies and 93 CEAs. It also provides a summary of the reactor coolant flow path. The reactor coolant enters the inlet nozzles of the reactor vessel, flows downward between the reactor vessel wall and the core support barrel, and passes through the flow skirt section where the flow distribution is equalized, and into the lower plenum. The heated coolant enters the core outlet region, where it flows around the outside of the CEA guide tubes to the reactor vessel outlet nozzles.

The reactor internals support and orient the fuel assemblies, CEAs, and ICI and guide the reactor coolant through the reactor vessel. The reactor internals also absorb static and dynamic loads and transmit the loads to the reactor vessel flange. The reactor internals perform their functions during normal operation, AOOs, and postulated accidents. The reactor internals are designed to safely withstand forces due to deadweight, temperature and pressure differentials, flow impingement, vibration, seismic acceleration and handling. All reactor internal components are considered seismic Category I for the seismic design. The stress values for all structural members under normal operating and expected transient conditions are not greater than those established by the ASME BPV Code, Section III. The effect of neutron irradiation on reactor internals materials is included in the design evaluation. The effect of accident loadings on the internals is included in the design analysis.

The following subsections provide the staff's evaluation of this DCD information, as well as detailed information on the subcomponents of the reactor internals, according to the regulations and guidance described above.

Design Arrangement – Hold-Down Ring

In DCD Tier 2 Section 3.9.5.1, the applicant states that the hold-down ring is classified as an internal structure. In DCD Tier 2 Section 3.9.5, the applicant states that core support structures are those structures or part of structures that are designed to provide direct support or restraint of the core within the reactor vessel. In DCD Tier 2 Section 3.9.5.1.2, the applicant provides a

description of the UGS assembly and states that the UGS support barrel consists of a right circular cylinder welded to a ring flange at the upper end and to a circular plate at the lower end. It further states that the flange, which is the supporting member for the entire UGS assembly, sits on its upper side against the reactor vessel head during operation. The lower side of the flange is supported by the hold-down ring, which rests on the core support barrel upper flange.

Based on the information provided in the DCD, it was initially unclear to the staff why the hold-down ring was classified as an internal structure instead of a core support structure, since it provides direct support of the UGS assembly, which is a core support structure according to DCD Tier 2 Section 3.9.5.1. In addition, it was unclear to the staff the potential effects on the functional and structural integrity of the core support barrel assembly and the UGS assembly as a result of a potential loss of preload of the hold-down ring due to stress relaxation during all service and accident conditions.

In a public meeting on June 23, 2015, to discuss this issue (Issue #1), the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that the hold-down ring provides axial force on the flanges of the UGS assembly and the core support barrel assembly in order to prevent movement of the structures under hydraulic forces. The hold-down ring is designed to accommodate the differential thermal expansion between the reactor vessel and the reactor internals in the vessel ledge region. The UGS assembly and core support barrel assembly including the hold-down ring are supported on the reactor vessel ledge. Therefore, the applicant clarified that the hold-down ring is classified as an internal structure since it is not a major component that provides direct support or restraint of the core within the reactor vessel.

The applicant also stated that loss of preload may occur due to loss of deflection of the hold-down ring as a result of wear on contact surface and stress relaxation during operation. The applicant explained that this loss of preload will decrease an axial load on the core support barrel and the UGS flange surface and then induce relative motion between the core support barrel flange and the UGS flange under service and accident loadings. Considering loss of preload, the hold-down ring is designed to have enough preload to prevent relative motion of reactor internal components. The applicant further stated that the function of the hold-down ring is inspected via the CVAP.

The staff reviewed this information and found the applicant's explanation to classify the hold-down ring as internal structure, and the explanation for the potential loss of preload of the hold-down ring, to be insufficient. Specifically, the information the applicant provided regarding the function of the hold-down ring (i.e., it provides axial force on the flanges of the UGS assembly and the core support barrel assembly in order to prevent movement of the structures under hydraulic forces) is the same information already provided in DCD Tier 2 Section 3.9.5.1.2. Simply stating that the hold-down ring is classified as an internal structure because it is not a major component is not sufficient. In addition, as described above, the applicant stated that loss of preload may occur and induce relative motion between the core support barrel flange and the UGS flange under service and accident loadings. However, the applicant further stated that the hold-down ring is designed to have enough preload to prevent relative motion of reactor internal components. The staff found the applicant's explanation regarding loss of preload of the hold-down ring to be contradictory, and therefore unacceptable.

The staff issued RAI 92-8068, Question 03.09.05-1 (ML15202A386), requesting the applicant to provide a detailed explanation as to why the hold-down ring is classified as an internal structure. In addition, the applicant was requested to further explain the consequences of a loss of preload of the hold-down ring during all normal and accident conditions. The staff also requested that the applicant provide information for any analyses performed to confirm the functional and structural integrity of the core support barrel assembly and UGS assembly due to a loss of preload of the hold-down ring.

In its response to RAI 92-8068, Question 03.09.05-1 (ML15289A615), the applicant stated that the hold-down ring is not required to directly support the fuel assemblies because the analysis of the reactor internals models the load path of the hold-down ring connected in parallel rather than in series with the fuel assemblies. The applicant explained that the vertical loads from the fuel assemblies will be transferred through the hold-down ring to the UGS and the core support barrel upper flanges and then to the reactor vessel ledge.

The applicant further stated that during normal operation, the core support barrel flange would not lift since the hydraulic lift force is smaller than the downward loads such as dead weight and hold down spring force of the fuel assemblies. However, during seismic accident conditions, the core support barrel may lift from the reactor vessel ledge, but the lift displacement is limited by the small stroke of the hold-down ring.

The applicant also stated that the design specification for reactor internals requires that ASME BPV Code, Section III, Subsection NG requirements be applied for the design and manufacturing of internal structures. Therefore, the applicant maintains that although the hold-down ring is classified as an internal structure, it is still constructed under the same requirements as a core support structure.

In addition, the applicant stated that the hold-down ring is designed to have sufficient preload to cover a loss of preload due to wear-in and stress relaxation during normal and accident conditions. Therefore, the configuration of the hold-down ring will remain unchanged even if the hold-down ring loses its preload from stress relaxation. The applicant stated that a CVAP inspection was used to confirm that there is no relative motion of the reactor internals components during all service level conditions. Also, the applicant noted no adverse effect on the function and structural integrity of the core support barrel assembly and UGS assembly due to the design basis loss of preload described above.

The staff reviewed the applicant's response and found the portion of the response related to the design code and standard of the hold down ring to be acceptable. However, additional information regarding the load path of the hold-down ring is necessary for the staff's safety finding. The staff found the applicant's response regarding the design and manufacturing of the hold-down ring in accordance with ASME BPV Code, Section III, Subsection NG, to be acceptable because ASME BPV Code, Section III, Subsection NG is the acceptable standard for design and construction for nuclear power plant reactor internals components in SRP Section 3.9.5. The applicant stated that in the reactor internals analysis, the load path of the hold-down ring is in parallel rather than in series with the fuel assemblies, but yet, the applicant also stated that the vertical loads from the fuel assemblies will be transferred through the hold-down ring, to the UGS and core support barrel flanges and then to the reactor vessel ledge. The staff is unclear how the hold-down ring is modeled in parallel with the fuel assemblies when the loads from the fuel assemblies are directly transferred to the UGS and core support barrel

flanges to the reactor vessel ledge through the hold-down ring. It appears to the staff that in order for the hold-down ring to be modeled in parallel with the fuel assemblies, another component has to be in place, in parallel with the hold-down ring, to sustain the loads from the fuel assemblies before the loads are transferred to the UGS and core support barrel flanges and ultimately to the reactor vessel ledge.

This issue was discussed with the applicant in a public meeting on November 24, 2015. In its supplemental response to RAI 92-8068, Question 03.09.05-1 (ML16050A245), the applicant stated that modeling the hold-down ring in parallel rather than in series with the fuel assemblies is appropriate because the beams of the lower support structure (LSS) directly support the weight of the fuel assembly and will transmit the loads to the lower end of the LSS cylinder and the core support barrel lower flange. The lower end of the LSS cylinder is welded to the core support barrel lower flange by a welded flexural connection. The loads of the core support barrel assembly and the fuel assembly are supported at the reactor vessel ledge. The major components supporting the loads are the LSS and core support barrel. The hold-down ring is not relied upon to support any of the design loads. In addition, the hold-down ring is designed to operate for 60 years.

Based on the information provided by the applicant, the staff understands that the load is transmitted from the LSS, through the core support barrel and directly onto the reactor vessel ledge. At the reactor vessel ledge, the reactor vessel head and the UGS flange sit above the hold-down ring, while the core support barrel flange and reactor vessel flange sit below the hold-down ring. Therefore, the major components that directly support the weight of the core are the core support barrel flange and the LSS. Upon tensioning of the reactor vessel head studs, all the components will act together to avoid any vertical movement of the core. Since the hold-down ring sits above the core support barrel flange, it does not directly support the weight of the core. Based on the information provided by the applicant, the staff finds the classification and design code of standard for the hold-down ring to be acceptable to the quality standards in accordance with the regulation in GDC 1 and acceptance criterion bullet for reactor internals other than core support structures in SER Section 3.9.5.3. In addition, the applicant stated that there is no relative motion of the reactor internals components during all service level conditions. The staff finds the applicant's answer acceptable in accordance with the regulation in GDC 1 and acceptable criterion bullet 3 in SER Section 3.9.5.3. Therefore, RAI 92-8068, Question 03.09.05-1, is resolved and closed.

Design Arrangement – Core Support Barrel Assembly

In DCD Tier 2 Section 3.9.5.1, the applicant provides a description of the core support barrel assembly. The core support barrel assembly consists of the core support barrel, the lower support structure, the ICI nozzle assembly, and the core shroud. The material of construction for the core support barrel assembly is austenitic stainless steel. In DCD Tier 2 Figure 3.9-9, the applicant provides a drawing of the core support barrel assembly.

In DCD Tier 2 Section 3.9.5.1.1, the applicant provides a general description of the core support barrel assembly. The core support barrel assembly is supported at its upper end by the upper flange of the core support barrel, which rests on a ledge in the reactor vessel. Alignment is accomplished by means of four equally spaced keys in the flange, which fit into the keyways in the reactor vessel ledge and closure head. The lower flange of the core support barrel supports, secures, and positions the lower support structure and is attached to the lower support structure by means of a welded flexural connection. The lower support structure provides support for the core by means of support beams that transmit the load to the core support barrel lower flange. The fuel locating pins in the support beams provide orientation for the lower ends of the fuel assemblies. The core shroud provides a flow path for the coolant and limits the amount of coolant bypass flow. Support and positioning for the fuel assemblies are provided by the lower support structure. The lower end of the core support barrel is restricted from excessive lateral and torsional movement by six snubbers that interface with the reactor vessel wall.

Based on the information provided in DCD Tier 2, Section 3.9.5.1.1 and Figure 3.9-9, the configuration and geometry of the lower flange of the core support barrel and the core support barrel welded flexural connection to the lower support structure were initially unclear. In addition, the applicant states in DCD Tier 2 Section 3.9.5.1.1, that the core support barrel assembly is supported at its upper flange on the reactor vessel ledge. However, since the core support barrel lower flange is attached to the lower support structure by means of welded flexural connection, it was initially unclear to the staff which component(s) support the weight of the core and how much of the core support barrel and the core is supported at the reactor vessel ledge. In DCD Tier 2, Figure 3.9-8 and Figure 3.9-11, the applicant indicates that the lower support structure assembly is the primary component that supports the weight of the core, and it also shows that the lower support structure assembly rests on the clevis at the bottom of the reactor vessel.

In a public meeting on June 23, 2015, the staff discussed the issue (Issue #2) and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that the lower flange of the core support barrel is attached to the lower end of the lower support structure cylinder by a welded flexural connection. The applicant further explained that the inside portion of the lower end of the lower support structure cylinder is welded circumferentially to the flexure portion of the lower flange top of the core support barrel. The outside portion of the lower end of the lower support structure cylinder slides on the inside surface of the lower flange top of the core support barrel to accommodate differential thermal expansion between the lower support structure and the core support barrel. This is accomplished by having a groove machined into the core support barrel lower flange that separates the welded surface from the free sliding surface. The bottom portion of the lower support structure cylinder moves on the top surface of the core support barrel lower flange in the radial direction only, but is restricted in the axial direction.

The applicant also stated that the lower support structure assembly does not rest on the clevis at the bottom of the reactor vessel but on the lower flange of the core support barrel flange. The lower support structure directly supports the weight of the core and then transmits the load to the core support barrel lower flange. All the loads of the core support barrel assembly and the core are supported at the reactor vessel ledge. The applicant also provided a detailed drawing of the weld between the core support barrel and the lower support structure cylinder.

Based on the discussion at the public meeting on June 23, 2015 and the written material provided, the staff found the applicant's response acceptable because it clarified the welded flexural connection between the lower flange of the core support barrel and the bottom portion of the lower support structure cylinder. It also clarified that the lower support structure assembly does not rest on the clevis of the reactor vessel, but on the core support barrel lower flange, which then transmits the load, including the core, to the reactor vessel ledge.

Design Arrangement – Core Support Barrel

In DCD Tier 2 Section 3.9.5.1.1.1, the applicant described the core support barrel as a right circular cylinder including a heavy external ring flange at the top end and an internal ring flange at the lower end. The core support barrel is supported on the reactor vessel ledge. The core support barrel supports the lower support structure upon which the fuel assemblies rest. Shrink-fit into the upper flange of the core support barrel are four alignment keys located 90 degrees apart. The reactor vessel, reactor vessel closure head, and UGS assembly flange are slotted in locations corresponding to the alignment key locations to provide proper alignment.

The location and function of the two ring flanges shown in DCD Tier 2 Figure 3.9-9, were initially unclear. In a public meeting on June 23, 2015, the staff discussed this issue (Issue #3) and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant clarified the location of the top ring flange and lower ring flange on the core support barrel. The applicant also stated that the core support barrel assembly is supported at its upper end by the top ring flange of the core support barrel, which rests on the reactor vessel ledge. The lower ring flange of the core support barrel supports, secures, and positions the lower support structure including the core.

Based on the information provided at the public meeting on June 23, 2015, the staff found the applicant's response acceptable because the applicant clarified the location of the top ring flange and the lower ring flange of the core support barrel, and provided explanation for the function of both the top ring flange and lower ring flange.

In DCD Tier 2 Section 3.9.5.1.1.1, the applicant states that since the weight of the core support barrel is supported at its upper end, it is possible that coolant flow could induce vibrations in the structure. Therefore, amplitude limiting devices, or snubbers, are installed on the outside of the core support barrel near the bottom end. The snubbers consist of six equally spaced lugs around the circumference of the core support barrel and act as a tongue and groove assembly with the mating lugs on the reactor vessel. Minimizing the clearance between the tongue and groove assembly limits the amplitude of vibration. It further describes that during assembly, as the core support barrel is lowered into the reactor vessel, the reactor vessel lugs engage the core support barrel lugs in an axial direction. As a result, the snubbers allow radial and axial

expansion of the core support barrel, but restrict lateral movement of the core support barrel. In DCD Tier 2 Figure 3.9-10, the applicant provides a drawing of the snubber assembly.

In the public meeting on June 23, 2015, the staff discussed these snubber assemblies (Issue #4) with the applicant, and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311), as described below.

Specific to vibration effects on the snubbers, the applicant stated that the core support barrel including the snubbers is evaluated for flow induced vibration. Pump pulsation and random turbulence loads are used for the response analysis to account for the effect of flow induced vibration on the core support barrel, including the snubbers. The applicant also provided a reference to APR1400 Z M-NR-14009, "Comprehensive Vibration Assessment Program for the Reactor Vessel Internals." Issues regarding flow induced vibration of reactor internals are addressed in SER Section 3.9.2.

The applicant stated that the snubber assembly does not support any weight of the core support barrel and the core. Only radial and axial expansions of the core support barrel are accommodated, but excessive lateral and torsional movement of the core support barrel is restricted by six snubbers. The applicant also clarified that there are a total of six snubbers equally spaced at the bottom of the core support barrel. The staff found this response acceptable because the applicant clarified the function of the snubber assembly in that it does not support any weight of the core support barrel or the core; its function is to only restrict excessive movement of the core support barrel.

The applicant stated that for each snubber assembly, a core stabilizing lug is attached to the reactor vessel with a full penetration weld. Two core stabilizing shims are assembled with one core stabilizing lug and four socket head cap screws are used to fasten the two core stabilizing shims to the two sides of the lug. After installing the cap screws, each cap screw is line drilled and one pin and one plug are inserted. The hole where the pin and plug pass through is welded to fix the screw. Because the core stabilizing lug is attached to the inside wall of the reactor vessel, all parts of the core stabilizing lug, including the structural fasteners, are classified and designed to ASME BPV Code, Section III, Subsection NB. The applicant also stated that the snubber lug is attached to the outside wall of the core support barrel by a full penetration weld and is designed in accordance with ASME BPV Code, Section III, Subsection NG. Based on the information provided, the staff found the method of attachment and design code standard for the snubber assembly acceptable in accordance with the regulation in GDC 1 and acceptance criterion bullet 3 in SER Section 3.9.5.3, because it comports with the ASME BPV Code, Section III, Subsection NG as referenced by SRP Section 3.9.5.

The applicant indicated that there are two additional areas in which threaded structural fasteners are used within the scope of reactor vessel internals: the fuel locating pins and socket head cap screws for the core shroud guide lug. The fuel locating pins are attached to the top of the lower support structure beams to provide orientation for the lower ends of the fuel assemblies. The fuel locating pins are secured by tack weld to the lock-bar. The fuel locating pins are designed in accordance with ASME BPV Code, Section III, Subsection NG.

The second area in which threaded structural fasteners are used is the socket head cap screws used to attach the guide lug inserts (shims) to the core shroud guide lug. Four guide lugs, spaced 90 degrees apart, protrude vertically from the top of the core shroud and engage in

corresponding slots in the UGS fuel alignment plate to provide proper alignment. The socket head cap screws are designed in accordance with ASME BPV Code, Section III, Subsection NG.

Based on the information provided, the staff found the applicant's response regarding the core shroud guide lug socket head cap screws acceptable because it clarifies that these socket head cap screws are designed to the design code of standard described in SRP Section 3.9.5; i.e., ASME BPV Code, Section III, Subsection NG.

However, the design of the fuel locating pins was unclear. Specifically, the staff was unsure if the entire fuel locating pin is designed to ASME BPV Code, Section III, Subsection NG, or if just the threaded portion of the fuel locating pin is designed to ASME BPV Code, Section III, Subsection NG. Therefore, the staff issued RAI 92-8068, Question 03.09.05-2 (ML15202A386), requesting that the applicant provide the detailed design of the fuel locating pin, its classification, and its design code for both the fuel pin portion and the threaded structural fastener portion.

In its response to RAI 92-8068, Question 03.09.05-2 (ML16050A245), the applicant stated that the fuel locating pins, also known as fuel insert pins, are designed to guide and laterally support the bottom of the fuel assembly. A fuel locating pin consists of a shank, flange, fuel lower end fitting to pin contact, pin to beam contact, thread bearing part, thread relief part, and the thread shear part. All parts of the fuel locating pins are evaluated to have large enough margins to support the fuel assemblies. All of fuel locating pins are classified as core support structure and are evaluated as such. The threaded portion of the fuel locating pins are also classified as core support structure. Therefore, the fuel locating pins, including the threaded portions, are evaluated in accordance with ASME BPV Code, Section III, Subsection NG. In its supplemental response to RAI 92-8068, Question 03.09.05-2 (ML16050A245), the applicant provided a detailed drawing of the fuel locating pins.

The staff reviewed the applicant's response and found the design of the fuel locating pins and the corresponding design code of standard acceptable in accordance with the regulation in GDC 1 and acceptance criterion bullet 3 in SER Section 3.9.5.3, because it comports with the ASME BPV Code, Section III, Subsection NG as referenced by SRP Section 3.9.5. Therefore, RAI 92-8068, Question 03.09.05-2, is resolved and closed.

Design Arrangement – Lower Support Structure and ICI Nozzle Assembly

In DCD Tier 2 Section 3.9.5.1.1.2, the applicant provides a description of the lower support structure and ICI nozzle assembly. The function of the lower support structure and ICI nozzle assembly is to position and support the fuel assemblies, core shroud, and ICI nozzles. It is a welded assembly consisting of a short cylinder, support beams, a bottom plate, ICI nozzles and ICI nozzle support plate, as shown in DCD Tier 2 Figure 3.9-11. The upper portion of the lower support structure is a short cylindrical section enclosing an assemblage of grid beams arranged in egg-crate fashion. The outer ends of these beams are welded to the cylinder. Fuel assembly locating pins are attached to the top of the beams.

The lower support structure, specifically the short cylindrical section with the welded main support beam, directly supports the fuel assemblies. It was initially unclear to the staff the type

of welds used to weld the main support beams to the short cylindrical section of the lower support structure and how these welds are qualified.

In a public meeting on June 23, 2015, the staff discussed this issue (Issue #5) and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that full penetration weld joints are used to weld the main support beam to the lower support structure cylinder. The welds are qualified by inspection per ASME BPV Code, Section III, Subsection NG-5230. The staff found the applicant's response acceptable because it clarified the type of weld between the main support beam and the lower support cylinder, and it provided the ASME BPV Code provision the welds are qualified to meet.

In DCD Tier 2 Section 3.9.5.1.1.2, the applicant further explains that the bottoms of the main support beams in one direction are welded to an array of plates which contain flow holes to provide proper flow distribution. These plates provide support for the ICI nozzles, support columns, and ICI nozzle support plate.

Additional information to further describe and identify the aforementioned array of plates that support the ICI nozzles, support columns, and ICI nozzle support plate was needed for the staff to make its finding under the area of review referenced above. This additional information (Issue #6) was discussed in the public meeting on June 23, 2015, and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that the plates of the lower support structure consist of a bottom plate and a raised bottom plate. The plates contain flow holes to provide a uniform distribution at the core inlet. Upon entering the inlet nozzles and into the downcomer region, the flow turns upward through the lower support structure plate and through the core. The plates are divided into various flow hole patterns. The patterns are determined by factors such as the ICI locations, the intersection of the support beams with the bottom plate, and the boundary between the raised (peripheral region) and the bottom (central region) portions of the bottom plate. The bottom plate is welded to the lower end of the main support beam, while the raised bottom plate is welded to the main support beam and the lower portions of the lower support structure cylinder.

Based on the response provided by the applicant, the design of the bottom plate, as well as its function, classification, and design standard were still unclear to the staff. The staff issued RAI 92-8068, Question 03.09.05-3 (ML15202A386), requesting that the applicant provide further explanation of the bottom plate for both the raised and bottom portions. The staff also requested that the applicant provide a drawing of the bottom plate.

In its response to RAI 92-8068, Question 03.09.05-3 (ML15289A615), the applicant stated that the lower support structure bottom plate and raised bottom plate differ in their location and elevation. The bottom plate, comprised of seven individual sections and of four different types of plates, is located in the central region (in the axial view), full penetration welded to the bottom of the main support beam. The raised bottom plate, comprised of twenty-four individual sections and five different types of plates, is located in the peripheral region (in the axial view), full penetration welded to the midsection of the main support beam and the lower support structure cylinder.

The applicant also stated that the pattern of the lower support structure bottom plates is designed to distribute the reactor coolant flow as uniformly as possible. The bottom plates provide axial support for the core. The bottom plates are classified as core support structures

according to ASME BPV Code, Section III Subsection NG-1120 and are designed to Subsection NG.

Based on the information provided by the applicant, the staff found the design of the lower support structure bottom plates and their design code of construction acceptable in accordance with the regulation in GDC 1 and the acceptance criterion bullet 3 in SER Section 3.9.5.3, because it comports with the ASME BPV Code, Section III, Subsection NG as referenced by SRP Section 3.9.5. Therefore, RAI 92-8068, Question 03.09.05-3, is resolved and closed.

The applicant also provided the following explanations to address specific questions raised by the staff at the June 23, 2015 public meeting.

- Specific to the ICI nozzle interfaces, the applicant stated that the upper part of the ICI nozzles is welded to the lower support structure bottom plate by gussets. For those ICI nozzles that are located in the central region, the lower portion is welded to the hole of the ICI nozzle support plate. For those ICI nozzles that are located in the peripheral region, the lower portion is welded to the ICI nozzle support plate by gussets. The applicant also provided a detailed drawing showing the bottom of the lower support structure and ICI assembly. The staff found the applicant's response acceptable because it clarified the interface between the ICI nozzle to both the bottom plate and the ICI nozzle support plate.
- Specific to the support column configuration and interfaces, the applicant stated that the lower support structure assembly has four support column assemblies to support the bottom plate and the ICI nozzle support plate. Each support column assembly consists of one column boss and three support columns. The upper part of the support column is welded to the lower support structure bottom plate, and the lower part of the support column is welded to the column boss attached to the ICI nozzle support plate. The applicant also provided a detailed drawing showing the support column assembly. The staff issued RAI 92-8068, Question 03.09.05-4 (ML15202A386), requesting that the applicant further explain the means by which the column boss is attached to the ICI nozzle support plate, as well as the function, classification, and design code used for the design of the support column assembly, including the support columns and column boss.

In its response to RAI 92-8068, Question 03.09.05-4 (ML15289A615), the applicant stated that the column boss is full penetration welded circumferentially to the ICI nozzle support plate and the column is full penetration welded on the surface of the column boss. In addition, the applicant stated the column and column boss connect the ICI support plate to the lower support structure and provide axial support for the ICI support plate. The column and column boss are not designed to provide direct support or restraint of the core. Therefore, the column and column boss are classified as internal structures and are designed according to ASME BPV Code, Section III Subsection NG. In addition, in its supplemental response to RAI 92-8068, Question 03.09.05-4 (ML16050A245), the applicant stated that the ICI nozzle support plate is designed to provide lateral and torsional restraint for the instrument nozzle and is not designed to provide direct support or restraint to the core. The applicant further stated that the ICI nozzle support plate is classified as an internal structure and is designed according to ASME BPV Code, Section III, Subsection NG.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-4, acceptable because the applicant clarified the design and function of the column and column boss and the means by which they are attached to the lower support structure bottom plate and the ICI nozzle support plate, as well as the design of the ICI nozzle support plate. Therefore, RAI 92-8068, Question 03.09.05-4, is resolved and closed.

- Specific to the function of the gusset, the applicant stated that the function of the gusset is to support the ICI nozzles between the bottom plate and the ICI nozzle support plate. The staff found the applicant's response acceptable because it clarified the function of the gusset.
- Specific to the main support beam and cross beams, the applicant stated that the peripheral region of the main support beam is welded to the inside of the lower support structure cylinder and the lower end of the main support beam is welded to the bottom plate. The main support beam and the secondary support beam are assembled by the cross over at the beam slot location and welded by a full penetration weld along the intersection line. The main support beam and the secondary support beam are welded to the lower support structure cylinder by a full penetration weld at the outermost beam side. The cross beams are connected to the main support beam and the secondary support beam by full penetration welds. The applicant also provided detailed drawings to show the assembly of the main support beam, secondary support beam, and the cross beam. The staff found the applicant's response acceptable because it clarified the configuration and methods in which the main support beam, the secondary support beam and cross beam are connected to each other and how they are connected to the lower support structure cylinder.

In DCD Tier 2 Section 3.9.5.1.1.2, the applicant states that the cylinder portion of the lower support structure guides the main coolant flow and limits the core shroud bypass flow by means of holes located near the base of the cylinder. The ICI nozzle support plate provides lateral support of the ICI nozzles. The ICI nozzle support plate is provided with flow holes for requisite flow distribution. The staff what the effect of flow-induced vibration on the ICI nozzle, in both the axial and lateral directions, is not clear to the staff.

In a letter dated July 6, 2015 (ML15187A311), the applicant responded to this issue (Issue #7), and stated that the ICI nozzles are evaluated for flow induced vibration. Vortex shredding, pump pulsation and random turbulence loads are used for the response analysis to account for the effect of flow induced vibration on the ICI nozzles. The applicant also provided a reference to APR1400-Z-M-NR-14009, Revision 0. Issues regarding flow induced vibration of reactor internals are addressed in SER Section 3.9.2.

Design Arrangement – Core Shroud

In DCD Tier 2 Section 3.9.5.1.1.3, the applicant provides a description of the core shroud. Its function is to provide an envelope for the core and limit the amount of coolant bypass flow. The core shroud consists of a welded vertical assembly of plates designed to channel the coolant through the core. Circumferential rings and top and bottom end plates provide lateral support. The rings are attached to the vertical plates by means of full length welded ribs and horizontal braces. A small gap is provided between the core shroud outer perimeter and the core support barrel in order to provide upward coolant flow in the annulus to minimize thermal stresses in the core shroud. Four hard-faced guide lugs protrude vertically at the top of the core shroud and engage in the corresponding hard-faced slots of the UGS fuel alignment plate to provide proper alignment between the UGS assembly and the core shroud. DCD Tier 2 Figure 3.9-12, provides a drawing of the core shroud.

Based on the information provided in the DCD, it was initially unclear to the staff how the circumferential rings are attached to the vertical plates by means of full length welded ribs and horizontal braces. In addition, in DCD Tier 2 Section 3.9.5.1.1.3, the applicant does not describe how the core shroud vertical plates are attached to each other. It was also unclear to the staff whether structural fasteners are used for the assembly of the core shroud and how the core shroud rests on the lower support structure.

In a public meeting on June 23, 2015, the staff discussed this issue (Issue #8) and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that the core shroud vertical plates consist of four W-type plates and four C-type plates welded to each other by means of full length welds axially along the plates. Ribs are attached to the outside of the vertical plates by means of full length weld axially. Cutouts on the ribs provide space to fit the circumferential rings, which are attached to the cutouts of the ribs by weld. The W-type and C-type vertical plates are welded to the bottom and top flanges. There are no structural fasteners used to attach the core shroud vertical plates. The applicant also provided detailed drawings of the W-type and C-type plates, as well as how the circumferential rings are attached to the ribs. The staff found the applicant's response acceptable because it clarified how the core shroud components are attached to each other and the means by which they are attached. However, it was unclear to the staff how the core shroud is secured to the lower support structure and the core barrel. The staff issued RAI 92-8068, Question 03.09.05-5 (ML15202A386), requesting that the applicant provide this explanation. The applicant was also requested to describe any core bypass flows.

In its response to RAI 92-8068, Question 03.09.05-5 (ML15289A615), the applicant stated the core shroud is secured to the lower support structure by a welded flexural connection between the lower support structure cylinder and the core shroud bottom plate. This assembly is then secured to the core support barrel by another welded flexural connection between the core support barrel lower flange and the lower support structure cylinder. A small gap is provided between the core shroud outer perimeter and the core support barrel to limit the amount of bypass flow.

The applicant also provided information for core bypass flow. The reactor core bypass flow path is through the outlet nozzle clearances, alignment keyways, core shroud annulus and guide tubes. In DCD Tier 2 Section 4.4.2.6.1, the applicant provides more information of the core bypass flow. In DCD Tier 2 Figure 4.4-6, the applicant provides a figure of the main coolant flow

and core bypass flow, while in DCD Tier 2 Table 4.4-3, the applicant provides the percentage of core bypass flow through the outlet nozzle clearances, alignment keyways, core shroud annulus and guide tubes.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-5, acceptable because the applicant clarified the means by which the core shroud is secured to the lower support structure and the core support barrel in accordance with the quality standards commensurate in GDC 1 because it comports with the ASME BPV Code, Section III, Subsection NG as referenced by SRP Section 3.9.5. In addition, the applicant provided information regarding core bypass flow. Therefore, RAI 92-8068, Question 03.09.05-5, is resolved and closed.

Design Arrangement – Upper Guide Structure Assembly

In DCD Tier 2 Section 3.9.5.1.2, the applicant describes the UGS assembly system and its functions. The functions of the UGS assembly are to align and laterally support the upper end of the fuel assemblies, maintain the control element spacing, hold down the fuel assemblies during operation, prevent fuel assemblies from being lifted out of position during a severe accident condition, and protect the control elements from the effects of coolant cross flow in the upper plenum.

The UGS assembly consists of two subassemblies, the UGS barrel assembly and the inner barrel assembly (IBA). The IBA sits inside of the UGS barrel assembly as shown in DCD Tier 2 Figure 3.9-13. The UGS barrel assembly consists of the UGS support barrel, fuel alignment plate, UGS support plate and control element guide tubes. The UGS support barrel is a right circular cylinder welded to a ring flange at the upper end and to the circular UGS support plate at the lower end. This ring flange at the upper end, which sits on the reactor vessel ledge, is the supporting member for the entire UGS assembly. The upper side of the ring flange contacts the reactor vessel head during operation, and the lower side is supported by the hold-down ring, which rests on the core support barrel upper flange. The UGS flange and the hold-down ring engage the core support barrel alignment keys by means of four machined keyways spaced 90 degrees apart.

The function of the IBA is to limit cross flow and provide separation of the CEA. The IBA consists of a top plate welded to a right circular barrel open at the bottom and contain an assemblage of large vertical tubes connected by vertical plates in a grid pattern as shown in DCD Tier 2 Figure 3.9-13. This grid structure is welded to the inside of the IBA cylinder. The IBA is held in position by continuous circumferential weld between the IBA cylinder flange and the top surface of the UGS barrel assembly upper flange.

The fuel alignment plate is positioned below the UGS support plate by cylindrical control element guide tubes. These guide tubes are attached to the UGS support plate and the fuel alignment plate by rolling the tubes into the holes in the plates and welded. The function of the alignment plate is to align the lower ends of the control element guide tubes, which in turn locate the upper ends of the fuel assemblies. The control element guide tubes bear the upward force on the fuel assembly hold down devices. This upward force is transmitted from the fuel alignment plate through the control element guide tubes to the UGS support plate.

Control Element Guide Tube

Based on the information provided in the DCD, additional information was needed regarding UGS barrel assembly and its subassemblies, including the interface between the UGS support plate and control element guide tubes, and the interface between the control element guide tubes and the fuel alignment plate. In a public meeting on June 23, 2015, the staff discussed this issue (Issue #9), and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311), as described below.

- The applicant explained that the control element guide tubes are attached to the top of the UGS support plate and the bottom of the fuel alignment plate by a full circumferential weld after tube rolling. The control element guide tubes are rolled into the UGS support plate and fuel alignment plate using a hydraulically operated rolling machine. The applicant also provided detailed drawings showing the location of the welds between the control element guide tubes and the UGS support plate, and the welds between the control element guide tubes and the fuel alignment plates. The applicant also stated that the IBA is inserted into the UGS barrel assembly and welded at the flange by a flexure weld. Inside of the IBA is the CEA shroud, which consists of shroud tubes and web plates. For each shroud tube, there are four web plates that are full penetration welded axially on the outside surface of the shroud tube and are equally spaced circumferentially. These shroud tubes and web plates form the inside assembly of the IBA, where the CEAs travel. The circular shroud tubes house the four element CEA shown in DCD Tier 2, Figures 4.2-4 and 4.2-5, while the squared tubes formed by the welding of four web plates house the twelve element CEA shown in DCD Tier 2 Figure 4.2-3. The applicant also provided detailed drawings showing the weld location in which the IBA is welded to the UGS barrel assembly upper flange.
- The applicant stated that the loadings that the control element guide tubes experience are mechanical static loads, thermal loads, hydraulic static loads, hydraulic dynamic loads (pump pulsation and random turbulence), IRWST discharge loads, SSE load, design basis pipe break (DBPB) load, branch line pipe break (BLPB) load including main steam/feed water pipe break (MS/FWPB) or LOCA loads.
- The applicant stated that control element guide tubes are evaluated for Level A, B, C, and D service conditions in accordance with ASME BPV Code, Section III, Subsection NG. Fatigue evaluation for the control element guide tubes is performed for 60 years of design life and inservice inspection is performed every 10 years. The control element guide tubes are also inspected via the CVAP program.
- The CEA and its corresponding drive shaft move in and out of the control element guide tubes into the IBA by the CEDM as described in DCD Tier 2 Section 3.9.4. When the CEAs are in the fully withdrawn position, the lower end of the CEAs is positioned slightly below the top of the active core within the fuel assemblies, with part of the CEAs retracted into the IBA region into either the circular shroud tubes (for four element CEAs) or the squared tubes formed by the web plates (for twelve element CEAs). When the CEAs are in the fully inserted position, the lower end of the CEAs is positioned near the bottom of the active core within the fuel assemblies, with the top of the CEA positioned slightly above the UGS support plate. Therefore, from the fully withdrawn position to the fully inserted position, control rods are always inside the control element guide tubes.

The applicant also provided a detailed drawing showing the location of the CEA during its fully withdrawn and fully inserted position.

In addition to the information provided by the applicant stated above, the staff conducted an audit of the applicant's design specification and summary stress report for reactor internals components from June 29, 2015, to July 2, 2015 (ML15173A245). Upon further discussion with the applicant during the audit and further review of the applicant's response above, the staff needed additional information related to the design of the control element guide tubes, as well as the overall design of the UGS assembly to support the necessary findings associated with this review section.

As indicated in the applicant's letter dated July 6, 2017, Figure 9-2 and Figure 9-3, and in DCD Tier 2 Table 3.9-16, there are a total of 820 control element guide tubes and 144 insert tubes. The control element guide tubes are the full-length tubes that are attached to both the UGS support plate and the fuel alignment plate by full circumferential weld and are located in the central region of the core. The insert tubes are the partial-length tubes that do not consist of the portion between the UGS support plate and the fuel alignment plate, but rather, they only consist of the bottom portion and are only welded to the bottom of the fuel alignment plate. The insert tubes are located at the peripheral region of the core, where CEAs are not used for those fuel assemblies located at the outermost region of the core. During operation, the control element guide tubes and the insert tubes fit onto the outside of the fuel assembly guide posts located on the top of the fuel assemblies. Each fuel assembly has four guide posts; each guide post on a fuel assembly is equipped with a coil spring to provide a compressive force to hold down the fuel assembly to prevent lift off during operation, as shown in DCD Tier 2 Figure 4.2-1. For those fuel assemblies equipped with CEAs, the CEA along with its drive shaft, travels through the IBA region, through the control element guide tubes and into the guide thimbles of the fuel assemblies. For those fuel assemblies located in the peripheral region of the core and mated with insert tubes, no CEA is used.

In DCD Tier 2 Section 3.9.5.1.2, the applicant states that the control element guide tubes bear the upward force on the fuel assembly hold down devices. The staff needed additional information to make a finding regarding the structural integrity of the control element guide tubes in both the normal operating condition and accident conditions. Specifically, it was initially unclear to the staff how the structural integrity of the control element guide tubes is maintained due to the upward force induced from the fuel assemblies through its stated design life of 60 years. For events such as an SSE, information is needed to support a finding that the structural integrity of the control element guide tubes can be maintained and that the ability of the CEA to perform its insert function and the ability to scram the reactor would not be compromised. Additionally, the mechanism to prevent the control element guide tubes from buckling during both normal operating conditions and other postulated conditions such as an SSE was initially unclear. Maintaining the structural integrity and rigidity of these control element guide tubes, under all conditions, is essential to the ability to scram the reactor.

The staff also needed additional information about design provisions that would prevent potential misalignment from the fuel assembly guide posts and its impact on the control element guide tubes and insert tubes after each refueling outage. In a letter dated July 6, 2015 (ML15187A311) related to Issue #9, the applicant stated that after the core is defueled and refueled, a total of 964 tubes (820 control element guide tubes and 144 insert tubes) need to fit onto the fuel assembly guide posts when the UGS assembly is lifted and installed back into the

reactor vessel, on top of the fuel assemblies. If there is any misalignment, the bottom end of these control element guide tubes or insert tubes could be pitched or crimped without any indication. This not only could potentially damage the fuel assemblies due to excess compressive force exerted on them, but in the case of a fuel assembly with CEA, this could also prevent the CEA from inserting into the fuel assembly if a control element guide tube is pitched or crimped.

Operating experience documented in PNO-IV-96-016, "Damaged Fuel Assembly Found During Core Defueling," dated March 28, 1996, and its supplements, detail an event that took place during a refueling outage on March 24-25, 1996, at Palo Verde Unit 2. A fuel assembly could not be removed and was found to be damaged. Damage was also found to the UGS in the area where the damaged fuel assembly was located.

Therefore, the staff issued RAI 92-8068, Question 03.09.05-6 (ML15202A386), requesting the applicant to address the issues stated above and provide any analyses for the control element guide tubes and insert tubes in terms of how the structural integrity can be maintained throughout its design life, and how to address any misalignment issue during refueling outages when the UGS assembly is installed in the reactor vessel. The staff also requested that the applicant provide any provisions to ensure that a similar incident to the Palo Verde event stated above, or other significant operating experience related to reactor internals, will not occur to the APR1400 design. This information was necessary for the staff to make the findings associated with SRP Section 3.9.5, as well as a finding in accordance with 10 CFR 52.47(a)(22) that operating experience insights have been incorporated into the design. The applicant was also requested to provide any inspection results from similar operating plants.

Issue regarding control element guide tube structural integrity

In its response to RAI 92-8068, Question 03.09.05-6 (ML15289A615), the applicant stated that the control element guide tubes and insert tubes are evaluated for stress due to fuel hold down springs, in-water weights and fluid-induced axial and lateral load for Level A, B, C and D service conditions. For the Level D condition, the stress as a result of an SSE is considered using the square root sum of square method with other stresses. The deflection limit between the CEA and the control element guide tube is evaluated to ensure that CEA ability to insert is maintained during accident conditions. Additionally, the cumulative fatigue usage factor corresponding with a design life of 60 years is evaluated taking into account normal operation and accident conditions, including an SSE.

The applicant also stated that the critical buckling stress of the control element guide tube at the design temperature is evaluated according to ASME BPV Code, Section III, Subsections NG-3211, and NG-3133. Specifically, according to NG-3133.6 (a) and (b), the maximum allowable compressive stress shall be taken to meet the minimum buckling stress at the design temperature.

The staff understands at the design stage, the applicant would compare the minimum buckling stress to the maximum compressive stress in the axial direction of the control element guide tubes at design temperature as stated in NG-3133. However, under Level D condition, in DCD Tier 2 Section 3.9.5.3, the applicant stated the deflection that would influence CEA movement is limited to less than 80 percent of the deflections required to prevent CEA insertion. It is unclear to the staff how this deflection limit would ensure the ability of CEA to insert during

Level D condition. Specifically, the staff was unsure whether the control element guide tubes are allowed to deflect or buckle as long as the deflection limit, which is set at 80 percent of the loss of function limit, is not exceeded. In other words, the staff was unsure whether the ability of the CEA to insert will be maintained as long as the deflection limit is not exceeded. This issue was discussed with the applicant during a public meeting on November 24, 2015.

In a supplemental response to RAI 92-8068, Question 03.09.05-6 (ML17255A932), the applicant provided a buckling analysis of the control element guide tubes because the deflection calculation of the guide tubes does not take buckling into account. The maximum deflection (worst case deflection) of the guide tube is calculated using the Level D loads which occur on the lateral deflection of the guide tube. If the guide tube is deflected, it cannot buckle. In addition, buckling analysis of the control element guide tube is evaluated in accordance with ASME Code Section III, Subsections NG-3211, and NG-3133. The buckling calculation is performed using ASME Code Subsection F-1334.3. The applicant provided this buckling calculation and the staff performed an independent calculation to verify the accuracy of the calculation. The result showed that under the worst compressive loading condition (Level D), the resulting force is still lower than the critical force required to buckle the control element guide tubes. The additional information demonstrates that the guide tubes will not buckle. Therefore, RAI 92-8068, Question 03.09.05-6, is resolved and closed.

Issue regarding control element guide tube misalignment

In its response to RAI 92-8068, Question 03.09.05-6 (ML15289A615), the applicant stated that to ensure control element guide tubes will properly engage the fuel assembly guide posts during installation of the UGS with the core in place, the true position tolerance for the fuel assembly guide post is tightly maintained. The true position tolerance should be within the allowable offset between the control element guide tube and the fuel assembly guide post.

In a public meeting on November 24, 2015, the staff and the applicant discussed the staff's concern regarding control element guide tube and fuel assembly guide post misalignment. The staff requested additional information about the true position tolerance and the process for maintaining this condition. The staff understands that the true position tolerance for each control element guide tube and each fuel assembly guide post can be tightly maintained at the design and manufacturing stage, but the staff's primary concern is that if such true position tolerance can still be maintained after each refueling outage. Specifically, staff sought information regarding whether there is any mechanism, such as visual inspection with an underwater camera, to check and ensure that every guide tube is engaged to a fuel assembly guide post. As stated above, there are at least 964 tubes (both control element guide tubes and insert tubes) that will need to fit onto a fuel assembly guide post. The staff was concerned that some will be out of tolerance due to wear and tear after a number of years in service.

In its supplemental response to RAI 92-8068, Question 03.09.05-6 (ML16050A245), the applicant clarified how the true position tolerance between the control element guide tube and the fuel assembly guide post is calculated. The applicant explained that the allowable control element guide tube to fuel assembly guide post offset represents the maximum offset between the centerlines of the control element guide tube and the fuel assembly outer guide post, permitting the chamfered surfaces of the guide tube and guide post to engage. Therefore, the applicant concluded that the design accounts for tolerance to allow for the ability to insert. The applicant also stated that during re-assembly after refueling, it is the responsibility of the

licensee to perform a visual or some other form of confirmation that there is no binding or constriction that could impact ability to insert. In addition, as part of the startup procedure, a CEA drop test is always required before startup.

Based on the information discussed above and the confirmation that CEA's ability to insert is ensured after refueling, the staff found the applicant's analysis to be acceptable. Therefore, this issue under RAI 92-8068, Question 03.09.05-6, is resolved and closed.

Issue regarding operating experience

In its response to RAI 92-8068, Question 03.09.05-6 (ML15289A615), the applicant stated that the APR1400 is a new type of reactor for domestic plants without any operational history. The visual inspection results of baseline and post-hot functional testing will be used to show that there will be no indications of damage at the outermost guide tubes, which are subjected to the highest loads and stress by the cross flow on the tubes.

The staff disagreed with the applicant's assessment that the APR1400 reactor internals design is a new type of reactor internals design for domestic plants without any operational history because the APR1400 reactor internals design is similar to the Palo Verde reactor internals design. In the CVAP report, the applicant stated that the APR1400 reactor internals design is substantially the same as Palo Verde, and the APR1400 takes credit for being non-prototype Category I per RG 1.20, with the Palo Verde Unit 1, Westinghouse System 80+ design being the prototype. The report also mentioned that a number of 1000 MWe reactors with non-prototype reactor internals referencing Palo Verde Unit 1 as a valid prototype are currently operating in Korea. Based on this information, there is operating experience for the APR1400 design. The original intent of the staff's concern is not necessarily to address issues regarding reactor internals vibration or fatigue. Rather, staff is interested in the operating experience that can be gleaned from a significant incident, such as the one that happened in Palo Verde, particularly with regard to the development of a refueling outage program to ensure that the risk of damaging fuel assemblies is minimized as much as possible.

In its supplemental response to RAI 92-8068, Question 03.09.05-6 (ML17219A190), the applicant explained that the operating experience referenced above pertaining to Palo Verde was due to swelling of the control rod tip as a result of the materials used. Palo Verde has since modified the design and the applicant has verified that there have not been any insertion issues since the modification was implemented. The applicant also reviewed the operating history of the Korean plants with CEA and control element guide tube designs similar to that of the APR1400 design and confirmed that no failures have occurred on these components that would prevent control rod insertion. Based on the information provided by the applicant, the staff found the response acceptable because the applicant has reviewed the operating history of current Korean plants that have similar design as APR1400 and found that no failures have occurred that would prevent control rod insertion. Based on the analysis of the information presented above, RAI 92-8068, Question 03.09.05-6, is resolved and closed.

Upper Guide Structure Assembly

In its review of information related to Issue #9, provided by the applicant in a letter dated July 6, 2015 (ML15187A311), the staff determined additional information needed to make its finding for the UGS assembly. Specifically, the staff was still unclear how the shroud tubes and web plates

inside the IBA are attached to the bottom of the UGS plate. It also appeared to the staff that in DCD Tier 2 Figure 3.9-13, the UGS assembly consists of two major barrels: the IBA and UGS barrel. No information was initially provided in terms of how these two barrels are attached to each other, how they are attached to the UGS support plate, and how the shroud tubes and web plates are connected to the IBA. In addition to requesting additional information about the issues above, the staff requested that the applicant provide justification for the classification of IBA as an internal structure in DCD Tier 2 Section 3.9.5.1, rather than as a core support structure. Lastly, in DCD Tier 2 Figure 3.9-13, the applicant shows a top plate at the top of the UGS assembly. No information was initially provided in the DCD for this top plate. Therefore, the staff issued RAI 92-8068, Question 03.09.05-7 (ML15202A386), requesting the applicant to provide information related to the above items and to submit a detailed drawing to demonstrate how the UGS assembly is assembled.

In its response to RAI 92-8068, Question 03.09.05-7 (ML15289A615), the applicant clarified that the UGS support plate is not attached to the IBA, rather, the IBA flange (at the top of the UGS assembly) is attached to the UGS upper flange by a circumferential full penetration weld on the upper surface of the UGS upper flange. The applicant also clarified that the shroud tubes and web plates inside the IBA are not attached to the bottom of the UGS support plate, rather, there is a gap between the bottom of the shroud tube/web plate and the UGS support plate. The CEA shroud is attached to the inside of the IBA cylinder only. The outer shroud tubes are welded axially with full penetration welds on the inside surface of the IBA cylinder.

The applicant also stated that the IBA is designed to guide the vertical movement of the CEA, to prevent interaction between adjacent CEAs, to provide guidance for the CEA extension shafts, and to provide lateral support for the CEAs. Because the IBA does not directly provide support or restraint to the core, it is classified as an internal structure instead of a core support structure. The applicant also stated that the top plate of the IBA provides guidance for the CEA extension shafts into the closure head nozzles when the closure head is being lowered onto the reactor vessel.

Based on the information provided by the applicant in its response to RAI 92-8068, Question 03.09.05-7, the staff determined the need for additional information to make its finding regarding the UGS and IBA design. Specifically, since a gap exists between the bottom of the shroud tube/web plate assembly and the top of the UGS support plate, the staff is concerned the bottom of the shroud tube/web plate assembly could shift from the UGS support plate, potentially affecting the ability of the CEA to insert during both normal and accident conditions. This issue was discussed with the applicant in a public meeting on November 24, 2015.

In its supplemental response to RAI 92-8068, Question 03.09.05-7 (ML16050A245), the applicant stated that to ensure that the web plates do not shift during level D service conditions, the component design evaluates the deflection and stress of the CEA shroud tube in accordance with the ASME BPV Code. The actual deflection of the CEA shroud tube is evaluated with the allowable limits, which is set at 80 percent of the worst deflection of the shroud tube. The worst deflection of the shroud tube is the point at which CEA ability to insert can be affected. The applicant also noted that the maximum stress intensity is compared to the allowable stress intensity during level D service conditions.

Based on the information provided by the applicant, the staff found the response acceptable because the applicant clarified the design of the CEA shroud tube and web plate and the design

criteria used to ensure the CEA shroud tube deflection is kept below the worst deflection limit in accordance with the quality standards commensurate in GDC 1 because it comports with the ASME BPV Code, Section III, Subsection NG, as referenced by SRP Section 3.9.5. Therefore, RAI 92-8068 Question 03.09.05-7, is resolved and closed.

Design Arrangement – Flow Skirt

In DCD Tier 2 Section 3.9.5.1.3, the applicant provides a description of the flow skirt. The flow skirt is a right circular cylinder, perforated with flow holes and reinforced with two stiffening rings. It is supported by nine equally spaced machined sections that are welded to the bottom head of the reactor vessel. The function of the flow skirt is to reduce inequalities in core inlet flow distribution and to prevent formation of large vortices in the lower plenum.

Additional information was needed to for the staff to understand the design arrangement of the flow skirt. Therefore, the staff issued RAI 92-8068, Question 03.09.05-8 (ML15202A386), requesting the applicant to provide a detailed drawing of the flow skirt and the location and method at which it is attached to the bottom head of the reactor vessel. In addition, the staff requested that the applicant clarify the classification of the flow skirt and the structural integrity of the flow skirt under all service level conditions.

In its response to RAI 92-8068, Question 03.09.05-8 (ML15289A615), the applicant clarified the design of the flow skirt, which is welded to a weld build-up pad at the reactor vessel bottom head, and provided detailed drawings of the flow skirt to show how it is attached to the reactor vessel bottom head. The applicant also stated that even though the flow skirt is located inside the reactor vessel, it is attached to the reactor vessel and thus is classified as ASME BPV Code Class 1 and is designed to ASME BPV Code, Section III, Subsection NB.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-8, acceptable because it clarified the design of the flow skirt, its method of attachment to the reactor vessel, and its classification and design code of standard in accordance with the regulation in GDC 1 because it comports with the ASME BPV Code, Section III, Subsection NG, as referenced by SRP Section 3.9.5. Therefore, RAI 92-8068, Question 03.09.05-8, is resolved and closed.

Design Arrangement – In-Core Instrumentation Support System

In DCD Tier 2 Section 3.9.5.1.4, the applicant provides a description of the ICI support system. The ICI support system begins outside the reactor vessel, penetrates the bottom of the vessel boundary, and terminates in the upper end of the fuel assembly. Each ICI is guided over the full length by the external guidance conduit, ICI guide tube nozzles of the reactor vessel, the lower support structure, and the guide post of the fuel assembly. The function of the ICI support system is to route in-core detectors in selected fuel assemblies throughout the core. The guide tube that routes the in-core detectors outside the reactor vessel is a 180-degree bend to the seal table. The pressure boundaries for the individual instruments include the seal table. Each instrument has an integral seal plug which forms a seal at the instrument seal table and through which the signal cables pass. Static o-ring seals are used to seal against operating pressure.

Based on the information provided in the DCD, additional information was needed for the staff to make its safety finding. Specifically, no information was provided for the static o-ring seal, which forms the reactor coolant pressure boundary. Therefore, the staff issued RAI 92-8068,

Question 03.09.05-9 (ML15202A386), requesting the applicant to provide information for the static o-ring seal, including its classification and design requirement.

In its response to RAI 92-8068, Question 03.09.05-9 (ML15289A615), the applicant stated that the static o-ring is classified as a safety-related component. The static o-ring is designed to be capable of leak-tight operation for a design life of two years. The static o-ring is replaced every refueling outage according to the supplier's recommendation. The applicant also provided the pressure, temperature and radiation level design conditions for the static o-ring.

In its supplemental response to RAI 92-8068, Question 03.09.05-9 (ML16050A245), the applicant stated that the static o-ring is not analyzed to a particular code or standard, but is analyzed using related information from the manufacturer's handbook which includes specification for qualification testing, functional testing, original physical mechanical properties and aged physical control. The material of the o-ring is ethylene propylene diene monomer (EPDM) rubber and is of a design and type which is commonly used in the operating fleet in Korea.

In its subsequent supplemental response to RAI 92-8068, Question 03.09.05-9 (ML16354A538), the applicant further clarified that the static o-ring is installed inside the ICI seal housing which is at the end of the ICI guide tube routed through the ICI chase and is located above the seal table in the refueling pool area. The ambient temperature of this area is maintained below 120 °F by cooling air from the HVAC system for the ICI chase and refueling pool area. Since the location of the static o-ring is far from the reactor vessel and the ICI guide tubes are cooled by air ventilation, the temperature of the seal housing is maintained at a much lower temperature than the reactor vessel area.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-9, and the design of the static o-ring acceptable because the applicant clarified the design temperature and pressure as well as the qualification criteria of the static o-ring as consistent with those in the operating fleet. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 92-8068, Question 03.09.05-9, is resolved and closed.

Design Arrangement – Surveillance Capsule Assembly

In DCD Tier 2 Figure 3.9-8, the applicant provides an overview of the reactor internals arrangement. A surveillance capsule assembly is shown in the figure, but no description is provided in DCD Tier 2 Section 3.9.5.

In a public meeting on June 23, 2015, the staff discussed this issue (Issue #10), and the applicant provided written material formally documented in a letter dated July 6, 2015 (ML15187A311). The applicant stated that the surveillance capsule assembly is not classified as reactor internals, but as part of the reactor vessel since it is attached to the inside wall of the reactor vessel. The applicant also stated that DCD Tier 2, Section 5.3.1.6, "Material Surveillance," provides information on the surveillance capsule assembly.

The staff understands that the surveillance capsule assembly is attached to the reactor vessel, but disagrees that by virtue of its location, it should not be classified as part of the reactor internals components. SRP Section 3.9.5 defines reactor pressure vessel internals as all structural and mechanical elements inside the reactor vessel, but does not specify a

component's mounting location. The review scope of SRP Section 3.9.5 is not the functionality of the surveillance capsules, but rather the structural integrity of the surveillance capsule assemblies and the method by which the surveillance capsule assemblies are mounted on the reactor vessel. Specifically, the DCD should demonstrate that the surveillance capsule assemblies are mounted to the reactor vessel walls so that their structural integrity can be maintained throughout its design life, and not become loose parts upon a high flow or severe seismic event. Therefore, the staff issued RAI 92-8068, Question 03.09.05-10, requesting that the applicant explain the design requirement and mounting mechanism of the surveillance capsule assemblies. In addition, the applicant was requested to provide similar information for other components, if any, mounted either on the reactor vessel wall or on the core support barrel (e.g., a neutron shield).

In its response to RAI 92-8068, Question 03.09.05-10 (ML15289A615), the applicant stated that the surveillance capsule assemblies fit within the confines of the surveillance capsule assembly holder tubes, which are attached to the reactor vessel wall. The applicant explained that the structural integrity of the surveillance capsule assemblies and the holder required wall thickness were determined by a structural evaluation based on design loads defined in the reactor vessel design specification and the requirements of ASME BPV Code, Section III, Subsection NB. Six surveillance capsule holders are attached to the inside of the reactor vessel by full penetration welds.

The applicant also stated that the other components mounted to the reactor vessel inside wall are the core stabilizing lug, core stop and flow skirts. As discussed previously, the staff resolved the core stabilizing lug in Issue #4 with the written material formally documented in a letter dated July 6, 2015 (ML15187A311). In addition, the staff evaluated the flow skirt issue in RAI 92-8068, Question 03.09.05-8, above; and the core stop issue below in evaluation of RAI 92-8068, Question 03.09.05-12.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-10, acceptable because the applicant provided information for the mounting mechanism and the design code for the surveillance capsule assemblies in accordance with the quality standards commensurate in GDC 1 because it comports with the ASME BPV Code, Section III, Subsection NG, as referenced by SRP Section 3.9.5; and the applicant clarified all the other components that are mounted to the inside of the reactor vessel wall. Therefore, RAI 92-8068, Question 03.09.05-10, is resolved and closed.

Design Arrangement – DVI Nozzle

In DCD Tier 2 Figure 3.9-8, the applicant provides an overview of the reactor internals arrangement. A DVI nozzle is shown in the figure, but no description is provided in DCD Tier 2 Section 3.9.5. The staff issued RAI 92-8068, Question 03.09.05-11, requesting the applicant to provide information on the impact of the core support barrel due to DVI nozzle injection. Specifically, the staff requested more information about the temperature difference between the injection water and the normal operating coolant temperature, its impact on the core support barrel stresses, and which operating transients listed in DCD Tier 2 Table 3.9-1, would cause a DVI nozzle injection.

In its response to RAI 92-8068, Question 03.09.05-11 (ML15289A615), the applicant stated that for a DVI nozzle initiation to occur, the RCS pressure has to be lower than the DVI pipe line pressure. This will not occur as a result of an operating, non-Level D transient, i.e. non-LOCA situation. Therefore, the applicant stated that the DVI line water will not be injected into the RPV and the core support barrel will not be affected.

The applicant also stated that in the event of a Level D condition, including LOCA and steam line break (SLB), DVI nozzle injection into the RPV may be possible. For Level D condition, ASME BPV Code, Section III, Subsection NG-3225, and Appendix F, require that only the primary stress intensity be evaluated. Therefore, the applicant stated that the impact of the temperature difference between the DVI injection water and the normal operating temperature of the RCS coolant need not be considered in Level D conditions.

In its supplemental response to RAI 92-8068, Question 03.09.05-11 (ML16050A245), the applicant stated that normal operational loads include loads due to differential pressure and temperature.

Based on the information provided by the applicant, the staff agrees that a DVI injection will not occur in non-Level D conditions because the RCS pressure is maintained at a pressure higher than the DVI injection line pressure. In addition, in DCD Tier 2, Section 3.9.5.2.5, "Level D Service Loadings," normal operating loads are listed as part of the Level D loading combination, and normal operating loads include loads due to differential pressure and temperature. Stress due to differential temperature is self-limiting by nature and is considered as secondary stress, thus is not required as part of the Level C or Level D stress analysis. A DVI injection will cause a change in pressure inside of the RPV and thus the primary stress intensity may increase as a result, which is accounted for in the normal operating loads as listed in DCD Tier 2 Section 3.9.5.2.5. Therefore, the staff found the applicant's response to RAI 92-8068, Question 03.09.05-11, acceptable because the applicant clarified the conditions that would result in a DVI injection and the impact to the loads experienced by the core support barrel and therefore, demonstrated that the integrity of the core support barrel will be ensured as a result of the DVI nozzle injection. Therefore, RAI 92-8068, Question 03.09.05-11, is resolved and closed.

Design Arrangement – Core Stop

In DCD Tier 2 Figure 3.9-8, the applicant provides an overview of the reactor internals arrangement. A core stop is shown in the figure, but no description is provided in DCD Tier 2 Section 3.9.5. The staff issued RAI 92-8068, Question 03.09.05-12, requesting the applicant

provide information for the core stop, its design and intended function, its quantity and location, and the means by which the core stop is attached. In addition, the staff requested that the applicant identify under what accident conditions or operating transients the core stop is expected to function.

In its response to RAI 92-8068, Question 03.09.05-12 (ML15289A615), the applicant stated that there are six core stops evenly located around the inside circumference of the reactor vessel bottom head, 60 degrees apart from each other. Each core stop is attached to the reactor vessel bottom head inside surface by a full penetration weld. The applicant explained that the intended function of the core stops is to sustain the load of the core and internals in the event of a hypothetical failure of the normal core support, to maintain the core cooling capability and provide sufficient reactivity control by limiting the displacement of the core and internals. Therefore, the applicant stated that the core stop is designed to sustain an impact load resulting from a drop of the internals along with the static weight of the internals and core. In its supplemental response to RAI 92-8068, Question 03.09.05-12 (ML16050A245), the applicant stated that the core stops are part of the reactor vessel assembly and thus are designed to ASME BPV Code, Section III, Subsection NB.

Based on the information provided by the applicant, the staff found the function and design code of construction for the core stops and their design code of construction acceptable in accordance with acceptance criterion bullet 3 in SER Section 3.9.5.3, because it comports with the ASME BPV Code, Section III, Subsection NG as referenced by SRP Section 3.9.5. Therefore, RAI 92-8068, Question 03.09.05-12, is resolved and closed.

3.9.5.4.2 *Loading Condition*

In DCD Tier 2 Section 3.9.5.2, the applicant provided information for the loading conditions for the design of the reactor internals. The loading conditions are:

- normal operating temperature differences
- normal operating pressure differences
- flow loads
- weight, reaction and superimposed loads
- vibration loads
- shock loads (including SSE)
- anticipated transient loads
- handling loads
- appropriate DBPB, secondary side break and LOCA loads
- IRWST discharge loads

Design loadings and service Levels A, B, C and D loading conditions are also included.

SRP Section 3.9.5, review item 2, includes the basis for the design of reactor internals, loading conditions of normal operation, AOOs, potential adverse flow effects of flow-excited vibrations and acoustic resonances, postulated accidents, and seismic events. All combinations of design and service loadings accounted for in the design of the reactor internals should be listed. The distribution of the design and service loadings acting on the internal components and structures should be described.

The staff issued RAI 92-8068, Question 03.09.05-13 (ML15202A386), requesting that the applicant provide information regarding any method different from that discussed in DCD Tier 2 Section 3.9.3, used to determine the loads listed in DCD Tier 2 Section 3.9.5.2, for reactor internals components under design loading and service Levels A, B, C, and D loading conditions.

In its response to RAI 92-8068, Question 03.09.05-13 (ML15289A615), the applicant stated the method used to determine the loads in DCD Tier 2 Section 3.9.5.2, for reactor internals under design loading and service Levels A, B, C, and D loading conditions is the same method used in DCD Tier 2, Section 3.9.3. The guidance in SRP Section 3.9.3, Appendix A, is also applicable to the core support structure and provides the appropriate loading combinations under service Levels A, B, C, and D loading conditions. Since the applicant clarified the method in which the design loading and all service level loadings are determined and the method is consistent with acceptance criterion for loading combination described in SRP Section 3.9.5, the staff found the applicant's response acceptable. Therefore, RAI 92-8068, Question 03.09.05-13, is resolved and closed.

Loading Condition – Design Loading

In DCD Tier 2 Section 3.9.5.2.1, the applicant provides information for loading combination for design loads. The design loads consist of normal operating loads in combination with IRWST discharge loads. Normal operating loads include loads due to pressure difference, temperature difference and mechanical loads. The mechanical loads include weight, loads from reactor coolant flow and reaction loads.

The staff found the design loads acceptable because loads due to pressure difference and temperature difference are the major loads the reactor internals components experience during normal operating condition. This method is consistent with acceptance criterion bullet 3 in SER Section 3.9.5.3, which provides method of load combination based on the guidelines from ASME BPV Code, Section II, Subsection NG.

Loading Condition – Level A Service Loading

In DCD Tier 2 Section 3.9.5.2.2, the applicant provides information for loading combination for service Level A. Service Level A loads consist of normal operating loads in combination with specified system operating transient loads resulting from normal events as listed in DCD Tier 2, Table 3.9-1.

The staff found the service Level A loading acceptable because normal operating loads and loads from service Level A operating transients are the major loads the reactor internals components experience during a service Level A condition. This method is consistent with acceptance criterion bullet 3 in SER Section 3.9.5.3, which provides method of load combination based on the guidelines from ASME BPV Code, Section II, Subsection NG.

Loading Condition – Level B Service Loading

In DCD Tier 2 Section 3.9.5.2.3, the applicant provides information for loading combination for service Level B. Service Level B loads consist of two separate loading combinations:

- Normal operating loads in combination with IRWST discharge loads and system operating transient loads from the upset events as listed in DCD Tier 2 Table 3.9-1.
- Normal operating loads in combination with the system operating transient loads from the upset event (the loss of external load with turbine control system failure). The loss of external load of the upset event, which is evaluated as if it occurs once during the plant lifetime, is an emergency event.

Based on the information provided in DCD Tier 2 Section 3.9.5.2.3, it was initially unclear to the staff whether the loss of external load with turbine control system failure is an upset event or emergency event. According to DCD Tier 2 Table 3.9-1, loss of external load is an Upset Event-2. However, DCD Tier 2 Section 3.9.5.2.3, states that the loss of external load is an emergency event. Therefore, the staff issued RAI 92-8068, Question 03.09.05-14 (ML15202A386), requesting the applicant to clarify this discrepancy.

In its response to RAI 92-8068, Question 03.09.05-14 (ML15289A615), the applicant stated the loss of external load event listed in Upset Event-2 in DCD Tier 2 Table 3.9-1, consists of two categories: (1) loss of external load with turbine control function (19 cycles), and (2) loss of external load with turbine control system failure (1 cycle). The loss of external load with turbine control function is a Level B upset event; while the loss of external load with turbine control system failure is a Level C emergency event. However, the loss of external load with turbine control system failure event is conservatively considered as a Level B service loading only to evaluate fatigue.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-14, acceptable because the applicant clarified the loss of external load event listed as Upset Event-2 in DCD Tier 2 Table 3.9-1, and the method to treat a Level C event as a Level B event in the fatigue evaluation is conservative because the allowable stress for a Level B event is lower than the allowable stress for a Level C event. Therefore, RAI 92-8068, Question 03.09.05-14, is resolved and closed.

Loading Condition – Level C Service Loading

In DCD Tier 2 Section 3.9.5.2.4, the applicant provides information for loading combination for service Level C. Service Level C loads consist of normal operating loads and the DBPB loads. The DBPB load is defined as a postulated pipe break that results in the loss of reactor coolant at a rate less than or equal to the capability of the reactor coolant makeup system.

In DCD Tier 2 Section 3.9.5.2.4, the applicant is inconsistent with DCD Tier 2 Table 3.9-1, which states that there are no events classified as a service Level C condition. In DCD Tier 2 Section 3.9.1.1.2, item (r), the applicant addresses the failure of small lines outside containment. In DCD Tier 2 Table 3.9-1, the applicant includes Upset Event-6, which includes item (r). These events appear to be similar to the DBPB load described above but are categorized as a service Level B event. Therefore, the staff issued RAI 92-8068, Question

03.09.05-15 (ML15202A386), requesting the applicant to address the inconsistency in the DCD Tier 2, Sections 3.9.1, 3.9.4, and 3.9.5.

In its response to RAI 92-8068, Question 03.09.05-15 (ML15289A615), the applicant stated the DBPB event considered in Level C service loading in DCD Tier 2 Section 3.9.5.2.4, is categorized conservatively as a Level B service condition in DCD Tier 2 Table 3.9-1. Therefore, DCD Tier 2 Table 3.9-1, does not include the DBPB event as a Level C service condition. According to SRP Section 3.9.3, Appendix A, it is required that DBPB loads be at least as stringent as Level C service conditions. Thus, for ASME BPV Code Class CS components, DBPB loads are considered as Level C service condition as a mechanical load.

Based on the information provided by the applicant, the staff found the response acceptable because the applicant clarified the conservative categorization of the DBPB load as a Level B service loading in DCD Tier 2 Table 3.9-1. The allowable stress for a Level B event is lower than the allowable stress for a Level C event and is therefore more stringent than what is required by SRP Section 3.9.3, Appendix A. Therefore, RAI 92-8068, Question 03.09.05-15, is resolved and closed.

Loading Condition – Level D Service Loading

In DCD Tier 2 Section 3.9.5.2.5, the applicant provides information for loading combination for service Level D for the reactor internals. Level D service loads consist of the following:

- Normal operating loads
- Either the main steam pipe break or main feedwater pipe break, or LOCA loads (including asymmetric blowdown loads), whichever are greater
- SSE loads
- IRWST discharge loads

LOCA is defined as the loss of reactor coolant at a rate in excess of the reactor coolant normal makeup rate, from breaks in the RCPB inside primary containment up to, and including, a break equivalent in size to the largest primary branch line not eliminated from leak-before-break (LBB) criteria.

The staff reviewed the service loads described in DCD Tier 2 Section 3.9.5, in comparison to the transients presented in DCD Tier 2 Table 3.9-1, and found several discrepancies in the description and categorization of these events. For example, based on the information provided in DCD Tier 2 Table 3.9-1, a main steam pipe break and a main feedwater pipe break are included as faulted events 1 and 2. It was, however, unclear to the staff whether the other faulted events (3-6) listed in DCD Tier 2 Table 3.9-1, are included in the service Level D loads for reactor internals. Therefore, the staff issued RAI 92-8068, Question 03.09.05-16 (ML15202A386), requesting the applicant to clarify this discrepancy and describe and justify any differences between Table 3.9-1, and the loads applied to the reactor internals.

In its response to RAI 92-8068, Question 03.09.05-16 (ML15289A615), the applicant stated for Level D service loading, DCD Tier 2 Section 3.9.5.2.5, includes all the system operating transient loads from the faulted events presented in DCD Tier 2 Table 3.9-1. Specifically, the

main steam pipe break, feedwater pipe break or LOCA loads are larger than the loads resulted from faulted events-3, -4 and -6, which are reactor coolant pump failure, control rod ejection and total loss of feedwater flow, respectively, in the Level D service loadings. Additionally, IRWST discharge loads are considered as faulted event-5.

In its supplemental response to RAI 92-8068, Question 03.09.05-16 (ML16050A245), the applicant stated that of the three events in faulted event-5 listed in DCD Tier 2 Table 3.9-1, the inadvertent opening of a pilot operated safety and relief valve (POSRV fails to close) event results in an IRWST injection and discharge loads.

Based on the information provided by the applicant, the staff found that the response clarified the service Level D faulted events that will result in loading on the reactor internals. It was, however, unclear to the staff as to why the IRWST discharge load is included under Level B service loading in DCD Tier 2, Sections 3.9.5.2.3, respectively, while only one of the faulted event-5, the inadvertent opening of a pilot operated safety and relief valve event, will result in IRWST injection. This issue was discussed with the applicant during a conference call on June 15, 2016.

In its subsequent supplemental response to RAI 92-8068, Question 03.09.05-16 (ML16306A441), the applicant stated of the upset events listed in DCD Tier 2 Table 3.9-1; i.e., the loss of condenser vacuum event and the main steam isolation valve closure' event in Upset Event-2, and the inadvertent opening of a pilot operated safety and relief valve (POSRV closed as expected) event in Upset Event-6, would result in an IRWST discharge. Therefore, the IRWST discharge loads are considered in the Level B service loading.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-16, acceptable because the applicant clarified the Level D service loading and the transient events in DCD Tier 2 Table 3.9-1, which would cause an IRWST discharge. Therefore, RAI 92-8068, Question 03.09.05-16, is resolved and closed.

3.9.5.4.3 *Design Bases for Reactor Internals*

In DCD Tier 2 Section 3.9.5.3, the applicant provided information for the design basis for reactor internals. Other areas related to reactor internals are addressed in different sections of the DCD. Specifically, the RCS transient design basis for reactor internals is addressed in DCD Tier 2 Section 3.9.1.1. The potential adverse flow effects for FIV and acoustic resonances on reactor internals are addressed in DCD Tier 2 Section 3.9.2.3. The CVAP for reactor internals is addressed in DCD Tier 2 Section 3.9.2.4. The dynamic system analysis of reactor internals under faulted conditions is addressed in DCD Tier 2 Section 3.9.2.5. The staff's evaluation of this information is included in SER Section 3.9.2.

In DCD Tier 2 Section 3.9.5.3, the applicant states that the reactor internals are designed to meet interface cold gaps between reactor internals and the reactor vessel and between the main parts of the reactor internals. The staff issued RAI 92-8068, Question 03.09.05-17 (ML15202A386), requesting the applicant to provide information on the design of the reactor internals to accommodate hot gaps at their operating temperature and pressure.

In its response to RAI 92-8068, Question 03.09.05-17 (ML15289A615), the applicant stated that the reactor internals are designed to have no interference between reactor internals and the reactor vessel. A table of the minimum and maximum cold and hot gaps between the core

support barrel outlet nozzle and the reactor vessel outlet nozzle was also provided. The applicant further stated that the cold gap between the core support barrel outlet nozzle and the reactor vessel outlet nozzle is calculated considering dimension and positional tolerances according to the requirements for alignment. The hot gap between the core support barrel outlet nozzle and the reactor vessel outlet nozzle is calculated considering the radial growth and contraction of the reactor vessel and the reactor internals. The applicant also provided equations used to calculate: (1) the radial growth of the reactor vessel due to pressure; (2) the radial growth of the reactor vessel due to temperature; (3) the radial contraction of the core support barrel due to pressure; and (4) the radial growth of the core support barrel due to temperature.

In its supplemental response to RAI 92-8068, Question 03.09.05-17 (ML16050A245), the applicant stated that the radial contraction of the core support barrel is induced by the different flow velocities between the core support barrel inside wall and outside wall.

The staff evaluated the information provided by the licensee and found that there is no interference between reactor internals and the reactor vessel under both cold and hot conditions. Therefore, RAI 92-8068, Question 03.09.05-17, is resolved and closed.

Design Bases for Reactor Internals – Classification

In DCD Tier 2 Table 3.9-12, the applicant stated that the reactor internals are designed to meet the design limits defined in ASME BPV Code, Section III, Subsection NG-3221, for design loadings. The reactor internals are classified as safety Class 3 and seismic Category I. DCD Tier 2 Table 3.2-1, lists the core support structures as safety Class 3, Quality Group C, seismic Category I, in full compliance with the 10 CFR Part 50, Appendix B, quality assurance requirement. Note N-2 states that only those core support structures necessary to support and restrain the core and to maintain safe shutdown capability are classified as seismic Category I.

GDC 1, and 10 CFR 50.55a, require that SSCs important to safety be designed to quality standards commensurate with the importance of the safety functions performed. However, it was initially unclear to the staff whether note N-2 from DCD Tier 2, Table 3.2-1 encompasses all core support structures, and if there are any core support structures that are not within the scope of note N-2, and therefore not classified as seismic Category I. In addition, in DCD Tier 2, Table 3.9-12 and Table 3.2.1, the applicant does not provide any safety class, quality group, seismic category classification, or quality assurance requirement for reactor internal structures other than core support structures. Therefore, the staff issued RAI 92-8068, Question 03.09.05-18 (ML15202A386), requesting the applicant to provide information for the issues identified above. The staff evaluated portion of DCD Tier 2 Table 3.2-1, and component classification in SER Sections 3.2.1 and 3.2.2.

In its response to RAI 92-8068, Question 03.09.05-18 (ML15289A615), the applicant stated that all of the core support structures within the scope of note N-2 in DCD Tier 2 Table 3.2-1c are classified as seismic Category I. In DCD Tier 2 Table 3.9-12, the applicant provided some classification for the reactor internals including internal structures, but is not a complete classification list. The applicant also stated that efforts are being made to address classification issues and an update to DCD Tier 2 Table 3.2-1, will be provided which will include core support structures and internal structures.

In its supplemental response to RAI 92-8068, Question 03.09.05-18 (ML16354A538), the applicant provided a markup to DCD Tier 2 Table 3.2-1, which states that both core support structures and internal structures are categorized as quality group B and seismic Category I. The staff found the response to RAI 92-8068, Question 03.09.05-18, regarding the quality group and seismic classifications of both core support structures and internal structures in accordance with SRP Sections 3.2.1 and 3.2.2, and therefore, acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 92-8068, Question 03.09.05-18, is resolved and closed.

Design Bases for Reactor Internals – Codes and Standards

In DCD Tier 2 Table 3.9-12, the applicant stated that core support structures are constructed in accordance with ASME BPV Code, Section III, NG-1100. The DCD further states that reactor internals other than core support structures meet the standard of ASME BPV Code, Section III, NG-3000 and are constructed so as not to adversely affect the integrity of the core support structures. The staff finds this acceptable and consistent with acceptance criterion bullet 3 in SER Section 3.9.5.3, because the applicant confirmed that non-core support structures will not adversely affect core support structures.

In DCD Tier 2 Table 3.9-12, the applicant states that the reactor internals are designed to meet the Level A service limits defined in ASME BPV Code, Section III, Subsection NG-3222, for Level A service loadings; Level B service limits defined in ASME BPV Code, Section III, Subsection NG-3223, for Level B service loadings; and Level C service limits defined in ASME BPV Code, Section III, Subsection NG-3224, for Level C service loadings. The DCD further states that reactor internals are designed to meet the Level D service limits defined in ASME BPV Code, Section III, Subsection NG-3225, for elastic system analysis, which references Appendix F of ASME BPV Code, Section III for Level D service loadings. Maximum stress intensity is obtained from principal stresses resulting from a square root sum of squares (SRSS) combination of the IRWST, BLPB, and SSE loads, plus normal operation loads in accordance with NUREG-0484, Revision 1.

The staff found the applicant's use of ASME BPV Code, Section III, Subsection NG as the principal code and standard of design used for reactor internals components for all four service levels acceptable and consistent with acceptance criterion bullet 3 in SER Section 3.9.5.3, which states, "ASME BPV Code, Section III, Subsection NG-3000 contains guidelines that should be met for the design criteria, loading conditions, and analyses that provide the bases for the design of core support structures."

Design Bases for Reactor Internals – Deformation Limit

In DCD Tier 2 Section 3.9.5.3, the applicant states that to properly perform their functions, the reactor internals are designed to meet the following deformation limits:

- Under Level A, Level B, and Level C service loadings, the core is held in place, and deflections are limited so that the CEAs can be inserted under their own weight as the only driving force.
- Under Level D service loadings that require the ability of CEA to insert, deflections are limited so that the core is held in place, adequate core cooling is preserved, and all

CEAs can be inserted. Those deflections that would influence CEA movement are limited to less than 80 percent of the deflections required to prevent CEA insertion.

The applicant establishes allowable deformation limits as 80 percent of the loss of function deflection limits. The staff issued RAI 92-8068, Question 03.09.05-19 (ML15202A386), requesting that the applicant explain and justify why the use of 80 percent as the loss of function deflection limit is acceptable. The staff also requested the applicant to provide references for this justification. In addition, the applicant was requested to clarify the applicability of this deflection limit to each of the reactor internals components.

In its response to RAI 92-8068, Question 03.09.05-19 (ML15289A615), the applicant stated the allowable deflections are based on the deflection that would cause a loss of function of the CEA's ability to insert. The insertion criteria are based on the reactor internals providing a clear straight path for the CEA to insert. The applicant explained that the allowable deflection is conservatively assumed to be 80 percent of the deflection required to prevent CEA insertion, i.e. the loss of function limit at the point where the CEA's ability to insert is compromised. This is a conservative requirement for successful CEA insertion, in addition to meeting ASME BPV Code, Section III, Subsection NG stress limits.

The applicant stated that for service Level D conditions, the resulting calculated deflections due to various loads are compared to the 80 percent allowable deflection limit. The applicant's justification for allowing 80 percent of the loss of function deflection limit is that it provides adequate margin consistent with that for structural failures when considering the uncertainty in the analytical calculation. The applicant also provided a table that shows the calculated deflections between the CEA and the CEA shroud tube, between the CEA and the IBA top plate, between the CEA and the fuel alignment plate and between the CEA and the CEA guide tube, are less than the allowable deflection limits under service Level D condition. In addition, the applicant also stated that this 80 percent deflection limit is applicable to the IBA top plate, CEA shroud tube, UGS support plate, CEA guide tube and fuel alignment plate related to the lateral deflection of the CEA guide path.

Based on the information provided by the applicant, the staff found the response acceptable because the 80 percent allowable limit is conservatively set as the maximum allowable deflection limit for CEA insertion. There is still a 20 percent margin before loss of function deflection limit is reached, which at that point, CEA ability to insert could be compromised. Therefore, RAI 92-8068, Question 03.09.05-19, is resolved and closed.

Design Bases for Reactor Internals – Fatigue

In DCD Tier 2 Section 3.9.5.3, the applicant states that in the design of critical reactor internals that are subject to fatigue, stress analysis is performed using the design fatigue curve of Figure I-9.2 of ASME BPV Code, Section III. A cumulative usage factor of less than one is used as the limiting criterion. The staff finds the use of ASME BPV Code, Section III, Figure I-9.2, as the design fatigue curve for reactor internals acceptable and consistent with the guidance in SRP Section 3.9.5.

However, it was initially unclear to the staff which components are considered critical reactor internals and are subjected to fatigue analysis. Therefore, the staff issued RAI 92-8068,

Question 03.09.05-20 (ML15202A386), requesting the applicant to clarify which reactor internals components are analyzed for fatigue.

In its response to RAI 92-8068, Question 03.09.05-20 (ML15289A615), the applicant stated the critical reactor internals that are subjected to fatigue analysis are the core support structures stated in DCD Tier 2 Section 3.9.5.1; i.e., the core support barrel, lower support structure and UGS barrel assembly, and any specific location where welding and structural discontinuity may create stress concentration.

Based on the information provided by the applicant, it was still unclear to the staff exactly which reactor internals, other the core support structures, will have fatigue analysis.

ASME BPV Code, Section III, Subsection NG-3300, "Core Support Structure Design," Subsection NG-3311(c), states that the requirements of that subsection apply to internal structures as specified in NG-1122, only as specifically stipulated by the certificate holder. However, the certificate holder shall certify that the design used for the internal structures shall not adversely affect the integrity of the core support structure.

In a public meeting on November 24, 2015, the staff requested the applicant to clarify which internal structures will be subjected to fatigue analysis. For those internal structures that are not subjected to fatigue analysis, staff requested that the applicant explain what measure will be taken so that if they were to fail, they shall not adversely affect the integrity of the core support structures.

In its supplemental response to RAI 92-8068, Question 03.09.05-19 (ML16050A245), the applicant stated that all of the core support structure and internal structure components as summarized in DCD Tier 2 Section 3.9.5-1, are evaluated for fatigue in accordance with ASME BPV Code Subsection NG. The applicant further stated that all the bolts and pins in the reactor internals are designed against becoming loose parts. The applicant also provided examples for the socket head cap screws and dowel pins used for the core shroud guide lugs, and the lock bars used for the fuel alignment insert pins to prevent the insert pins from loosening.

Based on the information provided by the applicant, the staff found the response to RAI 92-8068, Question 03.09.05-20, acceptable because the applicant clarified the reactor internals components that are subjected to fatigue evaluation and provided explanation on how some of the small components such as cap screws and dowel pins are secured so as not to become loose parts that could affect the integrity of the core support structures. This explanation is consistent with the standards in the ASME BPV Code, Section III, Subsection NG and SRP Section 3.9.5. Therefore, RAI 92-8068, Question 03.09.05-20, is resolved and closed.

3.9.5.4.4 *Computational Methods and Validation of Input for Reactor Internals*

SRP Section 3.9.5, item 3, states that if computational methods (e.g., the finite element method) are used to determine stresses in the reactor internals components and structures, validation of the modeling procedures for the analyses should be presented. The validation may include comparisons of simulated natural frequencies, mode shapes, and frequency response functions with experimental results.

The computational method and validation of inputs for computer models used for reactor internals design is addressed in SER Section 3.9.1.

3.9.5.5 *Combined License Information Items*

There are no COL items related to DCD Tier 2 Section 3.9.5.

3.9.5.6 *Conclusion*

The staff concludes that the information provided in the DCD with respect to the design bases for the mechanical design of the reactor pressure vessel internals is acceptable because the reactor internals design meets the acceptance criteria in SRP Section 3.9.5.

3.9.6 **Functional Design, Qualification, and Inservice Testing Programs for Pumps, Valves, and Dynamic Restraints**

3.9.6.1 *Introduction*

This section evaluates the descriptions provided in the DCA of the functional design, qualification, and inservice testing (IST) programs for safety-related pumps, valves, and dynamic restraints (snubbers) used in the APR1400 design.

3.9.6.2 *Summary of Application*

DCD Tier 1: The DCD does not specify Tier 1 requirements specific to the IST program to pumps, valves, and dynamic restraints in the APR1400 design. DCD Tier 1 specifies ITAAC for as-built components to confirm that their design requirements have been satisfied.

DCD Tier 2: The applicant describes the process for the design and qualification of pumps, valves, and the dynamic restraints that perform safety functions in the APR1400 nuclear power plant, in DCD Tier 2, Section 3.9.3, "ASME Code Class 1, 2 and 3 Components, Component Supports, and Class CS Code Support Structures," and Section 3.9.6.1, "Functional Design and Qualification of Pumps, Valves, and Dynamic Restraints." For example, in DCD Tier 2 Section 3.9.3.3, the applicant specifies provisions for the functional qualification of safety-related pumps and valves. In DCD Tier 2, Section 3.9.3.4, "Component Supports," the applicant specifies provisions for the functional qualification of safety-related dynamic restraints. In DCD Tier 2 Section 3.9.6.1, the applicant specifies that the functional design and qualification of safety-related pumps, valves, and dynamic restraints are performed in accordance with ASME QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," as endorsed by RG 1.100. In DCD Tier 2, Section 3.9.10, "References," the applicant lists the 2007 Edition of ASME QME-1 and Revision 3 (issued September 2009) of RG 1.100.

In DCD Tier 2 Section 3.9.6, "Functional Design, Qualification, and Inservice Testing Programs for Pumps, Valves, and Dynamic Restraints," the applicant describes the IST program for safety-related pumps, valves, and dynamic restraints that is developed in accordance with the requirements of the ASME Code for Operation and Maintenance of Nuclear Power Plants (OM Code). For example, in DCD Tier 2 Section 3.9.6.2, "Inservice Testing Program for Pumps," Section 3.9.6.3, "Inservice Testing Program for Valves," and Section 3.9.6.4, "Inservice Testing Program for Dynamic Restraints," the applicant provides specific provisions for the IST program for pumps, valves, and dynamic restraints. Section 3.9.6.5, "Relief Requests and Alternative Authorizations to ASME OM Code," discusses plans where the requirements of the ASME OM

Code will not be satisfied. In DCD Tier 2, Section 3.9.10, "References," the applicant lists the 2004 Edition with the 2006 Addenda of the OM Code.

In DCD Tier 2, Section 3.9.9, "Combined License Information," the applicant specifies information that future COL applicants will need to provide related to IST programs for pumps, valves, and dynamic restraints.

3.9.6.3 *Regulatory Basis*

The acceptance criteria for the staff's evaluation of the DCD for the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints include the following:

- Compliance with 10 CFR 50.55a and GDC 1 requires that pumps, valves, and dynamic restraints important to safety be designed, fabricated, installed, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed. Meeting the requirements of 10 CFR 50.55a, and GDC 1, provides assurance that pumps, valves, and dynamic restraints important to safety are capable of performing their intended safety functions.
- Compliance with GDC 2 requires that components important to safety be designed to withstand the effects of natural phenomena, appropriately combined with the effects of normal and accident conditions, without loss of capability to perform their safety functions. Meeting the requirements of GDC 2 provides assurance that pumps, valves, and dynamic restraints important to safety are capable of withstanding the effects of expected natural phenomena while performing their safety functions during and after the occurrence of those phenomena, as applicable.
- Compliance with GDC 4 requires that components important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Meeting the requirements of GDC 4 provides assurance that the components are capable of withstanding those effects and continuing to be capable of performing their intended safety functions.
- Compliance with GDC 14 requires that the RCPB demonstrate an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture. Meeting the requirements of GDC 14 provides assurance that RCPB components will have an extremely low probability of leakage or failure.
- Compliance with GDC 15 requires that the RCS be designed with sufficient margin to ensure that the design conditions of the RCPB are not exceeded during any condition of normal operation, including AOOs. Meeting the requirements of GDC 15 provides assurance that the RCS will perform its design functions.
- Compliance with GDC 37, "Testing of emergency core cooling system," requires that the ECCS be designed to permit appropriate periodic functional testing to ensure the structural and leak-tight integrity of its components, as well as the operability and performance of the active components of the system. Meeting the requirements of GDC

37 provides assurance that components important to safety are capable of performing their intended safety function.

- Compliance with GDC 40, “Testing of containment heat removal system,” requires that the containment heat removal system be designed to permit appropriate periodic functional testing to ensure the structural and leak-tight integrity of its components, as well as the operability and performance of the active components of the system. Meeting the requirements of GDC 40 provides assurance that components important to safety are capable of performing their intended safety function.
- Compliance with GDC 43, “Testing of containment atmosphere cleanup systems,” requires that the containment atmospheric cleanup system be designed to permit appropriate periodic functional testing to ensure the structural and leak-tight integrity of its components and the operability and performance of the active components of the system. Meeting the requirements of GDC 43 provides assurance that components important to safety will perform their safety intended function.
- Compliance with GDC 46, “Testing of cooling water system,” requires that the cooling water system be designed to permit appropriate periodic functional testing to ensure the structural and leak-tight integrity of its components and the operability and performance of the active components of the system. Meeting the requirements of GDC 46 provides assurance that components important to safety are capable of performing their intended safety function.
- Compliance with GDC 54, “Piping systems penetrating containment,” requires that piping systems penetrating the primary reactor containment be provided with leak detection and isolation capabilities. Such piping systems shall be designed with a capability to test the operability of the isolation valves periodically and to determine if valve leakage is within acceptable limits. Meeting the requirements of GDC 54 provides assurance that valves important to safety are capable of performing their intended safety function.
- Compliance with 10 CFR Part 50, Appendix B, requires that applicants establish and maintain an acceptable QA program, including design, testing, and records control. Meeting the requirements of 10 CFR Part 50, Appendix B, provides assurance that design, tests, and documentation, related to functional design, qualification, and IST programs for pumps, valves, and dynamic restraints, will comply with established standards and criteria, thereby ensuring that such equipment will be capable of performing its intended safety functions.
- Compliance with 10 CFR 50.55a(f), for pumps and valves, as well as 10 CFR 50.55a(g) for dynamic restraints, requires that applicable pumps, valves, and dynamic restraints whose function is required for safety be assessed for operational readiness in accordance with the applicable revision to the ASME OM Code.
- In 10 CFR 50.55a(b)(3), the regulations take exception to, or supplement, the ASME OM Code provisions for these components. Meeting the requirements of 10 CFR 50.55a(f) and (g), and 10 CFR 50.55a(b)(3), provides assurance that applicable pumps, valves, and dynamic restraints important to safety are capable of performing their intended safety function. The applicable ASME Codes for IST programs are as follows:

- Pumps and valves in facilities with a construction permit issued on or after November 22, 1999, must be designed and be provided with access to enable the performance of IST to assess operational readiness as described in editions and addenda of the ASME OM Code incorporated by reference in 10 CFR 50.55a, at the time the construction permit or DC under 10 CFR Part 52 was issued.
- IST programs implemented during the initial 120-month interval must comply with the requirements in the latest edition and addenda of the OM Code incorporated by reference in 10 CFR 50.55a, on the date 12 months before the date of issuance of the operating license under 10 CFR Part 50, or 12 months before the date scheduled for initial fuel loading under 10 CFR Part 52, for a COL.
- IST programs implemented during the successive 120-month intervals must comply with the requirements of the latest edition and addenda of the OM Code incorporated by reference in 10 CFR 50.55a, 12 months before the start of the 120-month interval.
- Compliance with 10 CFR 52.47(a)(21) requires that applications for a DC contain proposed technical resolutions of the unresolved safety issues and medium- and high-priority generic safety issues identified in the version of NUREG-0933, current on the date 6 months before application and that are technically relevant to the design.

In evaluating the APR1400 for compliance with the above regulatory criteria, the staff followed guidance provided in the SRP Section 3.9.6, Revision 3. The staff also considered positions provided in applicable NRC Commission papers, Commission Staff Requirements Memoranda (SRMs), Generic Letters (GLs), RGs, and Regulatory Issue Summaries (RISs). These documents are discussed in more detail as part of the staff's evaluation in this section of this report.

The SRM dated September 11, 2002, for Commission paper SECY-02-0067, "Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) for Operational Programs (Programmatic ITAAC)," stated that ITAAC for an operational program are unnecessary if the program and its implementation are fully described in a COL application and found to be acceptable by the NRC. In its SRM dated May 14, 2004, for SECY-04-0032, "Programmatic Information Needed for Approval of a Combined License without Inspections, Tests, Analyses and Acceptance Criteria," dated February 26, 2004, the Commission defined the term, "fully described," as when the program is clearly and sufficiently described in terms of the scope and level of detail to allow a reasonable assurance finding of acceptability. The Commission also noted that operational programs should always be described at a functional level and at an increasing level of detail where implementation choices could materially and negatively affect the program effectiveness and acceptability. Commission paper SECY-05-0197, "Review of Operational Programs in a Combined License Application and Generic Emergency Planning Inspections, Tests, Analyses, and Acceptance Criteria," summarizes the NRC position regarding the full description of operational programs to be provided by COL applicants. In RG 1.206, the NRC provides guidance in Section C.IV.4, "Operational Programs," for COL applicants with respect to fully describing plant operational programs. The staff implements the NRC positions in SECY-05-0197, and RG 1.206, in addition to the review guidance in SRP Section 3.9.6, in reviewing the descriptions of the functional design and qualification, and IST programs for pumps, valves, and dynamic restraints in DC and COL applications.

3.9.6.4 *Technical Evaluation*

The staff reviewed DCD Tier 2 Section 3.9.6, and related sections, for the description of the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints to be used in the APR1400 design for consistency with the criteria in SER Section 3.9.6.3, for reference in a COL application.

At a public meeting on April 14 and 15, 2015, the staff discussed its initial review of the DCD with the applicant. Further information on the meeting is provided in the associated meeting summary dated May 14, 2015 (ML15124A886). Based on the discussions, the applicant submitted a list of action items and a markup of DCD Tier 2 Section 3.9.6, on June 1, 2015 (ML15152A248).

Based on its review of the DCD and the markup of DCD Tier 2 Section 3.9.6, submitted on June 1, 2015, the staff issued RAIs requesting the applicant to provide information regarding the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints in the DCD. In the following sections, the staff describes its review of the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints to be used in the APR1400 design.

3.9.6.4.1 *Functional Design and Qualification of Pumps, Valves, and Dynamic Restraints*

In DCD Tier 2 Section 3.9.6.1, "Functional Design and Qualification of Pumps, Valves, and Dynamic Restraints," the applicant specifies that the functional design and qualification of safety-related pumps, valves, and dynamic restraints are performed in accordance with ASME Standard QME 1, as endorsed by RG 1.100. The markup of the DCD indicated that the functional design and qualification of safety-related pumps, valves, and dynamic restraints will address all aspects of qualification (such as seismic and dynamic, environmental, and functional qualification). The markup also referenced DCD Tier 2, Section 3.11, "Environmental Qualification of Mechanical and Electrical Equipment," for the environmental qualification of safety-related pumps and valves. The provisions for the functional design and qualification of pumps, valves, and dynamic restraints in the DCD for the application of ASME Standard QME 1-2007, as endorsed in RG 1.100, Revision 3, provide an acceptable methodology for the functional design and qualification of pumps, valves, and dynamic restraints that satisfy the NRC regulations and guidance. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In SRP Section 3.9.6, the guidance specifies in its acceptance criteria that functional design and qualification of each safety-related pump and valve should be accomplished such that each pump and valve is capable of performing its intended function for a full range of system differential pressure and flow, ambient temperatures, and available voltage (as applicable) under all conditions ranging from normal operating to design-basis accident conditions. Based on operating experience with the performance of nuclear power plant components, the staff issued RAI 69-7994, Question 03.09.06-1 (ML15195A530), requesting the applicant to specify in the DCD that the functional design and qualification of pumps, valves, and dynamic restraints will be implemented in accordance with ASME QME-1-2007 as accepted in Revision 3 (or later revision) to RG 1.100, unless specific approval for a modification to that methodology is provided by the NRC. For example, this could be accomplished by specifying the functional design and qualification of pumps, valves, and dynamic restraints as a Tier 1 or Tier 2*

requirement with long-term provisions during plant operation, or by specifying that the functional design and qualification methodology for pumps, valves, and dynamic restraints may not be modified under the change control provisions of the design certification rule unless NRC prior approval is obtained. This level of change control is consistent with other certified designs, for which this information has been categorized as DCD Tier 2*.

In its response to RAI 69-7994, Question 03.09.06-1 (ML15253A869), the applicant stated that the APR1400 DCD would be revised to incorporate the final results of the discussions regarding the level of change control between the NRC and the industry. Additional information on the review of the APR1400 ITAAC was found later in this section and SER Section 14.3.3.4.7.

In its response to RAI 546-8782, Question 14.03.03-8 (ML17248A364), the applicant planned ITAAC modifications to verify the implementation of ASME Standard QME-1, as accepted in RG 1.100, Revision 3, for the qualification and testing of safety-related pumps and valves. The staff found that these planned ITAAC modifications to APR1400 DCD Tier 1 were acceptable to verify implementation of the qualification process for safety-related pumps and valves. As discussed later in this SER section, the APR1400 DCD has incorporated the planned ITAAC modifications. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-1, is resolved and closed.

In DCD Tier 2 Section 3.9.3.3, the applicant described the functional design and qualification of pumps and valves for the APR1400 design. In DCD Tier 2 Section 3.9.3.3.1, "Operability Assurance Program," the applicant stated that functional design and qualification of safety-related pumps and valves are performed in accordance with ASME Standard QME-1-2007, as endorsed by RG 1.100. In RAI 62-7995, Question 03.09.03-1 (ML15189A485), the staff requested that the applicant clarify the sections in DCD Tier 2 Section 3.9.3.3, with the provisions of ASME QME-1-2007 as accepted by RG 1.100, Revision 3.

In its response to RAI 62-7995, Question 03.09.03-1 (ML15236A371), the applicant provided a proposed revision to DCD Tier 2 Section 3.9.3, to clarify the provisions for the qualification of pumps and valves to be used in the APR1400 reactor in response to this RAI. These proposed changes included proper references to pump and valve functionality in ASME QME-1-2007, and NRC regulations. Following feedback provided by the staff on the proposed revision to the DCD, the applicant provided an updated response on April 20, 2016 (ML16111B333), to include a change inadvertently omitted from the original response. The staff found that the proposed revision to DCD Tier 2 Section 3.9.3, clarifies the provisions for the qualification of APR1400 pumps and valves consistent with the NRC regulations and regulatory guidance for pump and valve qualification. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 62-7995, Question 03.09.03-1, is resolved and closed.

The requirements in 10 CFR 52.47 states, in part, the "information submitted for a DC must include performance requirements and design information sufficiently detailed to permit the preparation of acceptance and inspection requirements by the NRC, and procurement specifications and construction and installation specifications by an applicant. The Commission will require, before DC, that information normally contained in certain procurement specifications and construction and installation specifications be completed and available for audit if the information is necessary for the Commission to make its safety determination." The staff conducted an initial audit and follow-up audit of the information to be provided in design and procurement specifications for pumps, valves, and dynamic restraints made available by the

applicant in accordance with 10 CFR 52.47. The staff provided the results of the initial audit in a report dated April 20, 2016 (ML15350A057). The staff performed a follow-up audit that is documented in a report dated June 30, 2017 (ML17095A782). As discussed in the audit reports, the staff finds that the planned changes to the design and procurement specifications for pumps, valves, and dynamic restraints to be used in the APR1400 reactor in response to the follow-up audit are acceptable. For example, the APR1400 design specifications require the implementation of ASME Standard QME-1-2007, for the qualification of safety-related pumps and valves. In addition, the applicant provided planned changes to revise the design specifications to be consistent with the qualification provisions specified in ASME QME-1-2007 as accepted in RG 1.100, Revision 3. The staff issued RAI 550-8737, Question 03.09.03-7 (ML17195B072), requesting the applicant to confirm the completion of the planned changes to the design and procurement specifications. In its response to RAI 550-8737, Question 03.09.03-7 (ML17237B993), the applicant stated that the design and procurement specifications for pumps, valves, and dynamic restraints to be used in the APR1400 reactor were revised as committed. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 550-8737, Question 03.09.03-07, is resolved and closed.

3.9.6.4.2 *Overview of Inservice Testing Program for Pumps, Valves, and Dynamic Restraints*

In DCD Tier 2 Section 3.9.6, the applicant provides a description of specific aspects of the IST program for pumps, valves, and dynamic restraints. SECY-05-0197, and RG 1.206, indicate that COL applicants should provide a full description of their operational programs (including preservice testing [PST], IST, and motor-operated valve [MOV] testing) to avoid the need for ITAAC for those programs. Some COL applicants incorporate in its FSAR, the description of these programs provided in the DCD for their applicable certified design. Therefore, the staff issued RAI 69-7994, Question 03.09.06-2 (ML15195A530), requesting the applicant to clarify whether DCD Tier 2 Section 3.9.6, is intended to provide a full description of the IST (including PST and MOV testing) program for pumps, valves, and dynamic restraints with plant-specific components to be addressed by the COL applicant. If the DCD is not intended to fully describe the IST program, the staff requested that the applicant specify those aspects of the IST program description that need to be provided by the COL applicant.

In its response to RAI 69-7994, Question 03.09.06-2 (ML15253A869), the applicant stated that DCD Tier 2 Section 3.9.6, is not intended to provide a full description of the IST program. The applicant stated that DCD Tier 2 Section 3.9.6, would be revised to state that the COL applicant will provide a full description of the IST program (including preservice testing (PST) and MOV testing) for pumps, valves, and dynamic restraints, as required by 10 CFR 50.55a, that will be administratively controlled such that the applicable requirements of ASME OM Code edition and addenda are incorporated in the IST program.

The staff found that the proposed revision to the APR1400 DCD would clarify the scope of the description of the IST program and the responsibility of the COL applicant to fully describe the IST program in the COL application. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-2, is resolved and closed.

The requirements in 10 CFR 50.55a(f) and (g) require that the design of a nuclear power plant provide access for inservice testing and inspection activities, as applicable, for pumps, valves,

and dynamic restraints. The markup of DCD Tier 2 Section 3.9.6, submitted on June 1, 2015, included provisions for the accessibility for inservice testing and inspection activities, as applicable, for pumps, valves, and dynamic restraints. The staff evaluated the planned changes to the DCD and found them to be consistent with the regulatory requirements for accessibility to perform inservice testing and inspection of pumps, valves, and dynamic restraints specified in 10 CFR 50.55a. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

In DCD Revision 0, Tier 2, Section 3.9.10, "References," the applicant specified in Reference 34, the ASME OM Code of record for the description of the IST program for pumps, valves, and dynamic restraints to be used in the APR1400 design as, "[the] 2004 Edition with the 2006 Addenda" of the ASME OM Code. The staff issued RAI 69-7994, Question 03.09.06-3 (ML15195A530), requesting the applicant to clarify Reference 34 in DCD Tier 2 Section 3.9.10, to specify a complete set of edition and addenda of the ASME OM Code (for example, 2004 Edition with the 2005 and 2006 Addenda) that are used as the basis for the description of the IST program for the APR1400 DCA.

In its response to RAI 69-7994, Question 03.09.06-3 (ML15253A869), the applicant stated that the APR1400 DCD would be revised to specify a complete set of the ASME OM Code as, "the 2004 edition with the 2005 and 2006 addenda." Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-3, is resolved and closed.

The staff found that use of the ASME OM Code (2004 Edition through the 2006 Addenda—i.e., with the 2005 and 2006 Addenda) as incorporated by reference in 10 CFR 50.55a, complies with the applicable regulatory requirement and is acceptable as part of the description of the IST program for the APR1400 design. The staff noted that the regulations in 10 CFR 50.55a require an eventual COL licensee to update its IST program to the most recent edition of the ASME OM Code incorporated by reference in 10 CFR 50.55a (or the optional ASME OM Code Cases listed in RG 1.192, "Operation and Maintenance Code Case Acceptability, ASME OM Code," incorporated by reference in 10 CFR 50.55a) 12 months before initial fuel loading. The staff found this clarification of the APR1400 DCD regarding the applicable edition and addenda of the ASME OM Code in the description of the IST program to be acceptable.

As referenced above in SER Section 3.9.6.3, GDC 1 states that:

Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be 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 structures, systems, and components will satisfactorily perform their safety functions.

The requirements in 10 CFR Part 50, Appendix B, Criterion XI, "Test Control," states that:

A test program shall be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is

identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents. The test program shall include, as appropriate, proof tests prior to installation, preoperational tests, and operational tests during nuclear power plant or fuel reprocessing plant operation, of structures, systems, and components.

The markup of DCD Tier 2 Section 3.9.6, specified that ASME BPV Code, Section III, Class 1, 2, and 3, and non-ASME Code safety-related pumps, valves, and dynamic restraints will be incorporated in the IST program for the APR1400 design. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

The staff found the scope of the IST program for the APR1400 design to include all safety-related pumps, valves, and dynamic restraints as required by the requirements in 10 CFR 50.55a and 10 CFR Part 50, Appendices A and B.

As stated in SECY-05-0197, the PST program is categorized as an operational program. The ASME OM Code includes provisions for the PST program as a prerequisite for the IST program of pumps, valves, and dynamic restraints. The markup of DCD Tier 2 Section 3.9.6 specified that the ASME OM Code describe the IST scope and establish the requirements for PST and IST and examination of certain components to assess their operational readiness, with specific PST provisions in applicable subsections. The staff found that the markup of DCD Tier 2 Section 3.9.6 includes a description of the PST program for pumps, valves, and dynamic restraints that is consistent with the requirements and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

The markup of DCD Tier 2 Section 3.9.6 specifies that the APR1400 IST program will incorporate the guidance and information on the format and content for the IST program and relief requests provided in NUREG-1482, Revision 2, "Guidelines for Inservice Testing at Nuclear Power Plants." In Supplement 1 to GL 89-04, "Guidance on Developing Acceptable Inservice Testing Programs," the staff stated that it was issuing NUREG-1482 to describe perspectives on the regulatory requirements for inservice testing of pumps and valves in nuclear power plants. The staff indicated that NUREG-1482 included information on the format and content for IST programs and relief requests, examples of relief requests, clarification of issues described in information notices and other NRC letters on IST, and considerations for positions in GL 89-04. The staff stated that the guidance in NUREG-1482 may be used in developing IST programs for nuclear power plants. In October 2013, the staff issued Revision 2 to NUREG-1482 to provide updated guidance to assist nuclear power plant applicants and licensees in establishing a basic understanding of the regulatory basis for pump and valve IST programs and dynamic restraint examination and testing programs. The staff stated that Revision 2 to NUREG-1482 updated the guidance in previous revisions to NUREG-1482 to reflect IST lessons learned and operating experience. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

3.9.6.4.3 *Inservice Testing Program for Pumps*

In DCD Tier 2, Section 3.9.6.2, “Inservice Testing Program for Pumps,” the applicant specifies that the IST program for safety-related pumps is developed in accordance with the requirements of the ASME OM Code, Subsection ISTA, “General Requirements,” and Subsection ISTB, “Inservice Testing of Pumps in Light-Water Reactor Nuclear Power Plants.”

The markup of DCD Tier 2 Section 3.9.6.2 clarified that safety-related pumps and piping configurations accommodate IST at a flow rate at least as large as the maximum design flow for the pump application. The markup also specified the testing requirements and acceptance criteria as identified in Paragraph ISTB-5000, “Specific Testing Requirements,” of the ASME OM Code, which includes provisions for Group A, Group B, and Comprehensive Testing, and their frequency. In DCD Tier 2 Section 3.9.6.2, the applicant describes the ASME OM Code provisions for PST, reference values, and methods, range, and accuracy of pump parameter measurements. The staff found that DCD Tier 2 Section 3.9.6.2, includes a description of the IST program for pumps that is consistent with the specified ASME OM Code edition and addenda as incorporated by reference in 10 CFR 50.55a. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

3.9.6.4.4 *Inservice Testing Program for Valves*

DCD Tier 2, Section 3.9.6.3, “Inservice Testing Program for Valves,” specifies that the IST program for safety-related valves is developed in accordance with the requirements of the ASME OM Code, Subsection ISTA and Subsection ISTC, “Inservice Testing of Valves in Light-Water Reactor Nuclear Power Plants.”

The markup of DCD Tier 2, Section 3.9.6.3 described the IST provisions specified in the ASME OM Code as incorporated by reference in 10 CFR 50.55a. For example, Section 3.9.6.3 describes the OM Code categories for valves, and references the specific testing requirements and acceptance criteria in Paragraph ISTC-5000, “Specific Testing Requirements.” The staff also noted that NUREG-1482 includes guidance for developing the IST program for valves, including supplementing the provisions for valve position indication in the ASME OM Code. The staff evaluated the changes and found that DCD Tier 2, Section 3.9.6.3 includes an overall description of the IST program for valves that is consistent with the specified ASME OM Code edition and addenda as incorporated by reference in 10 CFR 50.55a. The staff’s review of the IST program description for specific valve types is provided in the following subsections. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Inservice Testing Program for Motor-Operated Valves

The markup of DCD Tier 2, Section 3.9.6.3.1, “Inservice Testing Program for Motor-Operated Valves,” described the IST program for MOVs for the APR1400 design. In DCD Tier 2 Section 3.9.6.3.1, the applicant specifies that the IST program for MOVs applies the ASME OM Code requirements as incorporated by reference in 10 CFR 50.55a, and the supplemental requirements for periodic verification of the design-basis capability of MOVs in accordance with 10 CFR 50.55a(b)(3)(ii). In addition, in DCD Tier 2 Section 3.9.6.3.1, the applicant describes the program for periodic verification of the design-basis capability of MOVs in accordance with

10 CFR 50.55a(b)(3)(ii), including the use of ASME OM Code Case OMN-1, "Alternative Rules for Preservice and Inservice Testing of Active Electric Motor-Operated Valve Assemblies in Light-Water Reactor Power Plants," as accepted in RG 1.192, and incorporated by reference in 10 CFR 50.55a. In DCD Tier 2 Section 3.9.6.3.1, the applicant also indicates the implementation of the recommendations from the Joint Owners Group MOV Periodic Verification Program as described in MPR-2524-A, "Joint Owners Group (JOG) Motor Operated Valve Periodic Verification Program Summary," (ML063470526) which was accepted in the NRC safety evaluation dated September 25, 2006 (ML061280315), and its supplement dated September 18, 2008 (ML082480638).

The staff confirmed that the DCD incorporated the changes for the IST program for MOVs. The staff found that DCD Tier 2 Section 3.9.6.3.1, provides an acceptable description of the IST program for MOVs consistent with the specified ASME OM Code edition and addenda as incorporated by reference in 10 CFR 50.55a, and the supplemental requirements for periodic verification of the design-basis capability of MOVs in accordance with 10 CFR 50.55a(b)(3)(ii). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Inservice Testing Program for Power-Operated Valves other than Motor Operated Valves

The markup of DCD Tier 2, Section 3.9.6.3.2, "Inservice Testing Program for Power-Operated Valves Other than Motor-Operated Valves," specified that the IST program for power-operated valves (POVs) other than MOVs (such as air-operated valves [AOVs], hydraulic-operated valves [HOVs], and solenoid-operated valves [SOVs]) for the APR1400 design applies the ASME OM Code as incorporated by reference in 10 CFR 50.55a, and lessons learned for POV periodic verification from valve testing programs and nuclear power plant operating experience. In DCD Tier 2 Section 3.9.6.3.2, the applicant references Subsection ISTC of the ASME OM Code for the IST activities for POVs other than MOVs in the APR1400 design. In addition, in DCD Tier 2 Section 3.9.6.3.2, the applicant specifies that periodic testing is conducted under adequate differential pressure and flow conditions per the guidance of RIS 2000-03, "Resolution of Generic Safety Issue 158: Performance of Safety-Related Power-Operated Valves Under Design Basis Conditions," and summarizes the provisions outlined in RIS 2000-03.

In its review of DCD Tier 2 Section 3.9.6.3.2, the staff found the applicant's summary of the provisions for an IST program for POVs in RIS 2000-03 to be incorrect in two aspects. The staff issued RAI 69-7994, Question 03.09.06-4 (ML15195A530), requesting that the applicant correct those two aspects in its description of the IST program for POVs in DCD Tier 2 Section 3.9.6.3.2 to be consistent with the specified use of the guidance in RIS 2000-03. First, the staff requested that the applicant correct the provision specified in DCD Tier 2 Section 3.9.6.3.2 for periodic dynamic testing of POVs by removing the comma after the terms, "if required," and prior to the terms, "based on valve qualification or operating experience." This provision in RIS 2000-03 is intended to specify that if required based on valve qualification or operating experience, periodic dynamic testing will be performed to re-verify the capability of the valve to perform its required functions. Second, the staff requested that the applicant modify the provision in DCD Tier 2 Section 3.9.6.3.2 for the categorization of safety-related valves to be consistent with RIS 2000-03.

In its response to RAI 69-7994, Question 03.09.06-4 (ML15253A869), the applicant stated that APR1400 DCD Tier 2 Section 3.9.6.3.2, paragraph b, would be revised to specify that if required

based on valve qualification or operating experience, periodic dynamic testing will be performed to re-verify the capability of the valve to perform its required safety function. In addition, the applicant stated that DCD Tier 2 Section 3.9.6.3.2 would be revised to align the categorization of AOVs in the POV program with industry and NRC guidelines. In particular, DCD Tier 2 Section 3.9.6.3.2 would be revised to specify that safety-related valves are categorized according to their safety significance and risk ranking to be consistent with the provision in RIS 2000-03. Further, DCD Tier 2 Section 3.9.6.3.2 would be revised to specify that safety-related AOVs are assigned the highest category according to the JOG AOV program (including staff comments provided in a letter to the Nuclear Energy Institute, dated October 8, 1999). The staff finds that the changes to the DCD are consistent with the guidance in RIS 2000-03 and, therefore, are acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-4, is resolved and closed.

Inservice Testing Program for Check Valves

The markup of DCD Tier 2, Section 3.9.6.3.3, "Inservice Testing Program for Check Valves," specified that the IST activities for check valves described in ASME OM Code, Subsection ISTC, are performed for the APR1400 design. The applicant described the IST program for check valves in DCD Tier 2 Section 3.9.6.3.3, which includes provisions for testing to demonstrate operability of check valves under design conditions; using advanced non-intrusive techniques, conditions of reverse flow, full disk opening and closing; and using disassembly and inspection based on suspected degradation. The staff evaluated the changes and found that DCD Tier 2 Section 3.9.6.3.3 provides an acceptable description of the IST program for check valves consistent with the specified ASME OM Code edition and addenda as incorporated by reference in 10 CFR 50.55a. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Pressure Isolation Valve Leak Testing

In DCD Tier 2, Section 3.9.6.3.4, "Pressure Isolation Valve Leak Testing," the applicant specifies that the leak-tight integrity is verified for each valve relied on to provide a leak-tight function. In DCD Tier 2 Section 3.9.6.3.4, the applicant indicates that these valves include pressure-isolation valves (PIVs) that provide isolation of a pressure differential from one part of a system to another part of between systems, and temperature-isolation valves (TIVs) whose leakage may cause unacceptable thermal stress, fatigue, or stratification in the piping and thermal loading on supports or whose leakage may cause steam binding of pumps.

In DCD Revision 0, Tier 2, Section 3.9.6.3.4, the applicant described the leak testing of PIVs in the APR1400 design, and specifies that PIVs associated with the reactor coolant system are defined in Section 4a, of Attachment 1, in GL 89-04, "Guidance on Developing Acceptable Inservice Testing Programs." In Supplement 1 to GL 89-04, the NRC stated that NUREG-1482, incorporates the provisions of GL 89-04. Therefore, the reference to GL 89-04 in DCD Tier 2 Section 3.9.6.3.4, was out of date. The staff issued RAI 69-7994, Question 03.09.06-5 (ML15195A530), requesting the applicant to update DCD Tier 2 Section 3.9.6.3.4 to reference the guidance in NUREG-1482, Revision 2, for leak testing of PIVs in the APR1400 design.

In its response to RAI 69-7994, Question 03.09.06-5 (ML15253A869), the applicant stated that DCD Tier 2 Section 3.9.6.3.4 would be revised to remove the reference to GL 89-04, and

replaced with the updated reference to NUREG-1482. The planned DCD change specified that the leak testing of PIVs associated with the RCS is defined in NUREG-1482, Revision 2. The staff found that this DCD change specified the application of the updated NRC guidance for PIV leak testing and, therefore, is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-5, is resolved and closed.

Containment Isolation Valve Leak Testing

In DCD Tier 2, Section 3.9.6.3.5, "Containment Isolation Valve Leak Testing," the applicant specifies that the leak-tight integrity is verified for each valve relied on to provide a leak-tight function. In DCD Tier 2 Section 3.9.6.3.5, the applicant indicates that these valves include containment isolation valves (CIVs) that provide isolation capability for the piping systems penetrating containment. In DCD Tier 2 Section 3.9.6.3.5, the applicant specifies that CIVs are leak tested in accordance with 10 CFR Part 50, Appendix J, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors." The staff finds that the specification of the leak testing of CIVs in accordance with 10 CFR Part 50, Appendix J, is acceptable in satisfying the NRC regulations and guidance.

Inservice Testing Program for Safety and Relief Valves

In DCD Tier 2, Section 3.9.6.3.6, "Inservice Testing Program for Safety and Relief Valves," the applicant specifies that pressure-relief devices are tested in accordance with ASME OM Code, including Appendix I, "Inservice Testing of Power Relief Devices in Light-Water Reactor Nuclear Power Plants," to the OM Code. In DCD Tier 2 Section 3.9.6.3.6, the applicant also specifies that power-operated relief valves subject to the IST program are tested in accordance with ASME OM Code, Subsection ISTC, Paragraph ISTC-5100, "Power Operated Valves (POVs)," for Category B valves, and Paragraph ISTC-5240, "Safety and Relief Valves," for Category C valves. The staff finds the provisions in DCD Tier 2 Section 3.9.6.3.6, acceptable for a description of the IST program for safety and relief valves where implemented in accordance with the ASME OM Code as incorporated by reference in 10 CFR 50.55a.

Inservice Testing Program for Manually Operated Valves

In DCD Tier 2, Section 3.9.6.3.7, "Inservice Testing Program for Manually Operated Valves," the applicant specifies that safety-related active manually operated valves are exercised periodically in accordance with the frequency and requirements specified in the ASME OM Code. In DCD Tier 2 Section 3.9.6.3.7, the applicant also specifies that manual valves are exercised at least every 2 years. The staff finds the provisions in DCD Tier 2 Section 3.9.6.3.7 to be acceptable for a description of the IST program for manually operated valves where implemented in accordance with the ASME OM Code as incorporated by reference in 10 CFR 50.55a.

Inservice Testing Program for Explosively Actuated Valves

In DCD Tier 2, Section 3.9.6.3.8, "Inservice Testing Program for Explosively Activated Valves," Revision 0, the applicant indicated that the IST program for explosively activated valves (commonly referred to as squib valves) is not applicable to the APR1400 design. The staff found that the reference to the terms, "not applicable," could be misinterpreted. The staff issued RAI 69-7994, Question 03.09.06-6 (ML15195A530), requesting that the applicant revise DCD

Tier 2 Section 3.9.6.3.8, to clarify that explosively actuated valves (squib valves) are not included in the APR1400 design.

In its response to RAI 69-7994, Question 03.09.06-6 (ML15253A869), the applicant stated that DCD Tier 2 Section 3.9.6.3.8 would be revised to more clearly state that squib valves are not used in the APR1400 design. The staff found the clarification of the DCD regarding use of squib valves in the APR1400 design to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-6, is resolved and closed.

Inservice Testing Program for Dynamic Restraints

The markup of DCD Tier 2, Section 3.9.6.4, "Inservice Testing Program for Dynamic Restraints," specified that the ASME OM Code provides inservice inspection methods and requirements for examinations and tests of snubbers at nuclear power plants. In DCD Tier 2 Section 3.9.6.4, the applicant also indicates that inservice functional testing is performed over the test plant intervals specified in ASME OM Code, Subsection ISTD, "Preservice and Inservice Examination and Testing of Dynamic Restraints (Snubbers) in Light-Water Reactor Nuclear Power Plants." In DCD Tier 2 Section 3.9.6.4, the applicant indicates the planned application of ASME OM Code Case OMN-13, "Requirements for Extending Snubber Inservice Visual Examination Interval at LWR Power Plants," as accepted in RG 1.192. In DCD Tier 2 Section 3.9.6.4, the applicant references the use of GL 90-09, "Alternative Requirements for Snubber Visual Inspection Intervals and Corrective Actions," for snubbers that fail the acceptance criteria of the visual inspection. In DCD Tier 2 Section 3.9.6.4, the applicant specifies that an engineering evaluation will be performed of snubbers that fail to satisfy the acceptance criteria in the dynamic restraint IST program, including adjustment, repair, modification, or replacement. In DCD Tier 2 Section 3.9.6.4, the applicant indicates that the methods addressed in Nonmandatory Appendix F, "Dynamic Restraints (Snubbers) Service Life Monitoring Methods," of the ASME OM Code will be applied for service life monitoring for dynamic restraints in the APR1400 design. The staff found the description in DCD Tier 2, Section 3.9.6.4, of the IST program for dynamic restraints to be acceptable where implemented in accordance with the ASME OM Code as incorporated by reference in 10 CFR 50.55a. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

Pump and Valve Inservice Testing Program Table

In DCD Tier 2, Table 3.9-13, "Inservice Testing of Safety-Related Pumps and Valves," the applicant specifies IST activities and frequencies for pumps and valves in the IST program for the APR1400 design. The acceptance criteria in SRP Section 3.9.6 specify that the IST program description should satisfy the IST activities and frequencies for pumps and valves provided in the applicable subsection of the ASME OM Code. The staff issued RAI 69-7994, Question 03.09.06-9 (ML15195A530), requesting the applicant to modify DCD Tier 2 Table 3.9-13 to be consistent with the requirements in 10 CFR 50.55a, and guidance for IST programs in NUREG-1482 (as referenced in DCD Tier 2 Section 3.9.6). The staff also requested that the applicant evaluate all pumps and valves in DCD Tier 2 Table 3.9-13 for appropriate changes consistent with NRC guidance.

In its response to RAI 69-7994, Question 03.09.06-9 (ML15253A869), the applicant provided a planned revision to DCD Tier 2 Table 3.9-13. The staff reviewed the RAI response and

provided comments to the applicant that were discussed during a public telephone conference on November 17, 2015. In its supplemental response to RAI 69-7994, Question 03.09.06-9 (ML16134A586), the applicant proposed a revision to DCD Tier 2 Table 3.9-13. The staff reviewed the supplemental response and provided feedback to the applicant. In its subsequent response to RAI 69-7994, Question 03.09.06-9 (ML16242A436), the applicant provided additional changes to DCD Tier 2 Table 3.9-13. The staff notes that the COL applicant will be responsible for finalizing the IST program scope, testing provisions, and frequency as part of its description of the IST program in its COL application. The staff found that the IST provisions for pumps and valves are consistent with the IST requirements in the ASME OM Code as incorporated by reference in 10 CFR 50.55a. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-9, is resolved and closed.

3.9.6.4.5 *Relief Requests and Proposed Alternatives*

In DCD Tier 2, Section 3.9.6.5, the applicant indicated that relief requests will be made on a case-by-case basis.

To address the current plans for relief requests and alternative authorizations to the ASME OM Code for the APR1400 design, the staff issued RAI 69-7994, Question 03.09.06-7 (ML15195A530), requesting the applicant to clarify DCD Tier 2 Section 3.9.6.5, to describe any planned alternative requests under 10 CFR 50.55a(z), and relief requests under 10 CFR 50.55a(f)(6) or (g)(6), for the IST programs for pumps, valves, and dynamic restraints, as applicable.

In its initial response to RAI 69-7994, Question 03.09.06-7 (ML15253A869), the applicant provided a planned revision to DCD Tier 2 Section 3.9.6.5. Following a public telephone conference with the staff on September 24, 2015, the APR1400 design certification applicant stated that it would provide a supplemental response to this RAI. In its revised response to RAI 69-7994, Question 03.09.06-7 (ML15293A597), the applicant provided a revision to its response to address relief requests, alternatives to the ASME OM Code, and use of OM Code Cases. The staff discussed the revised response with the applicant during a public telephone conference on November 17, 2015. At the conclusion of the telephone conference, the applicant stated that it would provide a supplemental response to the RAI. In its supplemental response to RAI 69-7994, Question 03.09.06-7 (ML16111B338), the applicant provided a planned revision to DCD Tier 2, Section 3.9.6.5, that clarified that the COL applicant will be responsible for submitting any proposed relief from or alternatives to the ASME OM Code in accordance with 10 CFR 50.55a(f), (g), or (z), as applicable. The staff found that the proposed revision to DCD Tier 2 Section 3.9.6.5 is consistent with the requirements in 10 CFR 50.55a for requesting relief from or alternatives to the ASME OM Code. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-7, is resolved and closed.

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

In DCD Tier 1, the applicant specified ITAAC for the qualification and preoperational testing of safety-related pumps and valves in the APR1400 design. The requirements in 10 CFR 52.47(b)(1) require that a DCA 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, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act, and the Commission's rules and regulations. Based on its review of the APR1400 DC application, the staff identified several ITAAC that needed to be updated to reflect the acceptable approach for ITAAC for pumps, valves, and dynamic restraints based on lessons learned from other certified designs. Rather than preparing multiple RAIs on the proposed APR1400 ITAAC, the staff prepared guidance for standard ITAAC that may be used by design certification applicants, including this applicant. The staff tracked resolution of these ITAAC updates in SER Section 14.3.3.

The staff issued RAI 546-8782, Question 14.03.03-8 (ML17123A458), requesting the applicant to address specific aspects of its ITAAC in DCD Revision 0 to ensure that they are sufficient to satisfy 10 CFR 52.47(b)(1) for the safety-related pumps and valves to be used in the APR1400 design. In its response to RAI 546-8782, Question 14.03.03-8 (ML17248A364), the applicant provided its planned modifications to APR1400 DCD Tier 1 in response to RAI 546-8782, Question 14.03.03-8, regarding the proposed ITAAC for APR1400 pumps and valves. The staff found that the planned modifications to APR1400 DCD Tier 1 provided acceptable ITAAC to verify that the safety-related pumps and valves are qualified, installed, and tested consistent with the APR1400 design. For example, the planned ITAAC would require that the applicable safety-related pumps are functionally designed and qualified to perform their safety-related function under the full range of fluid flow, differential pressure, electrical conditions, and temperature conditions with debris-laden coolant fluids up to and including design basis accident conditions. Similarly, the planned ITAAC would require that the applicable safety-related valves are functionally designed and qualified to perform their safety-related functions under the full range of fluid flow, differential pressure, electrical conditions, and temperature conditions up to and including design basis accident conditions. In their acceptance criteria, the planned ITAAC specified the completion of qualification reports in conformance with ASME Standard QME-1-2007 as accepted in RG 1.100, Revision 3 for the applicable safety-related pumps and valves. Further, the planned ITAAC specified preoperational testing of safety-related pumps and valves to verify their availability to perform the applicable safety functions. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 546-8782, Question 14.03.03-8, is resolved and closed.

3.9.6.5 Combined License Information Items

DCD Tier 2, and later revisions, Section 3.9.6, contain the following COL information items.

Table 3.9.6 Combined License Items In the DCD

Item No.	Description	Section
COL 3.9(2)	The COL applicant is to identify the site-specific active pumps.	3.9.3.3.1
COL 3.9(3)	The COL applicant is to provide a full description of the IST program (including PST and MOV testing) for pumps, valves and dynamic restraints that will be administratively controlled such that the applicable requirements of the ASME OM Code edition and addenda are incorporated in the IST program.	3.9.6

Item No.	Description	Section
COL 3.9(4)	The COL applicant is to provide an IST program including the type of testing and frequency of site-specific pumps subject to IST in accordance with the ASME Code and Table 3.9-13.	3.9.6.2
COL 3.9(5)	The COL applicant is to provide an IST program including the type of testing and frequency of any site-specific valves subject to IST in accordance with the ASME OM Code and Table 3.9-13.	3.9.6.3
COL 3.9(6)	The COL applicant is to provide a table listing all safety-related components that use snubbers in their support system.	3.9.6.4

In its review the DCD, the staff found the COL items in DCD Tier 2, Section 3.9.9 and Table 1.8-2, provided acceptable action items (with the need for editorial clarification of one item) for the COL applicant to fully describe the IST program (including PST and MOV testing) for pumps, valves, and dynamic restraints.

The staff issued RAI 69-7994, Question 03.09.06-8 (ML15195A530), requesting the applicant to make editorial corrections to COL 3.9(4) to clarify the action item regarding the COL applicant's responsibility to provide a full description of the IST program. In its response to RAI 69-7994, Question 03.09.06-8 (ML15253A869), the applicant stated that APR1400 DCD Tier 2 Section 3.9.9(4) would be revised to specify that the COL applicant is to provide a full description of the IST program (including PST and MOV testing) for pumps, valves, and dynamic restraints that will be administratively controlled such that the applicable requirements of the ASME OM Code edition and addenda are incorporated in the IST program. The staff found that the proposed DCD revision clarifies the COL 3.9(4) regarding the full description of the IST program consistent with NRC guidance and, therefore, is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 69-7994, Question 03.09.06-8, is resolved and closed.

3.9.6.6 Conclusion

The staff concludes that the information in the APR1400 DCD with respect to the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints used in the APR1400 reactor is acceptable. In particular, the staff reviewed the APR1400 DCD for compliance with the NRC regulations and the applicable edition and addenda of the ASME Code as incorporated by reference in 10 CFR 50.55a for the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints to be used in APR1400 nuclear power plants. The staff's evaluation of the DCD includes the consideration of lessons learned from operating experience with plant components at current nuclear power plants and the results of NRC and industry research programs. Based on its review, the staff concludes that the DCD provisions for the functional design and qualification of pumps, valves, and dynamic restraints to be used in an APR1400 reactor, and the general description of the IST programs for those components, satisfy the NRC regulations and address operating experience and research results in an adequate manner for a DCA. Therefore, the staff concludes that the DCD is acceptable with respect to the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints.

As discussed in this section, the applicant included in ITAAC in DCD Tier 1 to provide assurance that important plant systems and components are capable of performing their design-basis functions. Further, in DCD Tier 2, the applicant included COL items which require the COL applicant to provide a full description of the IST program and the snubber preservice and inservice inspection and testing programs, and milestones for full implementation of those programs. In its review of a COL application for an APR1400 nuclear power plant, the staff will evaluate the full description of the functional design, qualification, and IST programs for pumps, valves, and dynamic restraints provided by the COL applicant. The staff will also confirm the completion of the applicable ITAAC for APR1400 components during plant construction to ensure that design reports for piping systems and ASME components are in order, and to confirm that the applicant meets the NRC regulations and ASME Code requirements.

3.10 Seismic and Dynamic Qualification of Mechanical and Electrical Equipment

3.10.1 Introduction

The section describes the staff's evaluation of the methods of test and analysis employed to ensure the functionality of mechanical and electrical equipment (including instrumentation and controls) under the full range of normal and accident loadings (including seismic).

3.10.2 Summary of Application

DCD Tier 1: DCD Tier 1 information associated with this section is found in DCD Tier 1, Section 2.2.7, "In-core Instrument Guide Tube System," Section 2.4, "Reactor Systems"; Section 2.5, "Instrumentation and Control," Section 2.6 "Electric Power," Section 2.7, "Plant System," and Section 2.11, "Containment System."

DCD Tier 2: DCD Tier 2, Revision 0, Section 3.10, addresses the acceptance criteria, code and standards, procedures, and methods applied to the seismic and dynamic qualification of mechanical and electrical equipment (including instrumentation) to provide reasonable assurance that they will withstand the effects of postulated events and accidents and still be capable of performing their functions under the full range of normal, transient, seismic, and accident loadings. The mechanical and electrical equipment includes equipment associated with systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal; equipment essential in preventing significant release of radioactive material to the environment; and instrumentation needed to assess plant and environmental conditions during and after an accident. This section also covers equipment (1) that performs that above functions automatically, (2) that is used by the operators to perform these functions manually, and (3) whose failure can prevent the satisfactory accomplishment of one or more of the above safety functions.

The qualification of electrical equipment is performed according to Institute of Electrical and Electronics Engineers (IEEE) Std. 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," and the qualification of active mechanical equipment conducted according to American Society of Mechanical Engineers (ASME) QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants." The qualification includes analysis, testing, or a combination of analysis and testing. The methods for analysis and testing are also described. Analyses typically include static coefficient analysis and dynamic analysis. Qualification testing involves

single-axis, biaxial, or triaxial testing to simulate the seismic motion. The methods of analysis and testing of supports of equipment and instrumentation is also discussed. Finally, the DCD describes the documentation of the equipment qualification records.

DCD Tier 2, Revision 0, Section 3.10, references APR1400-E-X-NR-14001, "Equipment Qualification Program," Revision 0, Part 2, "Seismic Qualification Program" for additional details on the equipment qualification program. This technical report establishes the seismic and dynamic qualification procedure and criteria for seismic Category I mechanical equipment, instrumentation and controls, and Class 1E electrical equipment. DCD Tier 2, Section 3.10, references Appendix 3.7B.7.4. for the evaluation of high frequency sensitive equipment due to hard rock high frequency (HRHF) GMRS exceedance of the certified seismic design response spectra (CSDRS). DCD Tier 2, Appendix 3.7B.7.4 references Technical Report APR1400-E-S-NR-14004, "Evaluation of Effects of HRHF Response Spectra on SSCs," Revision 0, for additional details on the qualification of high frequency sensitive equipment.

ITAAC: DCD Tier 1, Section 2 lists system-based ITAAC for the seismic qualification of equipment.

3.10.3 Regulatory Basis

The following regulatory requirements and guidelines provide the basis for the acceptance criteria for the review by the staff:

- GDC 1, and GDC 30 of Appendix A to 10 CFR Part 50, as related to qualifying equipment to appropriate quality standards commensurate with the importance of the safety functions to be performed.
- GDC 2, and Appendix S to 10 CFR Part 50, as related to qualifying equipment to withstand the effects of natural phenomena such as earthquakes.
- GDC 4, as related to qualifying equipment to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.
- GDC 14, as related to qualifying equipment associated with the reactor coolant boundary so as to have an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture.
- Appendix B to 10 CFR Part 50, as related to qualifying equipment using the quality assurance criteria provided.
- RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, issued March 2007.
- RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Revision 3, issued September 2012.
- RG 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants," Revision 4, issued June 2006.

- RG 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants," Revision 3, issued September 2009.

3.10.4 Technical Evaluation

The staff reviewed DCD Tier 2, Revision 0, Section 3.10, and Technical Report APR1400-E-X-NR-14001, Revision 0, Part 2, related to the seismic and dynamic qualification of mechanical and electrical equipment in accordance with the criteria and procedures delineated in SRP Section 3.10, Revision 3. The staff's evaluation is discussed in the following sections.

3.10.4.1 Seismic Qualification Criteria

DCD Tier 2, Revision 0, Section 3.10, describes the seismic qualification criteria for mechanical and electrical equipment and defines the scope of the equipment in the seismic qualification program. DCD Tier 2, Revision 0, Section 3.10, states that the following mechanical and electrical equipment are qualified for an earthquake including SSE: equipment associated with systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, containment and reactor heat removal or are otherwise essential in preventing significant release of radioactive material to the environment, and instrumentation that is needed to assess plant and environmental conditions during and after an accident, as described in RG 1.97. Also covered by this section is equipment (1) that performs the above functions automatically, (2) that is used by the operators to perform these functions manually, and (3) whose failure can prevent the satisfactory accomplishment of one or more of the above safety functions. The staff finds that the description of the equipment that should be designed for an SSE is consistent with the guidance in SRP Section 3.10.

However, in DCD Tier 2, Revision 0, Section 3.10, the applicant refers to this equipment within the scope of seismic qualification as safety-related equipment. Specifically, in DCD Tier 2, Revision 0, Section 3.10.4.1, COL 3.10(3), the applicant refers to the equipment within the scope of seismic qualification as safety-related seismic Category I equipment. The staff recognizes that the equipment within the scope of seismic qualification may contain more than the safety-related equipment within the scope of the definition in 10 CFR 50.2. As an example, the instrumentation that is needed to assess plant and environmental conditions during and after an accident, may not be included in the safety-related equipment as defined in 10 CFR 50.2. The staff issued RAI 81-8000, Question 03.10-4 (ML15197A265), requesting that the applicant update the DCD to refer to the equipment included in the scope of SRP Section 3.10, as "seismic Category I equipment," "equipment as defined in DCD Tier 2, Revision 0, Section 3.10," or other alternative terminologies. The staff also requested that the applicant review DCD Tier 2, Revision 0, Section 3.10, and apply the new terminology consistently. In its response to RAI 81-8000, Question 3.10-4 (ML15239B396), the applicant stated that DCD Tier 2, Section 3.10, and APR1400-E-X-NR-14001, will refer to the equipment that is included in the scope of SRP Section 3.10, as "seismic Category I equipment." The applicant also provided the changes in the marked-up DCD and technical report. In its revised response to RAI 81-8000, Question 3.10-4 (ML16058A000), the applicant provided additional changes in the marked-up DCD Tier 2, Section 3.10, to refer to the equipment that is included in the scope of SRP Section 3.10 as "seismic Category I equipment." The staff finds the applicant's response acceptable because the scope of the equipment dynamic qualification program includes seismic Category I equipment, and not only safety-related equipment. Based on the review of the DCD and

Technical Report APR1400-E-X-NR-14001, Revision 1, the staff has confirmed incorporation of the changes described above; therefore, RAI 81-8000, Question 3.10-4, is resolved and closed.

DCD Tier 2, Revision 0, Section 3.10.1, states that the seismic and dynamic qualification of mechanical and electrical equipment demonstrates the equipment's ability to perform its function during and after an SSE. The equipment is qualified with five one-half SSEs followed by one full SSE. Seismic Category I SSCs are designed for the SSE. The applicant states that since the OBE is defined as one-third of the SSE, an explicit analysis or design of the seismic Category I SSCs based on the OBE is not needed. The applicant specified COL 3.10(1), in DCD Tier 2, Revision 0, Section 3.10.5, for the COL applicant to provide documentation that the designs of seismic Category I SSCs are analyzed for the OBE, if the site-specific OBE is higher than 1/3 SSEs. The staff finds that qualifying equipment with five one-half SSEs followed by one full SSE is consistent with the recommendation in SRP Section 3.10 and the SRM dated July 21, 1993, for SECY-93-087, "Policy, Technical and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," dated April 2, 1993. The staff also finds that not performing explicit response or design analysis based on OBE when OBE is one-third or less of the SSE ground motion design response spectra is consistent with the requirement in 10 CFR Part 50, Appendix S. The specified COL item is acceptable because it provides reasonable assurance that the COL applicant will verify that the equipment is qualified to the appropriate OBE level.

DCD Tier 2, Revision 0, Section 3.10.1, describes the standards used for the seismic and dynamic qualification of mechanical and electrical equipment. The applicant states in DCD Tier 2, Revision 0, Section 3.10.1.1, that the seismic and dynamic qualification program provides reasonable assurance that equipment classified as seismic Category I meets functional performance requirements during and after dynamic loadings due to normal operating, transient, seismic, and accident conditions. Seismic qualification of active mechanical equipment follows the methods and guidance in ASME QME-1-2007, including Appendix QR-A, with exceptions provided in RG 1.100. The staff finds the applicant's approach on seismic qualification of active mechanical equipment acceptable because RG 1.100 endorses ASME QME-1-2007 with exceptions. The exceptions include the use of experience data for seismic qualification of equipment as discussed later in this section of the SER.

The applicant states in DCD Tier 2, Revision 0, Section 3.10.1.1, that the seismic and dynamic testing portion of the electrical equipment qualification program is performed in accordance with the provisions in RG 1.100 and IEEE Std. 344-2004. The development and implementation of the equipment seismic qualification program, and the methods and procedures for seismic qualification of mechanical and electrical equipment are in accordance with the recommended guidance in NRC 1.100 and IEEE Std. 344-2004. The staff notes that RG 1.100, endorses ASME QME-1-2007, for the qualification of active mechanical equipment and IEEE Std. 344-2004, for the seismic qualification of electrical equipment. ASME QME-1-2007 establishes the guidelines for the seismic qualification of active mechanical equipment. ASME QME-1 generally endorses the guidelines in IEEE Std. 344, for qualification of active equipment by testing, except as modified by ASME QME-1. Therefore, the staff finds that following the guidelines in IEEE Std. 344-2004, for equipment qualification is acceptable.

In DCD Tier 2, Revision 0, Section 3.10.1, the applicant states that the seismic and dynamic qualification are performed based on test, analysis, or a combination of test and analysis but does not include experience-based qualification. The staff notes that RG 1.100 endorses

IEEE Std. 344-2004 with exceptions. In RG 1.100, the NRC identified a number of concerns regarding the use of experience data (earthquake or test experience data) for seismic qualification of equipment. The concerns include (1) the credibility and completeness of the compilation of the experience database, (2) the inclusion and exclusion rules for electrical equipment in the experience database, (3) the justification used to demonstrate the similarity among the member items in a reference equipment class, (4) the justification used to demonstrate the similarity between electrical equipment in the experience database and equipment in the nuclear power plant for seismic qualification purposes, and (5) the justification used to demonstrate the functionality of candidate equipment and the member items in a reference equipment class during and after an earthquake. Therefore, not using experience based qualification of equipment is consistent with the RG 1.100, guidance.

However, APR1400-E-X-NR-14001, Revision 0, Part 2, Section 5.2, states that experience data may be used for qualification of the equipment when (1) qualifying equipment that is similar in function and physical characteristics to the equipment that has been previously qualified by testing, analysis, or a combination of testing and analysis, and (2) the equipment type is similar to the equipment that has been in service for various periods of time and has been exposed to in-plant vibration and natural seismic disturbances. SRP Section 3.10, states that if qualification by an experience-based approach is proposed, the staff reviews the details of the experience database, including applicable implementation procedures, to ensure structural integrity and functionality of the in-scope mechanical and electrical equipment. Therefore, in a public meeting on June 23, 2015, the staff requested that the applicant revise the technical report to be consistent with DCD, or provide details of the test experience database, including applicable implementation procedures. In a letter dated July 6, 2015 (ML15187A312), the applicant provided a markup of the Technical Report stating the experience-based approach is not used for equipment seismic qualification. The staff confirmed that the applicant made the changes described above in APR1400-E-X-NR-14001, Revision 1, to be consistent with the DCD. Therefore, this issue is resolved and closed.

The applicant stated in DCD Tier 2, Revision 0, Section 3.10.1, that the provisions for the seismic qualification are specified in the design specifications for equipment procurement. The equipment supplier will select testing, analysis, or a combination of testing or analysis according to the guidance in IEEE Std. 344-2004. The applicant specified COL 3.10(3) for the COL applicant to develop the equipment seismic qualification files that summarize the component qualification, including a list of equipment classified as seismic Category I in DCD Tier 2, Table 3.2.1, and seismic qualification summary data sheets (SQSDS) for each piece of seismic Category I equipment. The applicant also lists COL 3.10(4) for the COL applicant to perform equipment qualification for seismic Category I equipment and provide milestones and completion dates of the equipment seismic qualification program. The staff notes that RG 1.206, Section C.I.3.10, states that if the applicant has not completed the seismic and dynamic qualification testing at the time it files the COL application, the COL applicant should describe the implementation program, including milestones and completion dates. The COL items are consistent with the guidance in RG 1.206; therefore, the staff finds that the COL items are acceptable.

DCD Tier 1, Section 2, lists system-based ITAAC for the seismic qualification of equipment. The staff finds that the applicant has provided a summary of the equipment qualification program in the DCD, fully described the equipment qualification program in the APR1400-E-X-NR-14001, and listed CO 3.10(4), for the COL applicant to implement the

equipment qualification program. The acceptability of the ITAAC is addressed in SER Section 14.3.3.

DCD Tier 2, Revision 0, Section 3.10.1, provides a description of the dynamic loads for equipment qualification and the development of dynamic motion for the qualification. The postulated dynamic loads for qualification of seismic Category I equipment are seismic loads (OBE and SSE), non-seismic loads, and hydrodynamic loads (loads induced by pump trip, safety-relief valve opening, etc.). The applicable loads are combined as part of the qualification of seismic Category I equipment. These postulated dynamic loads are defined by the required response spectra (RRS). Floor response spectra are generated for specific buildings and floors within a building as described in DCD Tier 2, Revision 0, Section 3.7.2.5. When equipment is not directly mounted on floors, the RRS reflects the amplification of the floor response spectra due to the flexibility of equipment supporting structure. Damping values for equipment will be in accordance with the guidance in RG 1.61, and IEEE Std. 344-2004. The staff finds that dynamic qualification of mechanical and electrical equipment including the seismic loads and dynamic loads from normal, anticipated operational occurrence, and accident conditions is consistent with the guidance in SRP Section 3.10. An RRS that considers the amplification of the floor response spectra due to the flexibility of the equipment support is in accordance with the guidance in IEEE Std. 344-2004. The selection of damping values for equipment is acceptable because RG 1.100, states that damping values used in analysis should be in accordance with the damping values in RG 1.61, and the APR1400 damping values for equipment follow the guidance in RG 1.61, and IEEE Std. 344-2004.

In DCD Tier 2, Revision 0, Section 3.10.1, the applicant states that the COL applicant is to investigate if the site-specific spectra generated for the COL application exceed the APR1400 design spectra in the high-frequency range. The applicant specified COL 3.10(2), for the COL applicant to investigate if site-specific spectra generated for the COL application exceed the APR1400 design spectra in the high-frequency range. Accordingly, the COL applicant is to provide reasonable assurance of the functional performance of vibration-sensitive components in the high-frequency range. The staff finds COL 3.10(2), acceptable because it will ensure that the COL applicant verifies any site-specific spectra exceedance over the APR1400 design spectra and, if necessary, will address the exceedance.

The staff issued RAI 319-8360, Question 03.09.03-4 (ML15328A033), requesting the applicant to address how the HRHF GMRS exceedance of the CSDRS discussed in DCD Tier 2, Appendix 3.7B, was considered in the evaluation of component dynamic qualification in other DCD sections including DCD Tier 2, Section 3.10. In its response to RAI 319-8360, Question 03.09.03-4 (ML16060A036), the applicant stated that the seismic qualification test/analysis will be performed for equipment to envelop the ISRS resulting from the entire set of CSDRS, including the group motions for the COL sites with high frequency content. The applicant also added this statement to the marked-up DCD Tier 2 Section 3.10.1.2. The staff finds that the added statement in DCD Tier 2 Section 3.10.1.2, acceptable because the equipment qualification will use the seismic input that envelop CSDRS-based ISRS and the HRHR-based ISRS at the COL sites. The evaluation of RAI 319-8360, Question 03.09.03-4, is further discussed in SER Section 3.9.3.

DCD Tier 2, Appendix 3.7B.7.4, and APR1400-E-S-NR-14004, Revision 0, Section 6, "Evaluation," Subsection 1.18, "Safety-Related Equipment," state that safety-related equipment is evaluated for the effect of high frequency input motion for the safety of the plant. However,

the purpose and details of the evaluation are not clear. Interim Staff Guidance DC/COL-ISG-01, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion," Section 4.0, "Identification and Evaluation of HF Sensitive Mechanical and Electrical Equipment/Components," provides guidance for the identification and evaluation of high frequency sensitive equipment. The guidance includes the need to provide a basis for the criteria used for each screening step that is used to identify equipment with potential for high frequency sensitivity, and describe the process for evaluating the equipment sensitive to high frequency. The staff issued RAI 344-8407, Question 03.10-7 (ML15356A017), requesting the applicant to describe the evaluation process fully and provide the information discussed in DC/COL-ISG-01, and update the DCD and technical report.

In its response to RAI 344-8407, Question 3.10-7 (ML16133A604), the applicant provided additional information in the marked-up DCD Tier, 2, Appendix 3.7B.7.4 and APR1400-E-S-NR-14004, Section 6.4. The applicant stated that the new seismic qualification testing/analysis of seismic Category I equipment will be performed to envelop the ISRS resulting from the entire set of CSDRS, including the ground motions for the COL sites with high frequency content. Seismic Category I equipment that has undergone prior qualification testing/analysis is classified as either high frequency sensitive or high frequency insensitive. The applicant noted that criteria for identifying mechanical and electrical equipment sensitive to high frequency seismic input are described in the marked-up APR1400-E-S-NR-14004, Section 6.4. High frequency sensitive equipment includes equipment that: (1) can inadvertently change state permanently or temporarily or have the output signals affected as a result of vibratory motions, and (2) contain non-ductile components such as ceramic insulators and cast iron that can fail due to high frequency shock-type loads. The list of types of high frequency sensitive equipment is provided in the marked-up DCD Tier 2, Table 3.7B-4, "Potentially HF Sensitive Components." The applicant explained that potentially high frequency sensitive equipment is evaluated for high frequency sensitivity. The HRHF evaluation is in addition to the CSDRS-based seismic qualification program as stipulated for a certified design. The applicant stated that the evaluation of high frequency sensitive equipment uses either: (1) the existing qualification data method or (2) the screening test method. In the existing qualification data method, the existing test result could be confirmed to envelop the RRS generated for both HRHF-based ISRS and CSDRS-based ISRS including proper margins. In the screening test method, tests using RRS enveloping the HRHF-based ISRS are conducted to identify any high frequency sensitivities or abnormalities of equipment. The applicant stated that the upper limit of the high frequency screening evaluation is set to 50 Hz which is the typical limit for HRHF based ISRS; however, if there is any ISRS that shows high frequency content above 50 Hz, this frequency content will also be evaluated. Finally, the applicant added two COL items in DCD Tier 2, Appendix 3.7B.8, for the COL applicant to verify the applicability of evaluation of equipment sensitive to high frequency [COL 3.7B(2)] and to perform the HRHF evaluation of seismic Category I equipment [COL 3.7B(1)].

The staff finds that the evaluation of the high frequency sensitive equipment described by the applicant to be acceptable because the evaluation process and criteria are consistent with the guidance described in DC/COL-ISG-01. The use of the existing test data method and high frequency screening test method are acceptable approaches as described in DC/COL-ISG-01. In addition, for equipment not sensitive to high frequency, if the natural frequency of the equipment is at the region where CSDRS-based ISRS exceedance occurs, applicant will impose the higher seismic load based on the HRHF-based ISRS to the equipment instead of the CSRS-based ISRS. This approach is conservative because the applicant will also evaluate

equipment not sensitive to high frequency. Finally, the COL items provide reasonable assurance that the COL applicant will verify the existence of the seismic input exceedance and perform the HRHF evaluation of equipment. Based on the review of the DCD and APR1400-E-S-NR-14004, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, RAI 344-8407, Question 3.10-7, is resolved and closed.

APR1400-E-S-NR-14004, Revision 0, Table 6-8, "List of Potential Equipment to Evaluate Against High Frequency Seismic Input," lists by category the electrical equipment sensitive to high frequency seismic input. However, DC/COL-ISG-01, states that for the evaluation of high frequency sensitive equipment, the applicant should provide a table containing the list of high frequency sensitive mechanical and electrical equipment that will be qualified by testing or analysis. The staff issued RAI 344-8407, Question 3.10-8 (ML15356A017), requesting the applicant to provide a complete list of mechanical and electrical equipment sensitive to high frequency seismic input in APR1400-E-S-NR-14004. Alternatively, the staff noted that the applicant could modify APR1400-E-X-NR-14001, "Equipment Qualification Program," Table 2, "Equipment Qualification Equipment List," to indicate which equipment is sensitive to high frequency. In its response to RAI 344-8407, Question 3.10-8 (ML16133A604), the applicant referred to its response to RAI 115-8066, Question 03.11-4 (ML16145A534). The applicant provided a mark-up of Table 3, in APR1400-E-X-NR-14001, to indicate equipment that is high frequency sensitive. The staff confirmed that the applicant made the changes in APR1400-E-X-NR-14001, Revision 1, as described above. The staff finds the response acceptable because the applicant has provided a complete list of equipment sensitive to high frequency. Therefore, RAI 344-8407, Question 3.10-8, is resolved and closed.

DCD Tier 2, Revision 0, Appendix 3.7B.7.4, states that representative items were selected for the evaluation because they are susceptible to high frequency seismic inputs. It also states that susceptibility to excitation caused by high frequency input depends on the presence of the following factors:

- a. The local HRHF ISRS exceed the APR1400 CSDRS ISRS in the high frequency range.
- b. Safety-related equipment has modes or natural frequencies in the high frequency range.
- c. Safety-related components have potential failure modes involving a change of state, chatter, signal change/drift, and/or connection problems.

The staff recognizes that equipment with natural frequencies in the high frequency range is expected to experience higher loads and amplification than equipment with natural frequencies outside the high frequency range. However, equipment sensitive to high frequency that have natural frequencies outside the high frequency range may still be affected by the high frequency exceedance. Therefore, the staff issued RAI 344-8407, Question 3.10-9 (ML15356A017), requesting the applicant to provide the basis for not performing an evaluation of equipment with natural frequency outside the high frequency range (i.e., low frequency) for exceedance of CSDRS.

In its response to RAI 344-8407, Question 3.10-9 (ML16133A604), the applicant described the high frequency sensitive equipment evaluation process in the marked-up DCD and APR1400-E-

S-NR-14004. The HRHF evaluation will be performed for high frequency sensitive equipment regardless of whether their natural frequencies are in the high frequency range. The staff finds the response acceptable because the HRHF evaluation will be performed for all high frequency sensitive equipment including equipment that has natural frequencies that are outside of the high frequency range as equipment that has natural frequencies outside the high frequency range may still be affected by the high frequency exceedance. Based on the review of the DCD and APR1400-E-S-NR-14004, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, RAI 344-8407, Question 3.10-9, is resolved and closed.

DCD Tier 2, Revision 0, Section 3.10.1.3, states that with the elimination of OBE, analysis checks for fatigue effects can be performed at a fraction of the SSE peak amplitude (such as 50 cycles at one-half of the SSE peak amplitude, or 150 cycles at one-third of the SSE peak amplitude). In a letter dated June 1, 2015 (ML15152A248), the applicant references SECY-93-087, and IEEE Std. 344, as the basis for this approach. The staff recognizes that SECY-93-087, discusses this approach as one of the alternatives; however in the SRM for SECY-93-087, the NRC does not specifically approve this alternative. The approved alternatives for equipment qualification are: (1) five one-half SSE events followed by one full SSE event, and (2) a number of fractional peak cycles equivalent to the maximum peak cycle for five one-half SSE events may be used in accordance with Appendix D to IEEE Std. 344-1987 when followed by one full SSE. SRP Section 3.10.III.3.C, also states the same guidance for equipment qualification. Therefore, the staff issued RAI 81-8000, Question 03.10-1 (ML15197A265), requesting the applicant to revise the DCD to conform to one of the options in SRP Section 3.10, and the SRM on SECY-93-087, or justify in the DCD any deviation from the SRP guidance on equipment qualification. In its response to RAI 81-8000, Question 3.10-1 (ML15239B396), the applicant stated that the DCD will be revised to be consistent with the approved alternatives in SRM and the reference to the SRM will be added to the DCD. The applicant also provided a markup of the DCD changes. The staff finds that the response acceptable because the applicant revised the DCD to be consistent with the NRC guidance in SRM for SECY-93-087, and SRP Section 3.10. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 81-8000, Question 3.10-1, is resolved and closed.

In DCD Tier 2, Revision 0, Section 3.10.1.3, the applicant described the criteria for the selection of dynamic qualification methods. The dynamic qualification is performed by analysis, testing, or a combination of testing and analysis. In general, electrical equipment for which functional operability must be demonstrated is qualified by tests. Analysis alone is used for qualification of mechanical equipment if structural integrity alone can provide reasonable assurance of the design function. For equipment whose functional operability cannot be demonstrated by analysis or testing because of its size, complexity, or the large number of similar configurations, a combination of test and analysis may be used. The staff finds that the criteria based on structural integrity and functional operability for selecting the equipment qualification methods which include testing, analysis, or a combination of analysis and testing, are consistent with the guidance in IEEE Std. 344-2004.

During August 24-27, 2015, the staff performed a regulatory audit of the component design and procurement specifications. The purpose of the audit was to confirm that the APR1400 component design and procurement specifications are prepared in accordance with the equipment seismic qualification criteria and methodologies in the DCD and are consistent with SRP Section 3.10. This includes verification that the seismic qualification information described in the DCD is adequately translated into documents for mechanical and electrical equipment

that is within the scope of seismic qualification. An audit report (ML15350A057) documents the staff's observations and the applicant's responses. In general, the staff found that design and procurement specifications for seismic Category I equipment meet the provisions in ASME QME-1-2007, and IEEE Std. 344-2004, and are consistent with the criteria and methodologies described in the DCD. In response to the staff's audit observations, the applicant committed to revise the design and procurement specifications. The staff conducted a follow-up audit from July 18, 2016, through August 30, 2016 (ML17095A782). As discussed in the associated audit report, the NRC finds that the changes to the design and procurement specifications for equipment seismic qualification to be used in the APR1400 reactor in response to the follow-up audit are acceptable to support the APR1400 reactor DC. The proposed changes are consistent with the provisions in ASME QME-1-2007.

3.10.4.2 Methods and Procedures for Qualifying Mechanical and Electrical Equipment and Instrumentation

In DCD Tier 2, Revision 0, Section 3.10.2, the applicant described the methods and procedures for qualifying mechanical and electrical equipment. The applicant states that the qualification of equipment and its supports meets the guidance in RG 1.100, and IEEE Std. 344-2004. As discussed earlier, the qualification of equipment consists of analysis, testing, or a combination of analysis and testing. Seismic analysis is based on dynamic analysis or static coefficient analysis.

In DCD Tier 2, Revision 0, Section 3.10.2.1, and APR1400-E-X-NR-14001, Revision 0, Section 5.11.5.1, the applicant described the static coefficient analysis method. If the equipment support is rigid, a static coefficient analysis may be performed to determine the stresses and deflections due to the dynamic loads. The static coefficient analysis, while simpler to perform, is more conservative. A static coefficient of 1.5 has been established from experience to take into account the effects of multi-frequency excitation and multimode response for the linear frame-type structures which can be represented by a simple model. A lower static coefficient may be used when it can be shown to yield conservative results. The stresses resulting from each force of the three orthogonal directions are combined by taking the square root of the sum of the squares (SRSS) to yield the dynamic stresses. The dynamic deflections follow the same calculation method. These dynamic stresses and deflections are added to all stresses and deflections resulting from all applicable loads to obtain the final resultant stresses and deflections. The staff finds that performing the static coefficient analysis for rigid equipment when the equipment has no resonances in the frequency range below the cutoff frequency of the RRS is consistent with the IEEE Std. 344-2004, guidance. Additionally, the static coefficient analysis including the use of a static coefficient of 1.5 to account for the effects of multi-frequency excitation and multimode response, and combining the stresses and deflections by SRSS method is consistent with the guidance in IEEE Std. 344-2004, and therefore, acceptable.

DCD Tier 2, Revision 0, Section 3.10.2.1, and APR1400-E-X-NR-14001, Revision 0, Section 5.11.5.2, describe the dynamic analysis method. When acceptable justification for static coefficient analysis cannot be provided, a dynamic analysis is necessary. A finite element model may be constructed to represent the dynamic behavior of the equipment. The model can be analyzed using the response spectrum modal analysis or time-history analysis. The response spectrum analysis allows the determination of responses by combining each modal response considering all significant modes. The maximum inertia forces at each mass point from each mode are applied at that point to calculate the modal stresses and modal responses.

The various modal contributions are combined by the SRSS method. Closely spaced modes are combined by using an approach from RG 1.92. The dynamic stresses and responses from all applicable loads are added algebraically and then compared to the stress limits. If a system exhibits significant nonlinearity, such behavior should be recognized and accounted for any subsequent analysis so as to accurately predict the system response. If the nonlinearities cannot be adequately modeled, an alternative qualification method should be considered according to the guidance in IEEE Std. 344-2004. The staff finds the dynamic analysis described by the applicant to be conservative, as it considers all significant response modes, applies the maximum inertia forces at each mass point from each mode, and sums the dynamic stresses and all stresses resulting from all applicable loads algebraically. Additionally, accounting nonlinearity in equipment qualification is consistent with the guidance in IEEE Std. 344-2004, and RG 1.92. Therefore, the staff concludes that the dynamic analysis method is acceptable.

DCD Tier 2, Revision 0, Section 3.10.2.2, states that seismic qualification by testing is conducted for equipment that cannot be qualified with analysis alone or equipment having components that potentially cause any malfunctions related to their intended functions. Seismic testing is performed by subjecting equipment to vibratory motion that conservatively simulate movement at the equipment mounting while the operating conditions are simulated, and monitoring the performance of these devices during the test. In APR1400-E-X-NR-14001, Revision 0, Section 5.1, the applicant provides further details on the conditions in which qualification testing is appropriate. These conditions include the capability of the test machine to produce the RRS, ability to simulate the equipment actual mounting, capability to monitor the active equipment functionality during test, and the nonlinearity of the equipment response. The staff finds that imposing the loadings simulating the plant operating condition upon the seismic loading for equipment testing is consistent with the SRP Section 3.10 guidance. Additionally, the equipment and test machine conditions under which selection of qualification by testing is appropriate, are consistent with the guidance in IEEE Std. 344-2004. Therefore, the staff finds the seismic qualification testing method acceptable.

DCD Tier 2, Revision 0, Section 3.10.2.2, states that seismic ground motion occurs simultaneously in all directions in a random fashion. However, for test purposes, single-axis, biaxial, and triaxial tests are used. The section goes on to state that single-axis test should be done in a conservative manner to account for the absence of the input motion in some of the orthogonal directions. Single-axis and biaxial tests should be applied in a number of directions relative to the equipment to account for potential failure modes. The factors to be considered include the dynamic nature of the equipment (flexible or rigid) and the degree of spatial cross-coupling response. Single-axis tests are justified when the input motion can be shown to be essentially unidirectional or when the equipment being tested can be shown to respond independently in each of the three orthogonal axes. Biaxial tests should conservatively simulate the seismic event at the equipment mounting location and account for the motion response among the three axes. Triaxial tests are performed when significant couplings exist simultaneously among the three preferred axes of the equipment. Triaxial tests should be performed with a simulator capable of statistically independent motions in all three orthogonal directions. The staff finds that performing single-axis, biaxial, and triaxial equipment qualification tests to simulate the seismic ground motion, and the methods for selecting and conducting these tests are consistent with the IEEE Std. 344-2004 guidance. Therefore, the staff concludes that this approach is acceptable.

DCD Tier 2, Revision 0, Section 3.10.2.2, provides a description of the development and input of vibratory motion for the equipment test shake table. The description indicates that test response spectra (TRS) for the shake table should envelop the RRS over the frequency range of interests. The TRS should be computed with a damping value equal to or greater than that of the RRS. The shake table peak acceleration should equal or exceed the ZPA of the RRS. The total test duration and number of equivalent maximum peak cycles should be calculated per IEEE Std. 344-2004. DCD Tier 2, Revision 0, Section 3.10.2.2 states that TRS may not envelop RRS at low-frequency end due to limitation of vibration test equipment; however, justification should be made when the TRS does not envelop the RRS. The staff finds that the enveloping of RRS, use of damping value, and the selection of test duration and number of cycles are consistent with the guidance in SRP Section 3.10 and IEEE Std. 344-2004. The staff also finds that IEEE Std. 344-2004 allows exception for TRS to envelop RRS at low frequency and with justification; therefore, this provision is acceptable.

DCD Tier 2, Revision 0, Section 3.10.2.2, states that vibration aging testing may be performed preceding the OBE and SSE tests to show that the lower levels of normal and transient vibration associated with the plant operation will not adversely affect the ability of the equipment to perform its function. The staff finds that conducting the tests to simulate the fatigue effects of the vibration resulting from normal and transient plant operating conditions prior to the seismic test is consistent with the guidance in IEEE Std. 344-2004, and therefore is acceptable.

APR1400-E-X-NR-14001, Revision 0, Section 5.3, describes the qualification method by using a combination of analysis and tests. The technical report states that combination of analysis and testing methods may include (1) supporting tests and analytical calculations, (2) supporting tests supplementing qualification tests, and (3) supporting analysis and qualification tests. In Method 1, to supplement analysis, supporting tests may be used to determine deflection limits, dynamic parameters needed for constructing or verifying mathematical models, damping values, assumptions to be used in the analysis, and the amount of nonlinearity. The supporting tests may be static or dynamic. After collecting the data from the supporting tests, analysis may be used to show that the structural integrity and/or operability of equipment is maintained without performing a complete test program. In Method 2, to supplement qualification tests, supporting tests may be used to obtain information related to natural frequencies, the amount of spatial cross-coupling, and the effect of decoupling of loads on the test results. In Method 3, analysis may be used to supplement qualification tests for assemblies such as control boards, switchgear, vertical pumps and motors, and diesel-generator units. An analysis approach may be used to determine the overall equipment integrity and response at the subassembly or component location. Subsequently, the subassemblies may be tested to the response levels that are obtained analytically.

The staff finds that IEEE Std. 344-2004 permits an analytical approach using supplemental test data. The test results of dynamic responses such as resonant frequencies, mode shapes, and amplitude can be used to verify the analysis predictions. IEEE Std. 344-2004 refers to supporting tests as exploratory tests. The exploratory tests are not part of the seismic qualification, but may be run on equipment to determine the dynamic characteristics of the equipment. The exploratory tests with input level normally lower than the seismic qualification vibration level can be used for determining resonances, spatial cross-coupling, and the optimal test method for qualification. Finally, IEEE Std. 344-2004 provides an option to use analysis to establish input response at subcomponent locations. The qualification of the subcomponent is demonstrated by full-level testing of that component to a level equal to or greater than the

established response at that location. Therefore, the staff concludes the described qualification method using a combination of analysis and tests including (1) supporting tests and analytical calculations, (2) supporting tests supplementing qualification tests, and (3) supporting analysis and qualification tests acceptable as consistent with IEEE Std. 344-2004.

SRP Section 3.10.II.1.A.ii, states that equipment should be tested in the operational condition. APR1400-E-X-NR-14001, Revision 0, Part 2, Section 5.7, states that active equipment should be tested under operating conditions in accordance with the provisions in RG 1.100, and IEEE Std. 344. The section goes on to state that equivalent operating loads should be simulated to act on passive equipment, but the equipment itself need not be under an operating condition. The staff issued RAI 81-8000, Question 03.10-3 (ML15197A265), requesting that the applicant provide the justification for not testing the passive equipment under operating conditions. In its response to RAI 81-8000, Question 03.10-3 (ML15239B396), the applicant clarified that if testing is conducted for passive equipment, equivalent loads (such as non-seismic operating loads) are imposed as the test input as well as the seismic loads. For passive equipment that must maintain its pressure boundary and/or structural integrity, but not necessarily perform mechanical motion or have certain deflection limits, during the course of accomplishing a system function, the passive equipment does not need to be in an operating condition. The applicant further stated that simple and passive equipment may be analyzed to confirm their structural integrity under postulated loadings. The staff finds the response acceptable because IEEE Std. 344-2004, allows analysis without testing only if structural integrity alone can ensure the design intended function. This provision supports the qualification option that the passive equipment does not need to be in an operating condition for testing, if structural integrity alone can ensure the design intended function. Therefore, RAI 81-8000, Question 3.10-3, is resolved and closed.

DCD Tier 2, Revision 0, Section 3.10.2.3.1, describes the qualification method for active mechanical equipment. Seismic Category I active mechanical equipment is designed to withstand seismic and other dynamic loads, including the service load conditions in the equipment design specifications in accordance with the provisions in ASME BPV Code, Section III described in DCD Tier 2, Revision 0, Section 3.9.3. For pumps, a static deflection analysis and/or test for the shaft and rotor should be performed under design basis loading, including the maximum allowable nozzle loads specified in the equipment design specification. The analysis and/or test results should demonstrate that the deflection is less than the allowable deflection specified by the equipment supplier. The staff finds that designing seismic Category I pumps to provisions for ASME BPV Code Section III, Class 1, 2, and 3, components is conservative. The review of load combinations and stress allowable for ASME BPV Code Section III, Class 1, 2, and 3, components is documented in SER Section 3.9.3. Including the nozzle loads as normal plant operating conditions for pump qualification is appropriate and consistent with the guidance in SRP Section 3.10. Also, according to the guidance in ASME QME-1-2007, nonmandatory Appendix QR-A, designing to parameters such as deflection and gap clearance can demonstrate the functionality of pumps. Therefore, the staff finds that the pump seismic qualification method is acceptable.

In DCD Tier 2, Revision 0, Section 3.10.2.3.1, and APR1400-E-X-NR-14001, Revision 0, Part 2, Section 5.13.2, the applicant described the method for qualification of valves. For manual valves, the equipment supplier should provide an analysis and/or test to demonstrate the valve moving parts are not permanently damaged due to design basis events along with the maximum operating and nozzle loads. For check valves, an analysis and/or test will demonstrate that the

integrity of the valve and its parts. The supplier should demonstrate that the impact of the valve disc does not damage its seat or other parts of the valve during and after an SSE. Other active valves are qualified according to the guidance in ASME QME-1-2007. The staff finds that including the plant operating loads and nozzle loads in the valve seismic qualification is consistent with the SRP Section 3.10 guidance, and the analysis and/or test provides reasonable assurance that the manual valves and check valves will maintain their function during and after an SSE. The staff also finds that using the qualification test methods according to IEEE Std. 344-2004, or ASME QME-1-2007, is acceptable in verifying the functional capability of other active valves under design-basis events.

The applicant described the seismic qualification approach of mechanical drive turbines, fans, and diesel engines in DCD Tier 2, Revision 0, Section 3.10.2.3.1. The analysis and/or test will determine the shaft and bearing deflections when the turbine and fans are subjected to the external design basis loads. The resulting clearance between the shaft and bearing will be smaller than the recommended clearance by the vendor. The operability of the diesel engine and its auxiliary active components will follow the methods in IEEE Std. 387-1995, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations." The staff finds that using analysis and/or test to demonstrate meeting the deflection, fit, and clearance limits will provide reasonable assurance that the drive turbines and fans will remain functional during and after an SSE. In RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," the NRC endorses IEEE Std. 387-1995, with supplements. IEEE Std. 387-1995, references IEEE Std. 344-2004, in its entirety for seismic qualification of diesel generators. Therefore, the staff finds that qualifying diesel generators to IEEE Std. 387-1995, and IEEE Std. 344-2004, is consistent with RG 1.9, and therefore acceptable.

3.10.4.3 Methods and Procedures of Analysis or Testing of Supports of Mechanical and Electrical Equipment and Instrumentation

In DCD Tier 2, Revision 0, Section 3.10.3, the applicant describes the methods and procedures of analysis and testing of supports of mechanical and electrical equipment including instrumentation. For supports of ASME BPV Code Section III mechanical equipment, the analysis includes loads, loading combinations, and combined stress limits described in DCD Tier 2, Revision 0, Section 3.9.3, for ASME BPV Code, Section III, Class 1, 2, and 3, component supports. The jurisdictional boundary between a support and the load-carrying building structure is established in accordance with the provisions in ASME BPV Code Section III, Subsection NF. The staff finds that designing the supports for ASME BPV Code Section III, mechanical equipment to criteria for ASME Section III, Class 1, 2, and 3, component supports is conservative, and therefore, acceptable. The staff also finds that the definition of the jurisdictional boundary between mechanical equipment support and building structures acceptable because the criteria are based on the NRC-approved ASME BPV Code Section III, Subsection NF.

DCD Tier 2, Revision 0, Table 3.2-1, references American National Standards Institute/American Institute of Steel Construction (ANSI/AISC) N690-1994, including Supplement 2 (2004), "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities." However, DCD Tier 2, Revision 0, Section 3.10.6, and APR1400-E-X-NR-14001, Revision 0, Part 2, reference the stress limits in ANSI/AISC N690-1994, without stating Supplement 2 (2004), for the seismic design of

non-ASME BPV Code Section III, equipment supports. The staff finds that SRP Section 3.8.3, endorses ANSI/AISC N690-94 including Supplement 2 (2004), for the design of containment internal structures including structural steel and various supports and anchors. The staff issued RAI 81-8000, Question 03.10-2 (ML15197A265), requesting the applicant to revise the DCD and technical report to reference ANSI/AISC N690-94, including Supplement 2 (2004), for consistency or justify using the earlier version of the ANSI/AISC standard in DCD Tier 2, Revision 0, Section 3.10. In its response to RAI 81-8000, Question 3.10-2 (ML15239B396), the applicant stated that DCD Tier 2, Section 3.10.6, and APR1400-E-X-NR-14001, would be revised to incorporate ANSI/AISC N690-1994, including Supplement 2 (2004). The applicant also provided a markup of the DCD and technical report. The staff finds the response acceptable because the applicant will use the standard endorsed in SRP Section 3.8.3. Based on the review of the DCD and APR1400-E-X-NR-14001, Revision 1, the staff has confirmed incorporation of the changes described above; therefore, RAI 81-8000, Question 03.10-2, is resolved and closed.

APR1400-E-X-NR-14001, Revision 0, Part 2, Table 3, references ACI 349-01, Appendix B, for the design of equipment anchoring to building structure. The staff notes that per ASME BPV Code Subsection NF, the anchoring to building structure is designed as part of the building structure and the detailed review of anchoring to building structure is performed as part of the building structure in SER Sections 3.8.3 and 3.8.4. RG 1.199, endorses ACI 349-01, Appendix B, with conditions. The applicant indicated in DCD Tier 2, Table 1.9-1, it conforms to this RG. In a letter dated July 6, 2015 (ML15187A312), the applicant provided a markup of APR1400 E X NR 14001, Revision 0, Part 2, including the addition of a reference to RG 1.199, and indicating that the equipment anchoring design will follow the conditions set forth in RG 1.199. Based on the review of the DCD and APR1400-E-X-NR-14001, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, this issue is resolved and closed.

3.10.4.4 Documentation of Test and Analysis Results

In DCD Tier 2, Revision 0, Section 3.10.4, the applicant describes the documentation of analysis and test results for the qualification of mechanical and electrical equipment. The complete and auditable records are maintained for the life of the plant. These records are updated and kept current as equipment is replaced, further tested, or otherwise further qualified. The equipment qualification file should contain the list of equipment classified as seismic Category I in DCD Tier 2, Revision 0, Table 3.2-1, and SQSDS for each piece of equipment defined in DCD Tier 2, Revision 0, Section 3.10. The applicant identifies this action as COL 3.10(3). This seismic qualification file describes the qualification methods used for all equipment including information such as identification of equipment, physical and functional description, identification of design specifications and qualification reports, description of required loads, identification of test and/or analysis methods and summary of results, natural frequencies of equipment, identification of any vibration fatigue cycles effect, and a compilation of the RRS and the corresponding damping. The staff finds the description of the equipment qualification records to meet the SRP Section 3.10 guidance, and is therefore acceptable. As discussed earlier in SER Section 3.10.4, the staff finds COL 3.10(3) acceptable.

APR1400-E-X-NR-14001, Revision 0, Part 2, Section 6.1, discusses the format of the dynamic qualification reports. It states that the dynamic qualification reports should include information suggested in IEEE Std. 344-2004, Section 10.3. However, the reference to IEEE Std.

344-2004, Section 10.3, discusses test experience data, and therefore appears to be an error. The staff issued RAI 81-8000, Question 03.10-5 (ML15197A265), requesting the applicant to verify the IEEE Std. 344-2004, section number. In its response to RAI 81-8000, Question 3.10-5 (ML15239B396), the applicant stated that the technical report should refer to IEEE Std. 344-2004, Section 11.3, instead of Section 10.3, and provided a markup of the technical report. The staff finds the response acceptable because the technical report will be revised to reference the appropriate section in IEEE Std. 344-2004. Based on the review of APR1400-E-X-NR-14001, Revision 2, the staff has confirmed incorporation of the changes described above; therefore, RAI 81-8000, Question 3.10-5, is resolved and closed.

3.10.5 Combined License Information Items

DCD Tier 2, Revision 0, Section 3.10.5, contains the following four COL information items pertaining to equipment seismic qualification. The acceptability of the COL items is evaluated above in SER Section 3.10.4. The staff concluded that no additional COL information items were needed.

Table 3.10.5 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.10(1)	The COL applicant is to provide documentation that the designs of seismic Category I SSCs are analyzed for OBE, if OBE is higher than 1/3 SSEs.	3.10.1
COL 3.10(2)	The COL applicant is to investigate if site-specific spectra generated for COLA exceed the APR1400 design spectra in the high-frequency range. Accordingly, the COL applicant is to provide reasonable assurance of the functional performance of vibration-sensitive components in the high-frequency range.	3.10.1.2
COL 3.10(3)	The COL applicant is to develop the equipment seismic qualification files that summarize the component's qualification, including a list of equipment classified as seismic Category I in the Table 3.2-1 and SQSDS for each piece of safety-related seismic Category I equipment.	3.10.4
COL 3.10(4)	The COL applicant is to perform equipment seismic qualification for seismic Category I equipment and provide milestones and completion dates for the equipment seismic qualification program.	3.10.4.1

3.10.6 Conclusion

The staff concludes that the applicant's equipment qualification program is acceptable and meets the relevant requirements of 10 CFR Part 50, Appendix B; 10 CFR Part 50, Appendix S; and GDC 1, 2, 4, 14, and 30. The qualification program that will be implemented for mechanical and electrical equipment, including instrumentation and control components, meets the provisions of ASME QME-1-2007, and IEEE Std. 344-2004, and is consistent with the regulatory

positions of RGs 1.61, 1.92, 1.97, and 1.100. Therefore, the staff finds that the qualification program provides adequate assurance that such equipment will function properly under all imposed design and service loads including the loadings imposed by the SSE, postulated accidents, and LOCAs. This program constitutes an acceptable basis for satisfying the applicable requirements of GDC 2, 4, 14, and 30; 10 CFR Part 50, Appendix B, Criterion XI; and 10 CFR Part 50, Appendix S, as these relate to qualification of equipment. The applicant's equipment qualification file also constitutes an acceptable basis for satisfying the requirements of GDC 1 and 10 CFR Part 50, Appendix B, Criterion XVII.

3.11 Environmental Qualification of Mechanical and Electrical Equipment

3.11.1 Introduction

The mechanical, electrical, and Instrumentation and Control (I&C), including digital I&C equipment designated as important to safety, is addressed in the environmental qualification (EQ) program to verify it is capable of performing its design functions under all normal environmental conditions, AOOs, and accident and post-accident environmental conditions. EQ is the design verification process by which important to safety equipment is demonstrated to remain capable of performing its design functions during and after exposure to a design basis accident in a harsh environment.

The objective of the staff's review is to confirm that the set of equipment to be environmentally qualified includes safety-related equipment, nonsafety-related equipment whose failure under postulated environmental conditions could prevent satisfactory accomplishment of specified safety functions, and instrumentation to monitor parameters specified in RG 1.97.

The objective of the staff's review is also to confirm that the information in the application concerning equipment qualification is sufficient to provide reasonable assurance that the design will conform to the design bases including the requirements in 10 CFR Part 50, Appendix A, GDC 4, with an adequate margin for safety.

3.11.2 Summary of Application

DCD Tier 1: DCD Tier 1 requirements for environmental qualification of mechanical, electrical, and I&C equipment are contained in DCD Tier 1, Chapter 2, "System Based Design Descriptions and ITAAC Table of Contents." The DCD Tier 1 requirements are those pertaining to the qualification for the environmental variables specified in 10 CFR 50.49(e)(1)-(7) (temperature and pressure; humidity; chemical effects; radiation; aging; submergence; synergistic effects), and those pertaining to qualification for electromagnetic compatibility (EMC). DCD Tier 1 contains requirements for environmental qualification of electrical, mechanical, and I&C equipment and for the process variables specified in 10 CFR 50.49(e)(8) ("margins"). DCD Tier 1 also contains requirements for qualification to determine EMC.

DCD Tier 2: The applicant provided a description of EQ in DCD Tier 2, Section 3.11, summarized here, in part, as follows:

The applicant stated that their qualification program meets the requirements of 10 CFR Part 50, Appendix A, GDC 1, GDC 2, GDC 4; and GDC 23; and 10 CFR Part 50, Appendix B, Criteria III,

“Design Control”; Criteria XI, “Test Control”; and Criteria XVII, “Quality Assurance Records.” The applicant defines the scope of equipment for which qualification is required to include equipment essential for emergency reactor shutdown, core cooling, containment isolation, containment and reactor heat removal, and any equipment necessary to prevent a significant radioactive release to the environment. DCD Tier 2, Section 3.11.2.3, “Environmental Qualification Method,” provides the methodology for qualifying electrical and mechanical equipment important to safety. DCD Tier 2, Table 3.11-2, “Equipment Qualification Equipment List,” provides the equipment required to be qualified equipment important to safety.

Environmental Qualification of Electrical Equipment

DCD Tier 2, Section 3.11.1.2, “Definition of Environmental Conditions,” defines service condition environments (harsh and mild) and identifies the equipment that is within the scope of 10 CFR 50.49, “Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants.” Included in DCD Tier 2, Section 3.11, is a description of the approach used by the applicant to environmentally qualify electrical, mechanical, and I&C (including analog and digital) equipment. Harsh environment is an environment resulting from a design basis event (i.e., loss-of-coolant accident, high-energy line break, and main-steam line break). Mild environment is an environment that would at no time be significantly more severe than the environment that would occur during plant operation, including AOOs.

Environmental Qualification of Electrical and I&C Equipment

DCD Tier 2, Section 3.11.3.1, “Electrical and I&C Equipment,” provides a description of electrical and I&C equipment located in a harsh environment that is required to be qualified. The applicant identified areas of the plant that could be subjected to a harsh environment following an accident. Further, the information in DCD Tier 2 includes a tabulation of plant equipment by equipment tag number, the area in which the equipment is located, and whether the area in which the equipment is located could be subjected to a harsh environment. DCD Tier 2, Table 3.11-2, “Equipment Qualification Equipment List,” includes a detailed listing by equipment tag number of electrical and I&C equipment located in an environmentally harsh or radiation harsh environment that requires qualification.

The applicant discussed qualification of equipment located in mild environments in DCD Tier 2, Section 3.11.2.1, “Environmental Qualification during Normal Operation.” Electrical components, those used in digital I&C systems and located in a mild environment were included in the EQ program for EMC, where it involves testing to assure that electromagnetic interference (EMI) and radio frequency interference (RFI) would not adversely affect those I&C equipment.

ITAAC: There are no ITAAC for this area of review.

Technical Specifications: There are no Technical Specifications for this area of review.

Technical Reports: The applicant also provided APR1400-E-X-NR-14001, “Equipment Qualification Program,” Revision 0, to describe the APR1400 environmental qualification program for qualifying electrical, mechanical, and I&C equipment in DCD Tier 2, Section 3.11.

3.11.2.1 *Environmental Qualification of Mechanical Equipment*

DCD Tier 2, Section 3.11, describes the APR1400 process for the EQ of mechanical equipment—specifically, the nonmetallic parts of mechanical equipment (e.g., seals, gaskets, lubricants, fluids for hydraulic systems, and diaphragms). Nonmetallic materials are designed to meet the applicable environmental and service conditions and are qualified in accordance with Appendix QR-B, “Guide for Qualification of Nonmetallic Parts,” of ASME QME-1-2007, “Qualification of Active Mechanical Equipment Use in Nuclear Facilities.” Implementation of the APR1400 EQ plan for nonmetallic parts of mechanical equipment is described in Part 1, “Environmental Qualification Program,” of Technical Report APR1400-E-X-NR-14001, Revision 1, “Equipment Qualification Program,” dated February 2017. DCD Tier 2, Section 3.11 does not address the functional or seismic qualification of mechanical equipment that may be considered part of “equipment qualification”; these topics are addressed in DCD Tier 2, Section 3.9.6 and Section 3.10, respectively.

3.11.3 **Regulatory Basis**

3.11.3.1 *Environmental Qualification of Mechanical and Electrical Equipment*

The relevant requirements for this area of review, and the associated acceptance criteria, are given in the SRP Section 3.11, and are summarized below. Review interfaces with other SRP sections also can be found in SRP Section 3.11.

- Section 52.47(a)(13) of 10 CFR, requires an application for a standard DC to include “[t]he list of electric equipment important to safety that is required by 10 CFR 50.49(d).” The NRC understands that the standard design certification applicant may not be able to establish qualification files for all applicable components.
- Section 52.79(a)(10) of 10 CFR, requires an application for a combined license to include “[a] description of the program, and its implementation, required by § 50.49(a) of this chapter for the environmental qualification of electric equipment important to safety and the list of electric equipment important to safety that is required by 10 CFR 50.49(d).”
- Section 50.49 of 10 CFR, for electric equipment important to safety for nuclear power plants, as it relates to the applicant establishing a program for qualifying electrical equipment important to safety located in a harsh environment.
- Part 50, Appendix A of 10 CFR, “Quality Standards and Records,” as it relates to components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.
- GDC 1, as it relates to components important to safety be designed, fabricated, erected, and tested to quality standards, commensurate with the importance of the safety function to be performed.
- GDC 2, as it relates to components important to safety 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 function.

- GDC 4, as it relates to components important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss of coolant accidents (LOCAs).
- GDC 23, "Protection System Failure Modes," as it relates to protection systems be designed to fail in a safe state, or in a state demonstrated to be acceptable on some other defined basis, if conditions such as postulated adverse environments (e.g., extreme heat or cold, pressure, steam, water, or radiation) are experienced.
- Part 50 of 10 CFR, Appendix B, Criterion III, "Design Control," as it relates to measures be established to ensure that applicable regulatory requirements and the associated design bases are correctly translated into specifications, drawings, procedures and instructions.
- Part 50 of 10 CFR, Appendix B, Criterion XI, as it relates to a test control plan be established to ensure that all tests needed to demonstrate a component's capability to perform satisfactorily in service be identified and performed in accordance with written procedures that incorporate the requirements and acceptance limits contained in applicable design documents.
- Part 50 of 10 CFR, Appendix B, Criterion XVII, "Quality Assurance Records," as it relates to sufficient records be maintained to furnish evidence of activities affecting quality.
- Section 52.47(b)(1) of 10 CFR, which requires that a 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 facility that incorporates the DC is built and will operate in conformity with the DC, the provisions of the Atomic Energy Act, and the NRC rules and regulations.
- Section 52.47 of 10 CFR states, in part, that the "Commission will require, before DC, that information normally contained in certain procurement specifications and construction and installation specifications be completed and available for audit if the information is necessary for the Commission to make its safety determination."

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

- RG 1.89, "Environmental Qualification of Certain Electrical Equipment Important to Safety for Nuclear Power Plants," endorses IEEE Std. 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations" and provides the principal guidance for implementing the requirements and criteria of 10 CFR 50.49.
- RG 1.40, "Qualification Tests of Continuous-Duty Motors Installed inside the Containment of Water Cooled Nuclear Power Plants," endorses IEEE Std. 334-2006, "IEEE Standard for Qualifying Continuous Duty Class 1 Motors for Nuclear Power Generating Stations."

- RG 1.63, “Electrical Penetration Assemblies in Containment Structures for Nuclear Power Plants,” endorses IEEE Std. 317-1983, “IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.”
- RG 1.73, “Qualification Tests of Electric Valve Operators Installed inside the Containment of Nuclear Power Plants,” endorses IEEE Std. 382-2006, “Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations.”
- RG 1.97, provides guidance acceptable to the staff for the environmental qualification of the post-accident I&C monitoring equipment.
- RG 1.211, “Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants” endorses IEEE Std. 383-2003, “Standard for Type Test of Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations.”
- RG 1.152, “Criteria for Digital Computers in Safety Systems of Nuclear Power Plants.”
- RG 1.156, “Environmental Qualification of Connection Assemblies for Nuclear Power Plants,” endorses IEEE Std. 572-2006, “IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations.”
- RG 1.158, “Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants,” endorses IEEE Std. 535-1986, “IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations.”
- RG 1.180, “Guidelines for Evaluating Electromagnetic and Radio- Frequency Interference in Safety-Related Instrumentation and Control Systems,” provides guidance acceptable to the staff for determining EMC for I&C equipment during service.
- RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” provides guidance acceptable to the staff for determining the radiation dose and dose rate for equipment during postulated accident conditions.
- RG 1.209, “Guidelines for Environmental Qualification of Safety-related Computer Based Instrumentation and Control Systems in Nuclear Power Plants,” provides guidance acceptable to the staff for determining the environmental qualification procedures for safety related computer-based I&C systems for service within nuclear power plants.
- NUREG-0588, “Interim Staff Position on Environmental Qualification of Safety Related Electrical Equipment,” Category I guidance may be used if relevant guidance is not provided in RG 1.89.

In evaluating the APR1400 DCA for compliance with the above regulatory criteria, the staff followed guidance provided in SRP Section 3.11, Revision 3, “Environmental Qualification of Mechanical and Electrical Equipment.” SRP Section 3.11, provides the following acceptance criteria for the EQ of nonmetallic parts of mechanical equipment. For nonmetallic materials that are sensitive to environmental effects (e.g., seals, gaskets, lubricants, fluids for hydraulic systems, and diaphragms), the EQ program should contain provisions for the following:

1. Identify safety-related mechanical equipment located in harsh environment areas, including required operating time.
2. Identify non-metallic subcomponents of such equipment.
3. Identify the environmental conditions and process parameters for which the equipment must be qualified.
4. Identify non-metallic material capabilities.
5. Evaluate environmental effects.

The SRM dated September 11, 2002, for Commission paper SECY-02-0067, stated that ITAAC for an operational program are unnecessary if the program and its implementation are fully described in a COL application and found to be acceptable by the NRC. In its SRM dated May 14, 2004, for SECY-04-0032, "Programmatic Information Needed for Approval of a Combined License without Inspections, Tests, Analyses and Acceptance Criteria," dated February 26, 2004, the Commission defined "fully described" as when the program is clearly and sufficiently described in terms of the scope and level of detail to allow a reasonable assurance finding of acceptability. The Commission also noted that operational programs should always be described at a functional level and at an increasing level of detail where implementation choices could materially and negatively affect the program effectiveness and acceptability. Commission paper SECY-05-0197, "Review of Operational Programs in a Combined License Application and Generic Emergency Planning Inspections, Tests, Analyses, and Acceptance Criteria," dated October 28, 2005, summarizes the NRC position regarding the full description of operational programs to be provided by COL applicants. The staff would review and approve the proposed implementation milestones for each operational program in the course of reviewing the COL application and will make a reasonable assurance finding on each program and its proposed implementation, including the adequacy of the implementation milestones. These findings will be documented in the staff's SER for the COL application. SECY-05-0197, identified the EQ program as an operational program.

RG 1.206, provides guidance in Section C.IV.4 for COL applicants with respect to fully describing plant operational programs. The staff implements the staff's positions in SECY-05-0197, and RG 1.206, in addition to SRP Section 3.11, in reviewing the descriptions of the EQ program for mechanical and electrical equipment in DC and COL applications.

3.11.4 Technical Evaluation

3.11.4.1 Environmental Qualification of Electrical and I&C Equipment

The staff reviewed DCD Tier 2, Section 3.11, which describes the applicant's approach for satisfying 10 CFR 50.49 requirements pertaining to the EQ of equipment located in a harsh environment and identifies equipment that is within the scope of 10 CFR 50.49. The review evaluates whether the applicant's information presented in the DCD Tier 2, Section 3.11, is sufficient to support the conclusion that all items of equipment that are important to safety are capable of performing their design safety functions under: (1) normal environmental conditions (e.g., startup, operation, refueling, shutdown); (2) AOOs (e.g., plant trip and testing); (3) design-basis accidents (e.g., LOCA and high-energy line break) and post-accident environmental conditions.

The specific equipment within the scope of EQ requirements is mechanical, electrical, and I&C, including digital I&C equipment associated with systems that are (1) essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or (2) otherwise are essential in preventing significant release of radioactive material to the environment. The EQ equipment includes:

- Equipment that initiates the above functions automatically
- Equipment that is used by the operators to initiate the above functions manually
- Equipment whose failure can prevent the satisfactory accomplishment of one or more of the above safety functions
- Safety-related and nonsafety-related electrical equipment
- Certain post-accident monitoring equipment

3.11.4.2 *“Equipment Qualification Program” and Compliance with 10 CFR 50.49*

The methodology used to develop the EQ program is described in APR1400-E-X-NR-14001, “Equipment Qualification Program,” Revision 0.

The applicant identified all equipment in the scope of the EQ review, in DCD Tier 2, Table 3.11-2, to establish the EQ list for electrical and I&C equipment, according to provisions in 10 CFR 50.49(j). The equipment included in this table is based on the guidelines provided according to provisions 10 CFR 50.49(b)(1), (b)(2), and (b)(3) regarding:

- Section 50.49(b)(1) of 10 CFR – safety-related electrical equipment that is relied on to remain functional during and after design-basis events to ensure that certain functions are accomplished.
- Section 50.49(b)(2) of 10 CFR – nonsafety-related electrical equipment whose failure under the postulated environmental conditions could prevent satisfactory performance of the safety functions of the safety-related equipment.
- Section 50.49(b)(3) of 10 CFR – certain post-accident monitoring equipment and RG 1.97.

The applicant explained in APR1400-E-X-NR-14001, Section 3.1 that equipment important to safety is classified in four categories: (1) safety-related electric equipment which is required to function under the postulated accident conditions, (2) nonsafety-related electric equipment whose failure under postulated environmental conditions could prevent satisfactory accomplishment of safety functions by safety-related equipment, (3) certain post-accident monitoring equipment, and (4) safety-related active mechanical equipment.

The equipment important to safety subject to environmental qualification is divided in two plant areas, as described in DCD Tier 2, Section 3.11.1.1, “Equipment Location.” These plant areas are: (1) harsh environment and (2) mild environment. DCD Tier 2, Section 3.11.1.1 defines harsh environments as plant areas where the environmental conditions significantly exceed the normal design (service) conditions as a direct result of a DBE. A harsh environment is a

location where a significant increase in pressure, temperature, relative humidity, or chemical environment occurs as a result of a design basis accident, or where a total integrated dose (TID) of greater than 100 Gray (Gy), or 10 Gy for electronic components is predicted. Mild environment is defined in APR1400-E-X-NR-14001, Revision 0, as an environment expected as a result of normal service conditions and extremes (abnormal) in service conditions where seismic is the only DBA of consequence.

DCD Tier 2, Table 3.11-2, provides a detailed location of the equipment subject to EQ, including building, room, and whether the location is classified as harsh or mild environment. Equipment located in areas identified as harsh environments, which is within the scope of 10 CFR 50.49(e), requires consideration for the environmental stressors such as temperature, radiation, pressure, humidity, moisture, steam, water immersion, and chemicals.

The environmental conditions considered for the EQ program as required in 10 CFR 50.49(b)(1)(ii), are described in DCD Tier 2, Section 3.11.1.2, "Definition of Environmental Conditions," and include normal, AOOs, and accident and post-accident environments due to design basis events (DBEs). The applicable environmental parameters required in 10 CFR 50.49(e) are provided in DCD Tier 2, Section 3.11.2.3, "Environmental Qualification Method," which includes pressure, radiation, temperature, chemical spray, humidity, submergence, and electromagnetic and radio-frequency interference in specific plant building and room locations. All equipment important to safety that will be qualified undergoes aging analysis that focuses on the identification of aging mechanisms that significantly increase the equipment's susceptibility to DBA conditions. The applicant stated that it considered synergistic effects in the aging program. In addition, the applicant noted that it considered power supply voltage and frequency variation in equipment design as required in 10 CFR 50.49(d)(2). Service conditions are the actual environmental, physical, mechanical, electrical, and process conditions experienced by equipment during service. Plant operation includes both normal and abnormal operations. Abnormal operation occurs during plant transients, system transients, natural phenomena, or in conjunction with certain equipment or system failures. The service condition falls into two general categories: (1) harsh and (2) mild environments (as described in DCD Tier 2, Section 3.11.1). Methods for qualifications are defined in DCD Tier 2, Section 3.11.2.3, "Environmental Qualification Method," provides the methods for qualifying electrical equipment important to safety. The applicant stated that the methods to be used are (1) qualification by test, (2) qualification by analysis, (3) qualification by operating experience, and (4) combined qualification, using a combination of the above qualification methods. The staff finds these methods are acceptable for environmental qualification since they are the methods specified by regulation in 10 CFR 50.49(f).

DCD Tier 2, Section 3.11.2, "Qualification Tests and Analyses," stated that environmental qualification of Class 1E equipment is in accordance with the requirements of 10 CFR 50.49, RG 1.89, and IEEE Std. 323-2003, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations." In addition, DCD Tier 2, Table 1.9-1, "APR1400 Conformance with Regulatory Guides," states that the APR1400 conforms with RG 1.89 except for using IEEE Std. 323-2003 instead of IEEE Std. 323-1974, because RG 1.209 endorses IEEE Std. 323-2003. The staff has not endorsed IEEE Std. 323-2003 for environmental qualification of Class 1E electrical equipment in the harsh environment, with the exception of safety-related computer based I&C systems located in a mild environment as addressed in RG 1.209. RG 1.89, Revision 1, endorses IEEE Std. 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations." The procedures described by

IEEE Std. 323-1974, are acceptable to meet the requirements in 10 CFR 50.49, to ensure that the Class 1E equipment can perform its safety functions in harsh environments. The staff issued RAI 7944, Question 03.11-1 (ML15166A133), requesting the applicant to provide the justification why IEEE Std. 323-2003, is acceptable for qualification of Class 1E electrical equipment in the harsh environment, or to modify Section 3.11 of the DCD Tier 2, Revision 0, to reflect a change from IEEE Std. 323-2003, to IEEE Std. 323-1974.

In its response to RAI 7944, Question 03.11-1 (ML15198A260), the applicant stated that SRP Section 3.11 allows the use of information of other standards not endorsed by RGs, if appropriately justified. The applicant provided a justification for the use of IEEE Std. 323-2003, stating that it conforms with 10 CFR 50.49, that there are no technical differences between the 2003 and 1974 versions of the IEEE Std. 323, and that IEEE Std. 323-2003, reflects current practices for environmental qualifications. The staff recognizes that the applicant can use the other standards not endorsed by the NRC in regulatory guidance. The staff evaluated the information provided in response to the RAI and performed a comparison to verify the difference between IEEE Std. 323-1974 and IEEE Std. 323-2003, to confirm that using IEEE Std. 323-2003, meets the requirements of 10 CFR 50.49. The staff identified issues with regards to the definitions and content of IEEE Std. 323-2003. Based on this comparison, the staff issued a follow-up RAI, RAI 8686, Questions 03.11-18, 03.11-19, 03.11-20, 03.11-21, 03.11-22, 03.11-23, and 03.11-24 (ML16295A374), requesting the applicant to address the concerns with the use of IEEE Std. 323-2003.

The staff issued RAI 8686, Question 03.11-18 (ML16295A374), requesting the applicant to provide clarification on the definition of condition-based qualification. The definition in IEEE Std. 323-2003, does not address the equipment functionality following a design basis event (DBE), as required in 10 CFR 50.49(b)(1)(i). In its response to RAI 8686, Question 03.11-18 (ML17004A036), the applicant stated that in IEEE Std. 323-2003, Section 6.3.6, condition-based qualification is an adjunct to type testing. IEEE Std.323-2003, Section 6.3.1.7, "Test Sequence," describes how to perform type testing. IEEE Std. 323-2003 Section 6.3.1.7.g, states, "[t]he test sample shall perform its required safety function(s) while exposed to simulated accident conditions, including conditions following the accident for the period of required equipment operability, as applicable." The applicant concluded that because qualification via type testing addresses equipment functionality during a DBA and condition-based qualification is an adjunct to type testing, equipment functionality following a DBA is addressed under condition based qualification. The staff evaluated and verified the information in IEEE Std. 323-2003, and found that applicant addresses equipment functionality thru type testing. Therefore, the staff finds the response acceptable and meets the requirements in 10 CFR 50.49(b)(ii) regarding design basis events.

The staff issued RAI 8686, Question 03.11-19 (ML16295A374) part a, requesting the applicant to provide clarification on the definition 3.11, "Harsh environment," in IEEE Std. 323-2003. The definition in the standard does not include anticipated operating occurrences (AOOs). The staff requested the applicant to explain how SBLOCA and postulated AOOs that may create harsh environments are addressed, consistent with the definition of DBE in 10 CFR 50.49. In its response to RAI 8686, Question 03.11-19 (ML17004A036), the applicant stated: "[t]he environmental qualification equipment is demonstrated under the worst case environmental conditions to which it is exposed. Therefore, the most limiting conditions that the equipment is exposed to shall be specified. Since other accident conditions, including SBLOCA, result in a less severe environment than a LOCA, MSLB and HELB, they are not specified in the APR1400

environmental qualification.” The staff finds that this is consistent with environmental qualification program methodology described in IEEE Std. 323-1974, since LOCA, MSLB, and HELB envelops the effects of other AOOs, providing reasonable assurance that the equipment will remain functional during and after a DBE. The staff finds this acceptable and consistent with the requirement in the testing, as specified in IEEE Std. 323-1974.

The staff issued RAI 8686, Question 03.11-19 (ML16295A374) part b, requesting that the applicant address DBE when using condition monitoring as a method to determine if further qualified service is possible. In its response to RAI 8686, Question 03.11-18 (ML17004A036), the applicant stated that when using condition monitoring as a qualification method the equipment shall be qualified first to use the condition-based qualification method. IEEE Std. 323-2003, Section 4.1, “Qualification objective,” states that “the primary objective of qualification is to demonstrate with reasonable assurance that Class 1E equipment for which a qualified life or condition has been established can perform its safety function(s) without experiencing common-cause failures before, during, and after applicable design basis events.” Therefore, the staff finds DBE capability is addressed when using condition monitoring, since the equipment is qualified using type testing prior to using condition monitoring as a qualification method and DBE is addressed in the test sequence for type testing. Therefore, the staff finds the response to RAI 8686, Question 03.11-19, part b, acceptable.

The staff issued RAI 8686, Question 03.11-19 (ML16295A374), part c, requesting the applicant to confirm that material incompatibilities at interfaces are demonstrated under the worst case environmental conditions that it will be exposed to, such as DBE as defined in 10 CFR 50.49(b)(ii). In its response to RAI 8686, Question 03.11-19 (ML17004A034), part c, the applicant stated that: “for equipment qualification, type testing is performed by applying the actual installation configuration. Since the basic concept of qualification is simulating the worst case condition that the equipment is exposed, the interfaces of equipment are demonstrated under the worst case scenario.” The applicant stated that DCD Section 3.11.2.2, “Environmental Qualification during and after a Design Basis Accident,” will be revised to include the statement that “material compatibilities at interfaces are demonstrated under the worst case environmental conditions.” The staff finds the response acceptable since the interfaces are demonstrated under the worst case environmental conditions and is in accordance with 10 CFR 50.49(b)(ii). Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8686, Question 03.11-19, part c, is resolved and closed.

The staff issued RAI 8686, Question 03.11-19 (ML16295A374), part d, requesting the applicant to discuss the other applicable DBE conditions and how the design conforms to 10 CFR 50.49. In its response to RAI 8686, Question 03.11-19 (ML17004A036), part d, the applicant stated that the classification of DBEs are specified in DCD, Section 2.1 “Design Basis Conditions, Events, and Load Combination.” Specifically, the applicant stated: “environmental qualification is performed under the most limiting condition to which the equipment is exposed.” Since the applicant used the most limiting conditions to perform environmental qualification, the staff finds it provides reasonable assurance that the equipment will remain functional during and after a DBE meeting the requirements of 10 CFR 50.49. LOCA, MSLB, and HELB are the most limiting conditions and therefore, the accident scenarios used for qualifying equipment as required in 10 CFR 50.49. The staff finds this response acceptable because it is in accordance with the requirements specified in 10 CFR 50.49. The staff completed the evaluation of the applicant’s

response to RAI 8686, Question 03.11-19 and finds it to be acceptable. Therefore, RAI 8686, Question 03.11-19, part d, is resolved and closed.

The staff issued RAI 8686, Question 03.11-20 (ML16295A374), requesting the applicant to address staff concerns with the use of IEEE Std. 323-2003 to determine margins. Section 50.49(e)(8) of 10 CFR states, in part, that “margins must be applied to account for unquantified uncertainty, such as the effects of production variations and inaccuracies in test instruments. These margins are in addition to any conservatisms applied during the derivation of local environmental conditions of the equipment unless these conservatisms can be quantified and shown to contain appropriate margins.” Margin is defined differently in IEEE Std. 323-1974, and IEEE Std. 323-2003. Definition 3.13, “Margin,” in IEEE Std. 323-2003, is stated as “the difference between service conditions and the conditions used for equipment qualification.” Section 6.3.1.5, “Margin,” in IEEE Std. 323-1974, defines margin as, “the difference between the most severe specified service conditions of the plant and the conditions used in type testing to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance.” The staff issued RAI 8686, Question 03.11-20 (ML16295A374), part a, requesting the applicant to confirm that margin is applied on the most severe service condition as specified for temperature, pressure, chemical spray, and radiation during and following design basis accident in 10 CFR 50.49(e). In its response to RAI 8686, Question 03.11-20 (ML17004A036), part a, the applicant stated that: “IEEE Std.323-2003 still applies margin only to accident conditions (the most severe specified conditions of the plant).” Section 6.3.1.6 “Margin,” of IEEE Std.323-2003 states that: “The following suggested margins apply to design basis event service conditions and do not apply to age conditioning.” Therefore, the staff finds that the application of margin according to IEEE Std.323- 2003, is not different from IEEE Std.323-1974, and will be applied on the most severe service condition as specified for temperature, pressure, chemical spray, and radiation during design basis accident in accordance with the requirement of 10 CFR 50.49. The staff has confirmed that the margin is applied to the most severe condition and finds the response acceptable.

IEEE Std. 323-2003, Section 6.3.1.6, “Margin,” states that lesser values of margin may be adequate based on factors such as product design control, test sample size, and test measurement accuracy. The staff issued RAI 8686, Question 03.11-20 (ML16295A374), part b, requesting the applicant to confirm that the margins will meet the requirement in 10 CFR 50.49(e)(8), and, if seeking to use lesser values of margin, discuss how product design control, test sample size, and test measurement accuracy are addressed. In its response to RAI 8686, Question 03.11-20 (ML17004A036), part b, the applicant stated: “although IEEE Std.323-2003 opens the possibility to lessen the values of margin based on factors such as product design control, test sample size, and test measurement accuracy, it has not been used in the qualification process on the APR1400 and is not part of the APR1400 qualification program.” The staff finds the response acceptable because the use of lesser values of margins are not part of the applicant’s environmental qualification program.

The staff completed the evaluation of the applicant’s response to RAI 8686, Question 03.11-20, and finds the response acceptable and concludes that it meets the requirements of margin as required in 10 CFR 50.49(e)(8). Therefore, RAI 8686, Question 03.11-20, is resolved and closed.

The staff issued RAI 8686, Question 03.11-21 (ML16295A374), requesting the applicant to address staff concerns with the use of IEEE Std. 323-2003 for consideration of synergistic

effects. Section 50.49(e)(7) of 10 CFR states in part that “synergistic effects must be considered when these effects (temperature, pressure, humidity, chemical effects, radiation, aging, and submergence) are believed to have a significant effect on equipment performance.”

IEEE Std. 323-1974, Section 5.1, “Type Testing,” states: “type test qualifications must consider synergistic effects during the testing in order to address the worst effects in accordance with 10 CFR 50.49(e)(7). In contrast, IEEE Std. 323-2003, Section 5.1.1, “Type Testing,” does not address synergistic effects during the type tests. Although DCD Tier 2 Section 3.11.2.3(a), states that synergistic effects are considered in the aging program, the use of IEEE Std. 323-2003 does not address synergistic effects. RG 1.89, position C.5.a, states that if synergistic effects have been identified prior to the initiation of qualification, they should be accounted for in the qualification program. The staff issued RAI 8686, Question 03.11-21 (ML16295A374), part a, requesting the applicant to clarify the discrepancy and explain how synergistic effects are considered for type test qualification.

In its response to RAI 8686, Question 03.11-21 (ML17004A036), part a, the applicant stated that synergistic effects are considered in IEEE Std. 323-2003, Section 6.3.1.8.2, “Age conditioning.” This section states that: “the sequence of age conditioning should consider sequential, simultaneous, and synergistic effects in order to achieve the worst state of degradation.” Therefore, synergistic effects are considered at the stage of age conditioning. The staff has confirmed the synergistic effects will be addressed during the age conditioning in the qualification as described in IEEE Std. 323-2003, Section 6.3.1.8.2, “Age conditioning,” therefore, the staff finds the response acceptable.

RG 1.89, Position C.5.a, states that if synergistic effects have been identified prior to the initiation of qualification, they should be accounted for in the qualification program. The RG also states that the procedures described by IEEE Std. 323-1974, “IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations,” are acceptable to the staff for satisfying the Commission's regulations pertaining to the qualification of electric equipment for service in nuclear power plants. IEEE Std. 323-1974, Section 4, “Introduction,” states that “Qualification by analysis must include justification of methods, theories, and assumptions used. In general, electric equipment is too complex to be qualified by analysis alone.” The staff found that qualification by analysis would not address the combined effects of the operating environment if used alone. The staff issued RAI 8686, Question 03.11-21 (ML16295A374), part b, requesting the applicant to provide information regarding: (1) how synergistic effects are addressed, and (2) the justification of methods, theories, and assumptions used to address synergistic effects.

In its response to RAI 8686, Question 03.11-21 (ML17004A036), part b, the applicant stated that: “[b]ecause there is no applicable analysis model to simulate more than one environmental stress, it is not possible to address the combined effects solely by analysis.” IEEE Std. 323-2003 Section 5.1.3 states that “[a]nalysis alone cannot be used to demonstrate qualification,” and 10 CFR 50.49, does not specify a method to use analysis alone. Therefore, the applicant stated it will use test data or operating experience combined with analysis and, if synergistic effects exist, they shall be addressed during type testing or plant operation. The staff evaluated the applicant's response and confirmed that qualification by analysis will not be used by the applicant to address synergistic effects of the operating environment, therefore, the staff finds the response acceptable.

The staff has completed the evaluation of the applicant's response to RAI 8686, Question 03.11-21, and finds the response to the questions acceptable, as described above. Therefore, RAI 8686, Question 03.11-21, is resolved and closed.

The staff issued RAI 8686, Question 03.11-22 (ML16295A374), requesting the applicant to address staff concerns with the use of IEEE Std. 323-2003 for the consideration of analysis for natural aging. Section 50.49(e)(5) of 10 CFR states: "Equipment qualified by test must be preconditioned by natural or artificial (accelerated) aging to its end-of-installed life condition. Consideration must be given to all significant types of degradation which can have an effect on the functional capability of the equipment. If preconditioning to an end-of-installed life condition is not practicable, the equipment may be preconditioned to a shorter designated life. The equipment must be replaced or refurbished at the end of this designated life unless ongoing qualification demonstrates that the item has additional life."

IEEE Std. 323-2003 Section 6.3.1.8.1, "Natural aging," states that natural aging may be supplemented by analysis to account for differences between the specified service and the natural aging conditions to justify the qualified life of the sample. The staff issued RAI 8686, Question 03.11-22 (ML16295A374), part a, requesting the applicant to discuss how natural aging supplemented by analysis addresses the end-of-installed-life condition and demonstrates that the equipment remains functional during and following design basis events, in accordance with 10 CFR 50.49(e)(5). In its response to RAI 8686, Question 03.11-22 (ML17004A034), part a, the applicant stated that: "analysis and additional DBA testing shall be supplemented to use the natural aging process. First, analysis is performed to verify that the natural aging conditions (including service, loading, and environmental conditions) are at least as severe as the intended service condition. Then, DBA testing is performed on the naturally aged sample to demonstrate that the equipment can remain functional during and/or following the applicable design basis events. The end-of-installed-life condition is established when the analysis can ensure that the natural aging conditions are as severe as or more severe than the intended service condition and the DBA testing demonstrates the DBA capability." In response to the RAI, the applicant committed to revise Section in 3.2.1.2 of APR1400-E-NR-14001, to more clearly align it with the requirements of 10 CFR 50.49. The staff finds the response acceptable since DBA testing will be performed on the naturally aged sample to demonstrate that the equipment can remain functional during and/or following. Based on the review of APR1400-E-NR-14001, the staff has confirmed incorporation of the changes described above; therefore, RAI 8686, Question 03.11-22, is resolved and closed.

The staff issued RAI 8686, Question 03.11-23 (ML16295A374), requesting the applicant to address the staff's concerns with the use of IEEE Std. 323-2003 in consideration of humidity during age conditioning. Section 50.49(e)(5) of 10 CFR, requires the electric equipment qualification program to be preconditioned by natural or artificial (accelerated) aging to its end-of-installed life condition and since humidity is one of the types of degradation which can affect functional capability, humidity must be addressed in preconditioning. IEEE Std. 323-2003, Section 6.3.1.8.2, "Age conditioning," states: "age conditioning generally involves applying simulated in-service stresses, typically thermal, radiation, wear, and vibration, as appropriate, at magnitudes or rates that are more severe than expected in-service levels, but less severe than levels that cause aging mechanisms not present in normal service. It is the intent of the age conditioning process to put the test sample in the worst state of degradation that it would experience during the qualified life, prior to the design basis event." Thus, during age-conditioning humidity should be considered if it has an effect on the functional capability of the

equipment. The staff issued RAI 8686, Question 03.11-23 (ML16295A374), requesting that the applicant demonstrate how humidity is considered during age conditioning, in accordance with 10 CFR 50.49(e)(5).

In its response to RAI 8686, Question 03.11-23 (ML17004A034), the applicant stated: “there is no generally accepted model for accelerating aging degradation caused by humidity,” and that there is not a method endorsed by the staff specific to address accelerating humidity. The applicant also stated, “assurance can be obtained by demonstrating that equipment aging is not susceptible to humidity effects by consideration during the design process, providing a technical justification, and performing humidity conditioning or testing.” The staff finds that the applicant’s commitment to perform humidity conditioning or testing, or by establish that the equipment is not susceptible to humidity during the age conditioning of the equipment provides reasonable assurance that humidity will be considered as part of the age conditioning as required in 10 CFR 50.49(e)(5). Therefore, RAI 8686, Question 03.11-23, is resolved and closed.

The staff issued RAI 8686, Question 03.11-24 (ML16295A374), requesting that the applicant address the staff’s concerns with the use of IEEE Std. 323-2003 for qualification by analysis. IEEE Std. 323 -2003 Section 6.3.3, “Analysis,” states: “analytical techniques are limited for many types of equipment, and analysis supplemented by test data or operating experience is usually needed for a comprehensive qualification program.” The staff issued RAI 8686, Question 03.11-24 (ML16295A374), part a, requesting the applicant to discuss how it is ensured that the qualification requirements of 10 CFR 50.49(f) will be met when using the method allowed under 10 CFR 50.49(f)(4), considering that IEEE Std. 323-2003 recommends analysis should be supplemented with test data. In its response to RAI 8686, Question 03.11-24 (ML17004A034), part a, the applicant quoted Section 6.3.3 of IEEE Std.323-2003, which states: “Qualification by analysis requires a logical assessment, similarity evaluations, or a valid mathematical model to establish that the equipment to be qualified can perform its safety function(s) when subjected to the specified service conditions.” That is, qualification by analysis shall establish the base of qualification first (logical assessment, similarity evaluations, or valid mathematical model), and the base is supported with test data or operating experience.” The staff finds use of test data and operating experience must be used when qualification by analysis will be performed, and finds that the requirements in Section 6.3.3 of IEEE Std.323-2003, ensure the applicant will use the appropriate information for qualification by analysis. Therefore, RAI 8686, Question 03.11-24, is resolved and closed.

The staff issued RAI 8209, Question 03.11-13 (ML15244A365), requesting that the applicant explain how DCD Tier 2, Section 3.11, considers synergistic effects with respect to harsh environmental conditions in the qualification for electrical, mechanical, and I&C. In its response to RAI 8209, Question 03.11-13, (ML15345A018), the applicant stated that synergistic effects will be taken into account in the qualification performed by the equipment supplier. Furthermore, the applicant stated: “The procurement specifications state that the equipment is to consider the synergistic effects in the qualification process.” The applicant stated that it will also “review to ensure that the synergistic effects are properly considered in the qualification documentation and evaluate that these effects do not adversely affect the environmental qualification required in accordance with 10 CFR 50.49(e)(7).” Section 50.49(e)(7) of 10 CFR, states in part that “synergistic effects must be considered when these effects [temperature, pressure, humidity, chemical effects, radiation, aging, and submergence] are believed to have a significant effect on equipment performance.” Documentation is addressed in COL 3.11(2), which states, “The COL applicant is to document the qualification test results and qualification

status in an auditable file for each type of equipment in accordance with the requirements 10 CFR 50.49(j).” The applicant addressed staff concerns with synergistic effects; therefore, RAI 8209, Question 03.11-13, is resolved and closed.

The staff issued RAI 8038, Question 03.11-2 (ML15295A493), requesting that the applicant demonstrate that the APR1400 design conforms to the RGs listed in DCD Tier 2, Section 1.9, Table 1.9-1, “APR1400 Conformance with Regulatory Guides,” with regards to equipment qualification. DCD Tier 2, Revision 0, Section 3.11, did not specifically discuss how the APR1400 design is consistent with these RGs. In its response to RAI 8038, Question 03.11-2 (ML15336A996), the applicant stated that: “the equipment qualification is fundamentally performed by equipment suppliers who furnish their safety related equipment. By specifying the applicable RGs initially in the design and procurement specifications, the applicant requires that the suppliers comply with the qualification requirements contained in the RGs. By observing the qualification tests which are performed and reviewing the qualification documents supplied for the procured equipment, the applicant makes final confirmation that the supplied equipment complies with the RGs and satisfies the requirements of 10 CFR 50.49 for the APR1400 design.” The staff finds that since the applicable RGs are included in the DCD Tier 2, this provides the requirements for the qualification of electrical equipment. In addition, COL 3.11(2), requires the COL applicant to document the qualification test results and qualification status in an auditable file for each type of equipment. The staff finds the response meets the requirements of 10 CFR 50.49(j), since the qualification program provides the methodology to meet the requirements for qualification of electrical and mechanical equipment and the documentation will provide the applicable requirements and guidance to which the equipment is qualified. Therefore, RAI 8038, Question 03.11-2, is resolved and closed.

DCD Tier 2, Table 3.11-2, “Equipment Qualification Equipment List,” provides a list of electrical and I&C equipment that requires qualification, in both mild and harsh environments. The staff issued RAI 184-8209, Question 03.11-14 (ML15244A365), requesting the applicant to: (a) Provide the safety classification of the equipment, such as safety-related (Class 1E), nonsafety-related supporting safety-related, and Post-Accident Monitoring as described in 10 CFR 50.49(b); (b) Provide the equipment designated function so that it is identified to mark specific functions such as Reactor trip (RT), Engineered Safeguards (ESF), or Post-Accident Monitoring (PAM); (c) Provide EQ program designation, that identifies each equipment qualified for: electrical EQ, mechanical EQ, radiation, consumables, seismic, and for electromagnetic compatibility (EMC) depending on the environment it belongs to.

In its response to RAI 184-8209, Question 03.11-14 (ML16153A434), the applicant incorporated the requested information from DCD Tier 2, Table 3.11-3, into DCD Tier 2, Table 3.11-2, in order to provide all of the equipment information into a single consolidated table. The same was performed for Table 3, and Table 2, that are contained in APR1400-E-X-NR-14001, “Equipment Qualification Program.” The staff finds the table meets the requirements of 10 CFR 52.47(a)(13), which requires an application for a standard DC to include, “[t]he list of electric equipment important to safety that is required by 10 CFR 50.49(d).” However, the staff finds that range of environmental parameters, such as temperature, pressure, radiation, chemical spray, are not identified per area under DBA conditions pertinent to the particular area (i.e. LOCA, MSLB, etc.) as required in 10 CFR 50.49(d)(3). The staff requested clarification of where the environmental parameter are discussed within the DCD.

In its response to RAI 184-8209, Question 03.11-14 (ML 16153A434), the applicant also stated that: “environmental parameters are listed for the associated room numbers in Table 3 of APR1400-E-X-NR-14001-NP. Since the room numbers and the environmental parameters are included in technical report for the purpose of the categorization, the building category information was determined not to be needed and thus is not included in the DCD nor technical report.” The staff verified the information in Table 3 of APR1400-E-X-NR-14001, and found the table provided the environmental parameter. The staff finds the range of environmental parameters per area is included in the DCD, technical report such that a COL applicant should be able to qualify equipment. Therefore, RAI 184-8209, Question 03.11-14, is resolved and closed.

DCD Tier 2 Section 3.11.3, “Qualification Test Results,” states that the COL applicant must describe the equipment qualification program (EQP) and its implementation milestones based on the APR1400 EQP (COL 3.11(3)). The COL applicant is to document the qualification test results and qualification status in an auditable file for each type of equipment in accordance with the requirements 10 CFR 50.49(j) (COL 3.11(2)).

The borated water spray can affect equipment operation. Thus, the applicant has reviewed the effects of chemical spray that could affect equipment during normal and abnormal operating conditions. DCD Tier 2, Section 3.11.5.1 provides a description of the chemical environment and states that equipment is environmentally tested to these conditions, and performance requirements are demonstrated during and after the test.

Radiation environments are reviewed for normal and accident conditions. DCD Tier 2, Section 3.11, states radiation levels that are defined in revised technical report Table 3.11-4, are the worst-case values and are intended to represent an upper-bound dose value for that area.

For qualification methods, the applicant states that equipment may be qualified by testing, analysis, operating experience, or combination of methods. DCD Tier 2, Section 3.11.2.3, “Environmental Qualification Method,” provides details on each methodology. In the above analysis (b.) method, the applicant further discusses similarity. According to 10 CFR 50.49(f), each item of electric equipment important to safety must be qualified by one of the following methods:

1. Testing an identical item of equipment under identical conditions or under similar conditions with a supporting analysis to show that the equipment to be qualified is acceptable.
2. Testing a similar item of equipment with a supporting analysis to show that the equipment to be qualified is acceptable.
3. Experience with identical or similar equipment under similar conditions with a supporting analysis to show that the equipment to be qualified is acceptable.
4. Analysis in combination with partial type test data that supports the analytical assumptions and conclusions.

The staff issued RAI 184-8209, Question 03.11-15 (ML15244A365), requesting that the applicant define what are the attributes that are to be compared to define and establish similarity under the EQ program. Section 50.49(f)(2) of 10 CFR and 10 CFR 50.49(f)(3) state, in part, that

each electrical equipment important to safety must be qualified by testing a similar item of equipment or by experience with identical or similar equipment under similar conditions with a supporting analysis to show that the equipment to be qualified is acceptable. The staff also requested the applicant to provide a discussion on the determination of a qualified equipment and the process of qualifying it, when analyses are done by means of similarity. In its response to RAI 184-8209, Question 03.11-15 (ML15345A018), the applicant stated that in order for the analysis and operating experience to be applied to the equipment qualification and to define and establish similarity, the following attributes, as a minimum requirement, are compared; material, size, shape, stress, aging mechanism, and function. The applicant revised DCD Tier 2, Section 3.11.2.3b, "Qualification by analysis" to incorporate the criteria that should be met to establish equipment similarity. The staff finds that the applicant has addressed equipment similarity by comparing materials, size, stress, aging mechanism and function. The staff finds the equipment configuration and function are addressed to establish similarity. IEEE 323-1974, Section 6.2, "Equipment performance specifications" provides information regarding the equipment to be qualified, including installation requirements, environmental conditions, and equipment performance characteristics. The attributes provided by the applicant for similarity are included in the equipment performance specifications in IEEE 323-1974, Section 6.2 and thus, the response is acceptable. The staff finds that the applicant has addressed qualification by analysis of a similar item with the revision to DCD Tier 2, Section 3.11.2.3b. However, the applicant did not address qualification by experience with similar equipment. The staff issued requested the applicant to supplement the respond to RAI 184-8209, Question 3.11-15 to address the qualification by experience with similar equipment. The applicant supplemented the response and the staff finds the supplemental information to be acceptable because the attributes including, material, size, shape, stress, aging mechanism, and function, establish similarity for qualification by experience. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 184-8209, Question 03.11-15, is resolved and closed.

Section 50.49(j) of 10 CFR, states that record of the environmental qualification must be maintained in an auditable form. APR1400-E-X-NR-14001, Revision 0, Section 6, provides the description for qualification documentation. Section 6.1 of APR1400-E-X-NR-14001, Revision 0, states that qualification documentation will be organized in an auditable form and in accordance with the guidelines set forth in Sections 6.0 and 7.0, of IEEE Std. 323-2003, and in Section 5.0 and Appendix E, of NUREG-0588. The staff issued RAI 8686, Question 03.11-18 (ML16295A374), requesting that the applicant address the concerns with the use of IEEE Std. 323-2003, specifically, the qualification documentation to provide auditable records that show that equipment can perform its safety function during and following a DBE, as applicable. In its response to RAI 8686, Question 03.11-18 (ML17004A034), the applicant addressed the staff's concerns with the use of IEEE Std. 323-2003, therefore the applicant meets the requirements of 10 CFR 50.49(j).

Based on the staff's review of the applicant's EQ program provided in DCD Tier 2, Section 3.11, the staff finds that the program includes qualification criteria (Mild vs. harsh environments, qualified life, operability time), design specification (normal and abnormal operating conditions for temperature or radiation) qualification methods (type test, and combination of testing and analysis), and documentation (EQDP and maintenance records) needed to support electrical and I&C equipment.

3.11.4.2.1 *Conformance to RG 1.89*

RG 1.89 contains the guidance for implementing the requirements and criteria of 10 CFR 50.49 for environmental qualification of electrical equipment that is important to safety and located in a harsh environment. RG 1.89 endorses IEEE Std. 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," which provides guidance for demonstrating the qualification of Class 1E equipment by including test procedures and analysis methods. When these qualification requirements are met, the electrical and I&C equipment that is important to safety will perform its design function under normal, abnormal, DBE, post-DBE, and containment test conditions. APR1400-E-X-NR-14001, Section 1.3, "Criteria and Standards," states that NUREG-0588, Category I, guidance has been used to enhance the guidance provided in RG 1.89. The DCD further states that electrical equipment identified in DCD Tier 2, Table 3.11-2, will be environmentally qualified by type testing or type testing and analysis using the guidance provided in IEEE Std. 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations."

DCD Tier 2, Section 3.11, states that post-accident monitoring equipment will be environmentally qualified in accordance with RG 1.97, Revision 4, which endorses IEEE Std. 497-2002, "IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations." The method used to identify and qualify this equipment is described in DCD Tier 2, Section 7.5, "Information Systems Important to Safety." Qualification of electrical equipment and components in a mild location is based on the normal local environment and seismic event. The applicant's EQ program addressed the acceptability of important to safety electrical equipment located in a mild environment (not subject to 10 CFR 50.49) as follows:

An aging analysis will be performed prior to qualification type testing to determine whether or not known significant aging mechanisms exist for that equipment. The aging analysis will focus on the identification of known aging mechanisms that significantly increase the equipment susceptibility to its DBA (seismic only for mild environments).

Pending the results of the aging analysis, the equipment will either require an accelerated age conditioning program, periodic part replacement program, surveillance/preventive maintenance program, or any combination thereof to demonstrate and maintain qualification status.

The staff finds that the APR1400 EQ program uses the correct guidance document, RG 1.89, for environmental qualification of electrical equipment that is important to safety and located in a harsh environment. The staff issued RAI 8686, Question 03.11-18 through Question 03.11-24 (ML16295A374), requesting the applicant to provide the justification why IEEE Std. 323-2003, is acceptable for qualification of Class 1E electrical equipment located in harsh environment or, otherwise, revise Section 3.11 of the DCD Tier 2, to reflect the change from IEEE Std. 323-2003 to IEEE Std. 323-1974. In its response to RAI 8686, Question 03.11-19 (ML17004A034), the applicant provided justification in the use IEEE Std. 323-2003, as discussed in SER Section 3.11.4.2.1.

3.11.4.2.2 *Compliance with 10 CFR Part 50, Appendix A*

Per 10 CFR 52.47(a)(3), an application for a standard DC is required to include the design of the facility including: (i) the principal design criteria for the facility (Appendix A

to 10 CFR Part 50, (GDC, establishes minimum requirements for the principal design criteria); (ii) the design bases and the relation of the design bases to the principal design criteria; and (iii) information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the design will conform to the design bases with an adequate margin for safety. The staff's review relevant to equipment qualification is discussed below.

GDC 1, Quality Standards and Records

GDC 1, addresses requirements for quality standards that must be met, and records that must be kept concerning the quality standards for design, fabrication, erection, and testing of components important to safety. Components in the GDC 1, scope must have auditable records to document that environmental design and qualification requirements have been met.

All qualification records per DCD Tier 2, Section 3.11.3, "Qualification Test Results," will be documented and maintained in an auditable form for the entire installed life for quality standards. Records will be kept concerning the quality standards for design, fabrication, erection, and testing of components.

IEEE Std. 323-1974, is the standard used as principal guidance for implementing the requirements and record keeping criteria for environmental qualification of electrical equipment that is important to safety and located in a harsh environment. DCD Tier 2, Section 3.11.2, "Qualification Tests and Analyses," states that Environmental qualification of Class 1E equipment is in accordance with IEEE Std. 323-2003. The staff identified issues with regards to the definitions and content of IEEE Std. 323-2003. As discussed above, the staff issued RAI 8686, Question 03.11-18 (ML16295A374), requesting the applicant to clarify that the qualification documentation provides auditable records that show that equipment can perform its safety function during and following a DBE. GDC 1, states that: "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." In its response to RAI 8686, Question 03.11-18 (ML17004A034), the applicant provided justification for the use of IEEE Std. 323-2003 as discussed in SER Section 3.11.4.1.1. The staff finds that this complies with the requirements of GDC 1, and is therefore acceptable.

GDC 2, Design Bases for Protection against Natural Phenomena

GDC 2, addresses the design bases for components important to safety and requires these components to withstand the effects of the most severe natural phenomena without loss of capability to perform their safety function.

Components within the scope GDC 2, are designed with consideration of the environmental conditions or stressors resulting from natural phenomena as part of the environmental conditions outlined in 10 CFR 50.49(e). The applicant stated in DCD Tier 2, Section 3.1.2, "Criterion 2 – Design Bases for Protection Against Natural Phenomena," that SSCs important to safety are designed to accommodate, without loss of capability, the effects of the design basis natural phenomena along with appropriate combinations of normal and accident conditions. Satisfying the qualification testing requirements of 10 CFR 50.49(f), assures that equipment will be designed to withstand the effects associated with natural phenomena without loss of

capability to perform their safety functions during and after DBEs. The staff finds that this complies with the requirements of GDC 2.

GDC 4, Environmental and Dynamic Effects Design Bases

GDC 4, requires that components important to safety be designed to protect against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures, and be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs.

Section 50.49(f) of 10 CFR, describes the methodology used to qualify equipment that can perform its safety functions, under the specified conditions such as applicable normal, abnormal, and DBE service conditions during its qualified life. DCD Tier 2, Section 3.11, states that the qualification approach conforms with the requirement of 10 CFR Part 50, Appendix A, GDC 4, and the implantation of the program is describe in APR1400-E-X-NR-14001, Revision 0. Further, APR1400-E-X-NR-14001, Revision 0, Part 2, Section 3, provides the methodology for dynamic qualifications. Since all EQ equipment are tested and qualified for the requirements of 10 CFR 50.49(f) (i.e., to simulate the effects, or analyze with test data for equipment failures), to withstand the aforementioned normal operations, maintenance, and postulated accidents, including LOCAs, the staff finds components important to safety are protected against dynamic effects that may result from equipment failures. Therefore, the staff finds that this complies with the requirements of GDC 4.

GDC 23, Protection System Failure Modes

GDC 23, requires that protection systems be designed to fail in a safe state, or in a state demonstrated to be acceptable on some other defined basis, if conditions such as postulated adverse environments (e.g., extreme heat or cold, steam, water, or radiation) are experienced.

DCD Tier 2, Section 3.11.2.3, "Environmental Qualification Method," describes the qualification methods used and states that equipment undergoes aging analysis to focus on the identification of aging mechanisms that significantly increase the equipment's susceptibility to DBA. The applicant further states that 1) a where an aging mechanism is found that is known to significantly degrade the equipment and that aging mechanism is analyzed to determine whether an accelerated aging program or a periodic part replacement program is appropriate, or 2) where no known significant aging mechanisms are found, surveillance or preventive maintenance program will be developed to monitor for degradation. Since the qualification methods used to test its protection systems include the above aging analysis, as discussed in SER Section 3.11.4.2.1, for identification of aging mechanisms, the staff finds that this complies with the requirements of GDC 23.

3.11.4.2.3 Compliance with 10 CFR Part 50, Appendix B

Section 52.47(a)(19) of 10 CFR, requires a DCA to include a description of the quality assurance program applied to the design of the SSCs of the facility. Appendix B to 10 CFR Part 50, sets forth the requirements for quality assurance programs for nuclear power plants. The description of the quality assurance program for a nuclear power plant shall include a discussion of how the applicable requirements of Appendix B to 10 CFR part 50, were satisfied.

Part 50 of 10 CFR, Appendix B, requires that measures be established to ensure that applicable regulatory requirements and the associated design bases are correctly translated into specifications, drawings, procedures, and instructions. This criterion is applicable since it includes requirements for test programs that are used to verify the adequacy of a specific design feature. Such test programs include suitable qualification testing of a prototype unit under the most adverse design conditions.

The applicant stated that compliance with 10 CFR 50.49(f), requires that the environmental qualification process under the EQ program includes appropriate qualification testing of a prototype unit under the most adverse design conditions to verify the adequacy of a specific design feature. The staff finds that EQ related testing under the most adverse design conditions complies with 10 CFR Part 50, Appendix B, Criterion III.

Part 50 of 10 CFR, Appendix B, Criterion XI, requires development of a test control plan to ensure that all tests needed to demonstrate a component's capability to perform satisfactorily in service be identified and performed in accordance with written procedures that incorporate the requirements and acceptance limits contained in applicable design documents. RG 1.89, which endorses IEEE Std. 323-1974, outlines a planned sequence of test conditions (test plan) that meet or exceed the expected or specified service conditions. DCD Tier 2, Section 3.11.2, "Qualification Tests and Analyses," states that environmental qualification of Class 1E equipment is in accordance with IEEE Std. 323-2003. The applicant has provided justification for the use of IEEE Std. 323-2003, instead of IEEE Std. 323-1974, as discussed in SER Section 3.11.4.1.1, and there were no concerns with the test sequence described in IEEE Std. 323-2003. IEEE Std. 323-2003, Section 6.3.1.1, "Test plan," describes the test plan that meets the expected or specified service conditions. Therefore, the staff finds that information contained in DCD Tier 2, Section 3.11.2, "Qualification Tests and Analyses," and compliance with IEEE Std. 323-2003 is sufficient to demonstrate that the component's capability is in accordance with 10 CFR Part 50, Appendix B, Criterion XI. Part 50 of 10 CFR, Appendix B, Criterion XVII, "Quality Assurance Records," requires that sufficient records be maintained to furnish evidence of activities affecting quality. The EQ records must include inspections, tests, audits, monitoring of work performance, and materials analysis. Records pertaining to quality assurance must be identifiable and retrievable.

Section 50.49 (j) of 10 CFR, requires that records must be maintained to furnish evidence of activities affecting quality. DCD Tier 2, Section 3.11.3, "Qualification Test Results," states "the COL applicant is to document the qualification test results and qualification status in an auditable file for each type of equipment in accordance with the requirements 10 CFR 50.49(j) (COL 3.11(2))." Further, it states that because equipment qualification program is an operational program, the COL applicant is to describe the equipment qualification program and its implementation milestones based on the APR1400 EQP (COL 3.11(3)). The implementation of the environmental qualification program is performed by the COL applicant and therefore the staff finds that the COL items are acceptable. Meeting the requirements of 10 CFR Part 50, Appendix B, Criterion XVII, provides assurance that identifiable and retrievable records are maintained to furnish evidence of activities affecting quality, which includes environmental design and qualification.

Based on the above, the staff finds that the APR1400 EQ program complies with the requirements of 10 CFR Part 50, Appendix B.

3.11.4.3 *Environmental Qualification of Mechanical Equipment*

The staff reviewed DCD Tier 2, Section 3.11, and Part 1 of APR1400-E-X-NR-14001, for the description of the EQ program for nonmetallic parts of mechanical equipment to be used in APR1400 design for consistency with NRC regulations and guidance specified under SER Section 3.11.3, above to support the acceptability for reference in a COL application.

3.11.4.3.1 *Identification of Safety-Related Mechanical Equipment Including the Required Operating Times*

DCD Tier 2, Section 3.2, "Classification of Structures, Systems, and Components," states that AP1400 SSCs are categorized as safety-related or nonsafety-related. Safety-related SSCs (as defined in 10 CFR 50.2) are those SSCs relied upon to remain functional during and following design-basis events to ensure the following: (1) the integrity of the reactor coolant pressure boundary; (2) the capability to shut down the reactor and maintain it in a safe condition; or (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the applicable guideline exposures set forth in 10 CFR 50.34(a)(1), or 10 CFR 100.11. Safety-related SSCs must meet the quality assurance (QA) requirements of Appendix B to 10 CFR Part 50. SSCs that do not perform the above safety functions are classified as nonsafety-related, and the requirements of 10 CFR Part 50, Appendix B, are not applicable to these SSCs. APR1400 SSCs that are important to safety but are not safety-related are additionally classified so that they are designed to the appropriate quality standard. The augmented quality assurance requirements for these SSCs, which are described in Chapter 17, are commensurate with the importance of their safety functions.

DCD Tier 2, Table 3.11-2, "Equipment Qualification Equipment List" and Part 1 of APR1400-E-X-NR-14001, Table 2, "Equipment Qualification Equipment List," specify the safety-related mechanical equipment included in the APR1400 EQ program and its required operating time in the accident environment. The staff issued RAI 115-8066, Question 3.11-3 (ML15208A456), requesting that the applicant describe the scope of mechanical equipment listed in the APR1400 EQ program and basis for inclusion. In its response to RAI 115-8066, Question 3.11-3, (ML15252A095), the applicant stated the following:

The basis for determining the mechanical equipment in the EQ program is if the equipment is classified as safety related and Seismic Category I. There is not any non-safety related mechanical equipment in DCD Tier 2, Table 3.11-2 or Part 1 of APR1400-E-X-NR-14001, Table 2, "Equipment Qualification Equipment List." The table lists equipment classified as safety related and Seismic Category I only.

The staff finds the applicant's response that the EQ program includes mechanical equipment classified as safety related and Seismic Category I, to be acceptable because it describes the scope of mechanical equipment listed in the APR1400 EQ program and is consistent with the guidance in SRP Section 3.11.

DCD Tier 2, Section 3.11.1.3, "Equipment Operability Times," identifies the time during which equipment needs to operate in the accident environment as "continuous," "short-term," "intermittent," and "varies." These operating times vary from a few seconds to 6 months. DCD Tier 2, Table 3.11-2 and Part 1 of Technical Report APR1400-E-X-NR-14001, Table 2 list the equipment in the EQ program and specify the required operating time as "continuous,"

“short-term,” “intermittent,” and “varies.” Section 4 of the Technical Report APR1400-E-X-NR-14001, states that APR1400 procurement specifications contain the equipment operating times required under accident conditions.

The staff finds the applicant’s methodology for identification of safety-related mechanical equipment including the required operating times to be acceptable because it describes the scope of mechanical equipment listed in the APR1400 EQ program and is consistent with the guidance in SRP Section 3.11. Mechanical equipment listed in the APR1400 EQ program meets the regulatory requirements in GDC 1, that the equipment is within the established quality assurance program; GDC 2, which the equipment is classified as seismic Category I; and GDC 4, which equipment included within the EQ program is designed to accommodate environmental effects.

3.11.4.3.2 *Identify Nonmetallic Subcomponents of Mechanical Equipment*

DCD Tier 2, Table 3.11-2 and Technical Report APR1400-E-X-NR-14001, Table 2 identify the specific mechanical equipment in the EQ program that contains nonmetallic parts.

Also, DCD Tier 2, Section 3.11.2, “Qualification Tests and Analyses,” and COL 3.11(2) in Section 3.11.7, “Combined License Information,” state that the COL applicant is to identify the nonmetallic parts of mechanical equipment in the procurement process.

The staff finds that the identification of nonmetallic parts of mechanical equipment in DCD Tier 2, Table 3.11-2, and APR1400-E-X-NR-14001, Table 2, are consistent with the guidance in SRP Section 3.11, and is therefore acceptable.

3.11.4.3.3 *Identification of Environmental Conditions*

For mechanical equipment, the environmental design and qualification considers both the external and internal service conditions of the equipment. The external environmental conditions are similar to the environmental conditions for electrical equipment and are described by the applicant in the DCD and APR1400-E-X-NR-14001. DCD Tier 2, Section 3.11.1.2, “Definition of Environmental Conditions,” indicates that the environmental conditions under which the equipment performs its design safety functions include all normal conditions, AOOs, accidents, and post-accident conditions due to design-basis accidents. External environmental parameters such as temperature, pressure, relative humidity, radiation, and chemical spray for the various locations such as reactor containment, buildings, and rooms are provided in DCD Tier 2, Figure 3.11-1, “Design Basis Containment Atmosphere Temperature and Pressure EQ Profile for Accident,” and Table 3.11-2, “Equipment Qualification Equipment List.” Environmental parameters are also provided in APR1400-E-X-NR-14001, Figure 1, “Design Basis Containment Atmosphere Temperature and Pressure EQ Profile for Accident,” Table 2, “Equipment Qualification Equipment List, and Table 3, “Environmental Parameters Data.”

DCD Tier 2, Section 3.11.6, “Qualification of Mechanical Equipment,” states the effect of process medium temperature and radiation on the nonmetallic parts is evaluated for any process medium whose temperature and radiation are higher than the highest external environmental temperature and radiation, and the combined effect of time- temperature and radiation degradation is considered. The applicant also states that consideration is given to process pressure, process media type and chemistry, and process humidity.

APR1400-E-X-NR-14001, Section 5.6, “Qualification of Safety-Related Active Mechanical Equipment,” states that service requirements and the environmental requirements are defined in the APR1400 design specification.

The staff finds the description in the DCD Tier 2, Section 3.11, and APR1400-E-X-NR-14001, for the identification of nonmetallic parts of mechanical equipment is consistent with the guidance in SRP Section 3.11, and is therefore acceptable.

3.11.4.3.4 *Identify Nonmetallic Material Capabilities*

Technical Report APR1400-E-X-NR-14001, Section 5.6, states that materials are selected based on extensive testing and long-time service that is compatible with the APR1400 design service requirements. The applicant also states that quality assurance of design and quality control processes provide reasonable assurance that the component meets the specification requirements and the design and manufacturing organizations certify compliance.

The staff finds the description in the Technical Report APR1400-E-X-NR-14001, for the identification of nonmetallic material capabilities is consistent with the guidance in SRP Section 3.11, and is therefore acceptable.

3.11.4.3.5 *Evaluate Environmental Effects on the Non-metallic Components*

DCD Section 3.11.2, Section 3.11.3.2, “Mechanical Equipment,” and Section 3.11.6, as well as Section 5.6 in Part 1 of APR1400-E-X-NR-14001, describe the APR1400 provisions for EQ for non-metallic parts of mechanical equipment. The staff issued RAI 115-8066, Questions 3.11-03, 3.11-05, and 3.11-06 (ML15208A456), requesting the applicant to further describe provisions for the EQ of mechanical equipment. In its response to RAI 115-8066, Question 3.11-0 (ML15252A095) and RAI 115-8066, Question 3.11-06 (ML15356A727), the applicant stated that the DCD and technical report would be revised to specify that safety-related mechanical equipment that contains nonmetallic parts is environmentally qualified in accordance with ASME Standard QME-1-2007, “Qualification of Active Mechanical Equipment,” and Appendix QR-B, “Guide for Qualification of Non-Metallic Parts,” as endorsed by RG 1.100, Revision 3, and is listed in [DCD Tier 2] Table 3.11-2. The applicant also stated that qualification by test or a combination of test and analysis is consistent with the qualification methodology described in Appendix QR-B of ASME QME-1-2007. The staff finds the applicant’s response acceptable for Question 03.11-03, because ASME QME-1-2007, Appendix QR-B, is the staff approved methodology for the EQ of non-metallic parts of mechanical equipment and that qualification is performed by test or a combination of test and analysis. Based on the review of the DCD and APR1400-E-X-NR-14001, Revision 1, the staff has confirmed incorporation of the changes described above; therefore, RAI 115-8066, Question 03.11-03, is resolved and closed. RAI 115-8066, Question 03.11-06, is further evaluated below.

The staff issued RAI 115-8066, Question 03.11-05 (ML15208A456), requesting the applicant to further describe provisions for the EQ for nonmetallic parts of safety-related passive mechanical equipment identified in DCD Tier 2, Table 3.11-2, and Part 1 of APR1400-E-X-NR-14001, Table 2. In its response to RAI 115-8066, Question 3.11-05 (ML16085A357), the applicant stated that the DCD would be revised as follows:

Safety-related passive pressure boundary components are designed and qualified for the appropriate temperature and pressure environment in accordance with the requirement of ASME Boiler and Pressure Vessel Code, Section III. The qualification of non-metallic parts in safety related passive mechanical equipment is ensured through the means specified in DCD Tier 2 Section 3.11.2.3.

The staff finds the applicant's response acceptable because DCD Tier 2 Section 3.11.2.3, was revised to describe provisions for the environmental qualification of non-metallic parts in safety related passive mechanical equipment and the provisions are consistent with guidance in SRP Section 3.11. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 115-8066, Question 03.11-05, is resolved and closed.

The staff issued RAI 115-8066, Question 03.11-06 (ML15208A456), requesting the applicant to further describe provisions for the EQ for nonmetallic parts of mechanical equipment as specified in DCD Tier 2, Sections 3.11.3.2 and 3.11.6, and Part 1 of APR1400-E-X-NR-14001, Section 5.6. In its response to RAI 115-8066, Question 03.11-06 (ML15356A727), the applicant stated that the DCD and technical report would be revised to specify that EQ for nonmetallic parts of mechanical equipment located in mild and harsh environments are environmentally qualified in accordance with Appendix QR-B, "Guide for Qualification of Non-Metallic Parts," of ASME QME-1-2007, "Qualification of Active Mechanical Equipment," as endorsed by RG 1.100, Revision 3. ASME QME-1-2007, Appendix QR-B, is the staff approved methodology for the EQ of non-metallic parts of mechanical equipment in both mild and harsh environments is consistent with the guidance in SRP Section 3.11. The applicant identified equipment environments as mild and harsh in DCD Tier 2, Table 3.11-2, and Part 1 of APR1400-E-X-NR-14001, Table 3.

The staff finds the applicant's methodology to evaluate environmental effects for the non-metallic components of mechanical equipment to be acceptable because ASME QME-1-2007, Appendix QR-B, is the staff approved methodology and it is consistent with the guidance in SRP Section 3.11 and meets the regulatory requirements in GDC 1, that the equipment is tested to quality standards; and GDC 4, that the equipment is designed to accommodate the effects of environmental conditions. Based on the review of the DCD and APR1400-E-X-NR-14001, Revision 1, the staff has confirmed incorporation of the changes described above; therefore, RAI 115-8066, Question 03.11-06, is resolved and closed.

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

The requirements in 10 CFR 52.47(b)(1), require that a DCA 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, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act, and the Commission's rules and regulations. The staff issued RAI 546-8782, Question 14.03.03-06 (ML17123A458), requesting that the applicant address ITAAC for environmental qualification of nonmetallic parts of mechanical equipment. In its response to RAI 546-8782, Question 14.03.03-06 (ML17227A608), the applicant provided a mark-up of the proposed ITAAC changes and stated that DCD Tier 1 would be revised to specify ITAAC for the environmental qualification for nonmetallic parts of mechanical equipment as described below.

Design Commitment: Non-metallic parts, materials, and lubricants used in safety related mechanical equipment perform their safety-related function up to the end of their qualified life in the design basis harsh environmental conditions (both internal service conditions and external environmental conditions) experienced during normal operations, anticipated operational occurrences, design-basis accidents, and post-accident conditions.

Inspection, Tests, Analyses: A type test or a combination of type test and analysis will be performed of the [applicable system] non-metallic parts, materials, and lubricants used in safety related mechanical equipment.

Acceptance Criteria: A qualification report exists and concludes that the non-metallic parts, materials, and lubricants used in safety related mechanical equipment listed in [applicable system table] perform their safety related function up to the end of their qualified life under the design basis harsh environmental conditions (both internal service conditions and external environmental conditions) specified in the qualification report.

The staff finds the applicant's response acceptable because the proposed environmental qualification ITAAC for non-metallic parts of mechanical equipment meet NRC regulations in 10 CFR 52.47(b)(1). The ITAAC is necessary and sufficient for reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria are met, then a facility referencing the certified design can be constructed and operated in compliance with the DC and applicable regulations. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 546-8782, Question 14.03.03-06, is resolved and closed.

3.11.4.3.7 *Design Specification Audit*

The requirements in 10 CFR 52.47 states, in part, that the "information submitted for a DC must include performance requirements and design information sufficiently detailed to permit the preparation of acceptance and inspection requirements by the NRC, and procurement specifications and construction and installation specifications by an applicant. The Commission will require, before DC, that information normally contained in certain procurement specifications and construction and installation specifications be completed and available for audit if the information is necessary for the Commission to make its safety determination." The staff conducted an initial audit and follow-up audit of the information to be provided in design and procurement specifications for EQ of nonmetallic parts of mechanical equipment when made available by the applicant in accordance with 10 CFR 52.47. The staff provided the results of the initial audit in a report dated April 20, 2016 (ML15350A057), and the follow-up audit in a report dated June 30, 2017 (ML17095A782). As discussed in the audit reports, the staff finds that the changes to add environmental qualification parameters to the design and procurement specifications for the EQ of nonmetallic parts of mechanical equipment to be used in the APR1400 reactor in response to the follow-up audit are acceptable to support the APR1400 reactor DC because the specifications meet the requirements in 10 CFR 52.47, to specify performance requirements and design information sufficiently detailed to permit the preparation of acceptance and inspection requirements by the NRC, and procurement specifications and construction and installation specifications by an applicant. The staff issued RAI 550-8737, Question 03.09.03-07 (ML17195B072), requesting the applicant to confirm the completion of the changes to the design and procurement specifications. In its response to RAI 550-8737, Question 03.09.03-07 (ML17237B993), the applicant stated that the design and procurement

specifications for the EQ of nonmetallic parts of mechanical equipment were revised. Therefore, RAI 550-8737, Question 03.09.03-07, is resolved and closed.

3.11.4.4 *Radiation Protection*

The staff reviewed DCD Tier 2 Section 3.11, and supporting documentation to ensure that the radiological effects on electrical and mechanical equipment important to safety are in accordance with 10 CFR Part 50, Appendix A, GDC 4, and 10 CFR 50.49. The relevant information is found in DCD Tier 2 Section 3.11, and APR1400-E-X-NR-14001, "Equipment Qualification Program," which is referenced in the DCD. Guidance for the staff's evaluation appears in Revision 3 of SRP Section 3.11; NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety Related Electrical Equipment"; Revision 1 of RG 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants"; and RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Appendix I, "Assumptions for Evaluating Radiation Doses for Equipment Qualification."

As described in DCD Section 3.11 the equipment being qualified includes:

- Equipment associated with systems that are essential for emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise essential in preventing significant releases of radioactive material to the environment.
- Equipment that initiates the above functions automatically.
- Equipment that is used by the operators to initiate the above functions manually.
- Equipment whose failure can prevent the satisfactory accomplishment of one or more of the safety functions specified in above bullet 1.
- Electrical equipment important to safety, as described in 10 CFR 50.49(b)(1), and (2).
- Certain post-accident monitoring equipment as described in 10 CFR 50.49(b)(3), and RG 1.97, Revision 4.
- Accident monitoring equipment specified in RG 1.97, Revision 4.

The DCD and APR1400-E-X-NR-14001 both indicate that the radiation qualification for individual safety-related components is developed based on the maximum normal operation (including anticipated operational occurrences) dose and the limiting design basis accident for which the component provides a safety function. This general approach is consistent with applicable requirements and guidance.

APR1400-E-X-NR-14001 indicates that any area that is exposed to radiation of more than 102 Gray (corrected to 100 Gray in the response to RAI 8089, Question 03.11-9, below), or 10 Gray for electronic equipment, from both normal operation and the limiting design basis accident, is considered a harsh radiological environment. DCD Tier 2 Section 3.11.2.3, indicates that equipment that is exposed to harsh radiation levels will be tested by irradiating the test equipment to its anticipated total integrated dose (TID), before type testing, unless determined

by analysis that radiation does not affect its ability to perform its required function. This approach is consistent with SRP Section 3.11, and is therefore acceptable.

While the DCD and APR1400-E-X-NR-14001, provide the high level approach in the radiological analysis, staff identified numerous apparent inconsistencies within the application and with NRC guidance. For example, while DCD Tier 2 Table 3.11-2, provided the TID values for plant areas, the components included within certain areas were undefined and the boundaries of some of the areas were unclear. In addition, the DCD and APR1400-E-X-NR-14001 did not provide sufficient detail in describing the methodology used to calculate the TID values for staff to reach a safety conclusion.

The application (the DCD and APR1400-E-X-NR-14001, together) also appeared to be missing information and contained other apparent inconsistencies, including the following:

- The application did not provide limiting TID values for areas inside the biological shield wall which may contain components important to safety.
- The application was unclear as to what the TID value for certain components is because the application lists the maximum TID value for each room but does not list what room each component is located.
- DCD Tier 2 Table 3.11-3, listed the post-accident sampling system room isolation dampers as requiring short-term operability (a few seconds to a few hours after the onset of the accident), even though the DCD indicated that the post-accident sampling system requires access multiple times during an accident and the equipment would therefore require use beyond the onset of the accident.
- The application did not clearly define what is meant for components labeled as “short-time” use. For example, it was not clear if it applied only to components needed for one time use at the onset of an accident or if it also applied to components needed for one time use later in the accident.
- Some equipment operability times were listed as “varies” in DCD Tier 2 Table 3.11-3, making it unclear how long the component needed to be able to withstand the radiological conditions for which they are located.
- The application assumed that equipment listed as needing to be operated continuously, needed to operate 6 months following an accident without providing a clear basis for why the 6 month duration was acceptable.
- It was unclear if the applicant appropriately considered a fuel handling accident in their analysis for TID values in fuel handling areas.
- The normal operation TID values in certain areas appeared lower than what would be calculated using the 0.25 percent source term data and shielding and zoning criteria in Chapter 12, even though the TID values for equipment qualification (EQ) are based on 1 percent failed fuel (and therefore, staff would expect the EQ doses to be higher).

The staff issued RAI 8089, Question 03.11-9 (ML15252A562), requesting the applicant to provide additional clarification and correct inconsistencies, including those identified above, in

order to ensure that the applicant's approach for calculating TID values for components is accurate and acceptable.

The accident TID values for components for which the most adverse accident conditions are post-LOCA, are based on source term assumptions consistent with RG 1.183. It is acceptable to base the calculations on RG 1.183. However, it was unclear how the applicant calculated the accident TID values for components outside of containment, including the TID for components in plant areas where the limiting design basis accident is not the LOCA. Specifically, the application did not provide a source term for post-accident containment sump fluid which is used to determine the accident source terms for components outside containment, such as the shutdown cooling system or provide source term information for important post-accident sources, including airborne activity. In addition, the application did not adequately describe assumptions made in determining the dose contributions from these components. Finally, it was unclear if the same source terms were used to determine post-accident TID values for EQ as were used to determine post-accident radiation zoning in DCD Tier 2, Figures 12.3-30 through 12.3-51. Therefore, the staff requested that the applicant clarify the methodology that was used in calculating accident source terms for the purposes of EQ and post-accident zoning and access to vital areas. The staff issued RAI 8089, Question 03.11-11 (ML15252A562), requesting the applicant to provide this information.

In its response to RAI 8089, Question 03.11-9 (ML16215A124), and Question 03.11-11 (ML16103A492 and ML16217A383), for Revision 1 of the response, the applicant made significant changes to the information in the DCD and APR1400-E-X-NR-14001, and provided new information describing how the normal and accident TID values were calculated. The response to Question 03.11-11, provided the methodology used for calculating the accident TIDs, while the response to Question 03.11-9, provided the methodology used for calculating the normal operation TIDs, the final calculated TID values, environmental classifications of equipment, and other information. The modifications and additions to the methodology for calculating EQ dose were so substantive that the general radiological EQ approach is summarized and reviewed below in its entirety, instead of evaluating the individual specific changes made in the response to each question.

In its response to RAI 8089, Questions 03.11-9, and 03-11-11, the applicant proposed updating APR1400- E-X-NR-14001 to provide the methodology used in calculating the maximum normal operation EQ dose calculations (Appendix A, "Calculation Method for Determining of Normal Condition TIDs for Environmental Qualification," of APR1400-E-X-NR-14001), and accident EQ dose calculations (Appendix B, "Calculation Method for Determining Post-Accident TIDS for Environmental Qualification," of APR1400-E-X-NR-14001), for each room in the plant, which were then added together to give the maximum TID value for each room or plant area identified in Table 3 of APR1400-E-X-NR-14001 (including areas inside the biological shield wall that were not identified, previously). The TID dose calculations consider gamma, neutron, and beta radiation, as applicable. DCD Tier 2 Section 3.11.2.3, specifies that when actual qualification testing is performed that, instead of using a neutron source for neutron radiation, an equivalent gamma radiation dose may be used. As specified in the DCD, the gamma source must provide an equivalent simulation of the neutron exposure.

The locations of the significant equipment included in the EQ program, as well as their environmental and radiological classification (mild or harsh), and required operational time, are identified in Table 2, "Equipment Qualification Equipment List" of APR1400-E-X-NR-14001 and

Table 3.11-2, "Equipment Qualification Equipment List" of the DCD. However, for some equipment, the exact room in which the equipment is located is not identified in the DCD, and the COL applicant will determine where that equipment is located (this equipment is given the designation COL (7), instead of a room number).

Table 2 of APR1400-E-X-NR-14001, and DCD Tier 2 Table 3.11-2, also specifies the timeframe that the equipment is required to be operable following the onset of a design basis accident. Equipment is given the timeframe of either continuous, short-term, intermittent, or varies, depending on the specific operability requirements for the individual piece of equipment. For some of the equipment with a "short-term" timeframe, the specific timeframe the equipment is required to be operable is provided. The definition of each of these terms is defined in DCD Tier 2 Section 3.11.1.3, which specifies that components labeled continuous, intermittent, and varies are capable of operating at least 6 months following the onset of a design basis accident. For components labeled short-term, without a specific timeframe labeled in Table 2 of APR1400-E-X-NR-14001, and DCD Tier 2 Table 3.11-2, it is unclear how long it is required to operate. In addition, the post-accident TID values are calculated for one year following the onset of a design basis accident. Therefore, it is unclear why DCD Tier 2 Section 3.11.1.3, specifies that most of the equipment is required to operate at least 6 months following the onset of a design basis accident. The applicant is expected to provide more information in this area in a revised response (see below).

The TIDs used for environmental qualification are determined by summing the cumulative doses received during normal operation (typically 60 years, except for some refueling equipment), in addition to the accident doses.

As described in Appendix 3A of APR1400-E-X-NR-14001, the normal operation EQ dose is calculated assuming 1 percent fuel defects. The normal operation TID calculations consider three dose contributing factors, which are added together to get the total normal operation TID value: (1) the direct doses from the significant radiation sources inside the room; (2) indirect doses from sources in surrounding rooms; and (3) submersion doses from equipment leakage (generally insignificant compared to the other two, during normal operation). Gamma radiation is the only significant type of radiation contributing to the normal operation TID values, except in the vicinity of the core, where neutron radiation is significant. This general approach is consistent with RG 1.89, Appendix D, and is acceptable.

In the response to Question 03.11-9, the applicant notes that there are differences between the normal operation EQ TID calculations and the Chapter 12, normal operation radiation zoning information including: (1) that the radiation zoning information assumes 0.25 percent failed fuel and the EQ analysis assumes 1 percent failed fuel (this is consistent with SRP Section 12.2 and RG 1.89); (2) the Chapter 12 zoning uses the minimum radiation shield thicknesses provided in Chapter 12, and the EQ analysis uses the actual structural wall thicknesses; and (3) the dose contribution from adjacent rooms is calculated differently. The applicant stated that while the Chapter 12, analysis considers the dose from adjacent rooms directly, the EQ analysis only considers the actual dose contributions if it is greater than 20 percent of the total normal operation TID contribution. If not, the dose from adjacent rooms is assumed to be 20 percent of the TID, for conservatism. The EQ analysis also adds an extra 10 percent margin of uncertainty to the final normal operation TID values (as well as to the accident TID values), which is not added in the Chapter 12, radiation shielding and zoning review. Adding 10 percent to the TID values is specified in RG 1.89, to account for any uncertainty in the calculations.

Other than those differences described above, the applicant stated that the normal operation EQ doses were generally calculated using the same methodology provided for radiation shielding in DCD Tier 2 Chapter 12 (and as discussed in SER Chapter 12). As a result, for major components, the source term dimensions provided in DCD Tier 2 Table 12.2-25, are also used in the normal operation EQ analysis (as well as for the accident analysis, for applicable components). An exception to this is the approach used for heat exchangers in systems that recirculate IRWST sump fluids during an accident (which is discussed in detail below).

As described in Appendix B of APR1400-E-X-NR-14001, the accident TID values were calculated based on the most limiting design basis accident, which in most cases, is the LOCA. The LOCA source terms are based on the core inventory release fractions for each radionuclide group at the gap release and early in-vessel release phases, listed in DCD Tier 2 Table 15A-2, "Fraction of Fission Product Inventory in Gap." The staff notes that these release fractions are also consistent with RG 1.183, and are therefore acceptable. Iodines in containment are assumed to be 4.85 percent elemental, 95 percent particulate, and 0.15 percent organic, which is also consistent with RG 1.183. Accident doses were calculated for a period of one year following the onset of an accident.

The applicant stated that different methodologies are used to calculate the accident TID values depending on the location within the plant. The general methodology used in calculating accident TID values depends on the location and the potential radiological concerns in those areas.

Inside containment, the applicant noted that the TID values are calculated based on: (1) airborne fission products in the containment atmosphere; (2) fission products which plate-out on the containment walls; and (3) fission products in the IRWST sump water. Radioactive decay and subsequent daughter product buildup was considered. In addition, removal by the containment spray system is considered. The staff evaluated this approach and found it to be consistent with the methodology described in RG 1.89, and RG 1.183. Therefore, the staff finds this explanation to be acceptable.

During a LOCA, the accident doses outside of containment will increase significantly in areas near the safety injection, shutdown cooling, and containment spray systems, in the auxiliary building, since these systems will be used to recirculate IRWST sump fluid. The direct dose contribution from components in these systems is considered in the EQ dose calculations. The source term for the recirculating IRWST fluid is provided in the applicant's response to RAI 8247, Question 12.02-16 (ML15343A410).

The source terms in the EQ analysis for components are generally modeled based on the source component dimensions, as was done in the Chapter 12, shielding and zoning analysis (as was discussed above). However, the applicant modeled pumps based on the diameter of the piping connected to the pump. The staff found this to be conservative because it doesn't account for the extra shielding, beyond that of the piping, which would be expected to be provided by the pump housing. For heat exchangers, the applicant modeled the heat exchangers as a pipe with a diameter of the square root of the number of tubes that pass through the heat exchanger (counted twice for a U-tube heat exchanger) times the diameter of the tubes. The applicant indicates that this is an acceptable assumption because for the tube region, the shielding effects of the cooling water in the shell side and internal steel is not considered and for the plenum region of the heat exchanger, the same wall thickness and

diameter as the tube region are applied, when in reality the wall thickness in the plenum region would be thicker than the tube region. The staff agrees that the applicant's assumed source term dimensions for the tube region are acceptable because it considers the entire volume of the recirculating fluid in the tubes, without considering the shielding effect that would be present from CCW fluid and internal shielding. Since the steel shell of the plenum region will be thicker than what is modeled in the source term calculations, the staff also agrees that the applicant's methodology is acceptable for the plenum region.

In addition, consistent with RG 1.89 and RG 1.183, the applicant considered airborne activity and auxiliary building filter loading, due to leakage from the systems that re-circulate IRWST sump fluid. The applicant assumes that the following percentages of leaked nuclides will go airborne in the auxiliary building (100 percent noble gases, 10 percent halogens, 1 percent other nuclides). RG 1.183, Appendix A, Sections 5.4 and 5.5, provide guidance on the amount of iodine (a halogen) that is assumed to flash airborne. Using the maximum post-LOCA sump water temperature in DCD Tier 2 Table 15.6.5-13, and the equation in RG 1.183, Appendix A, Section 5.4, the staff calculated an iodine airborne flashing fraction of less than 10 percent. Consistent with the guidance of RG 1.183, if the value is less than 10 percent, the guidance indicates that 10 percent should be assumed. Therefore, assuming that 10 percent of the halogens leaked from systems that re-circulate IRWST sump fluid goes airborne, is acceptable.

The applicant also considered leakage from the containment atmosphere into the auxiliary building intakes as a contributor to the total auxiliary building filter loading and airborne activity levels, although this was not a significant contributor to the total TID calculations.

Loading of the main control room emergency filters was also considered in the TID values for components in those areas. As a conservative assumption, for the EQ analysis, the applicant assumes that the MCR emergency filters have the same inventory as the auxiliary building emergency filters. This appears to be conservative because the auxiliary building filters have a larger source term than the MCR filters (using the MCR filter inventory provided in the response to RAI 8247, Question 12.02-16). However, an error was discovered in the MCR filter loading source term that was corrected in the applicant's response to RAI 8247, Question 12.02-16, Revision 2 (ML16306A454). Using the corrected source term, the staff used the Microshield computer code to estimate the accident dose rate to the MCR filter rooms. The staff found that the doses provided for the filter areas were conservative compared to the staff's calculations. As a result, the staff finds that the MCR emergency filters were appropriately considered in the EQ analysis.

The only areas of the plant where a LOCA is not the most limiting design basis accident for calculating EQ TIDs is in the fuel handling area and the main steam valve house, in the auxiliary building. The accident TIDs for the fuel handling area are based on a fuel handling accident and the accident TIDs for the main steam valve house are based on a main steam line break. In its response to RAI 8089, Question 03.11-11, Revision 1 (ML16217A383), the applicant stated that the main steam line break is the limiting design basis accident for the main steam valve house, as opposed to a steam generator tube rupture, because during a steam generator tube rupture, the steam passes through the piping and out of the area quickly and the piping provides shielding for the radioactivity. The main steam line break also results in a larger dose at the exclusion area boundary, according to the Chapter 15, analysis. Based on this information, the staff agrees that the main steam line break would be the most significant design basis accident for equipment located in the main steam valve house.

The staff performed confirmatory calculations to verify the applicant's TID values for several areas of the plant. For example, staff calculated the 1 percent failed fuel dose rate for several components, such as the CVCS ion exchangers and the shutdown cooling pump, by using the 0.25 percent failed fuel source term which were reviewed and verified in Chapter 12, and increasing the source term to 1 percent and performing Microshield calculations using the source terms to verify that the staff calculated similar TID values to the applicant. The staff's results showed similar TID values for rooms in these areas to those values calculated by the applicant in Table 3 of APR1400-E-X-NR-14001, when the extra 10 percent conservatism was taken into account.

For accident conditions, for the components re-circulating IRWST sump water, the staff calculated the same radioactivity concentrations as those calculated by the applicant, and for areas reviewed by the staff, the accident TID values calculated by the applicant in Table 3 of APR1400-E-X-NR-14001, associated with these systems, were comparable to values estimated by the staff. The staff also verified that the applicant's calculated TID values were similar to other PWR new reactor designs.

As discussed above, APR1400-E-X-NR-14001, indicates that any area that is exposed to radiation of more than 100 Gray or 10 Gray for electronic equipment, from both normal operation and the limiting design basis accident, is considered a harsh radiological environment. DCD Tier 2 Section 3.11.2.3, indicates that equipment that is exposed to harsh radiation levels will be tested by irradiating the test equipment to its anticipated total integrated dose (TID), before type testing, unless determined by analysis that radiation does not affect its ability to perform its required function. This approach is consistent with SRP Section 3.11, and is therefore acceptable.

The staff also reviewed the equipment listed in Table 2 of APR1400-E-X-NR-14001, and DCD Tier 2 Table 3.11-2, in order to ensure that safety-related and important to safety equipment that is necessary to protect control room operators and to prevent the release of radioactive material in the event of a design basis accident are appropriately included in the table. The table includes safety-related radiation monitors, such as containment area monitors, spent fuel pool area monitors, and control room monitors. In addition, it includes valves and actuators for isolating containment, for the auxiliary building emergency ventilation system and for control room emergency ventilation. The staff finds this acceptable because the radiation monitors are used to monitor potential accident conditions and to initiate containment isolation and emergency ventilation, as appropriate, and meet the criteria in 10 CFR 50.49, and GDC 4, for equipment that should be included in the EQ program. Finally, the DCD application indicates that the COL applicant is to identify and qualify any site-specific mechanical, electrical, I&C, and accident monitoring equipment specified in RG 1.97 (COL 3.11(1)), which is acceptable.

As discussed in part above, in reviewing the EQ methodology and associated DCD and APR1400-E-X-NR-14001, changes provided in the responses to Questions 03.11-9, staff identified numerous apparent problems. Some of these issues are as follows:

- During a Chapter 12 audit, the applicant indicated that there would be significant neutron radiation on the refueling floor during normal operation due to radiation streaming through opening between the reactor vessel and radiation shield blocks that surround the cavity wall. However, in Table 3 of APR1400-E-X-NR-14001, the applicant indicates

that there will be no neutron radiation in the operating area. The applicant was asked to clarify this discrepancy.

- The revised Table 3 of APR1400-E-X-NR-14001, indicates that for Room 174-A16B, gamma doses during an accident are negligible. However, DCD Tier 2 Table 3.8-11, appears to indicate that two 60 inch diameter containment penetrations pass from containment into this room. During a LOCA, streaming of the radioactivity in the containment atmosphere, through penetrations, could constitute a significant radiation dose contribution to areas outside containment. The staff requested that the applicant consider radiation streaming through containment penetrations in this area and other areas where significant containment penetrations exist.
- The SFP Cooling HX rooms (100-A24A and 100-A32B) are listed as having a TID of 1,100 Gray (harsh radiation environment) in Table 3 of APR1400-E-X-NR-14001, however, the SFP HX Room Cubicle Cooler (VF-HV02B), which is located in that room is listed as being in a mild radiation environment in Table 2 of APR1400-E-X-NR-14001, and DCD Tier 2 Table 3.11-2. The applicant was asked to correct this discrepancy.
- As discussed above, for components labeled short-term in DCD Tier 2 Section 3.11.1.3, without a specific timeframe labeled in Table 2 of APR1400-E-X-NR-14001 and DCD Tier 2 Table 3.11-2, it is unclear how long it is required to operate. In addition, the post-accident TID values are calculated for one year following the onset of a design basis accident. Therefore, it is unclear why DCD Tier 2 Section 3.11.1.3, specifies that most of the equipment is required to operate at least 6 months following the onset of a design basis accident.
- As discussed earlier, the applicant indicated that while Chapter 12, radiation zoning is based on the minimum wall and floor thicknesses provided in DCD Tier 2 Table 12.3-4, the response indicates that the EQ analysis is based on the actual structural wall and floor thicknesses. However, while the DCD provides structural thicknesses for many of the walls in the plant, not all of the actual structural wall and floor thicknesses are provided in the DCD. These structural thicknesses are needed in the DCD to ensure that the design is provided with the shielding assumed in the EQ analysis. The staff requested that the applicant provide this information in the DCD.
- The proposed Table 3 of APR1400-E-X-NR-14001 did not provide any TID information for the fuel handling area in the auxiliary building. The staff requested that the applicant include this information.

In Revision 1 of the response to Question 03.11-9 (ML17102A408), the applicant made several changes, including the following changes to resolve the above issues.

In Revision 1, the applicant revised the normal operation TID values for the operating area, specifying the normal operation gamma and neutron TID values. These values were consistent with the dose rate information provided in Calculation Package 1-310-N-376-002 (which was provided to staff as part of the radiation protection shielding audit), considering the extra 20 percent margin added for consideration of dose from other nearby areas and the extra 10 percent added for uncertainty. The calculation accounts for radiation streaming through the reactor vessel and up through the gap between the vessel and the concrete wall, to the

operating floor (accounting for radiation streaming past and through the shield block). In Revision 3 of the response (ML17331A315), the applicant also provided actual dose rate information on the operating floor for the operating APR1400 unit in Korea (Shin Kori Unit 3). The actual dose rate information was significantly lower than what is calculated and used in the EQ analysis for the operating area for the APR1400 DCD. This helped to support the calculated total integrated dose on the operating floor. Therefore, the staff found the TID values for the operating floor to be acceptable.

In Revision 1 of the response to Question 03.11-9, the applicant also proposed updating the gamma TID to Room 174-A16B (which contains two 60 inch diameter containment penetrations, as discussed above), and several other Auxiliary Building rooms which appear to have containment penetrations. However, the applicant provided no discussion regarding the changes made or the information related to the assumptions made in calculating the TID values and the values were lower than what the staff estimated. This issue remained unresolved in Revision 1 of the applicant's response (see the discussion below on Revision 4 of the applicant's response to RAI 8089, Question 03.11-9, for more information and the resolution of this issue).

In Revision 1 of the response, the applicant proposed a change to DCD Tier 2 Table 3.11-2, specifying that the environmental condition for Room 100-A32B was harsh, but the radiation environment was listed as mild, which was inconsistent with the dose rate information for Rooms, 100-A24A and 100-A32B, as specified above. In addition, Room 100-A24A, was still listed as mild in all respects. There were also still several other discrepancies in the DCD and technical report regarding whether the equipment in these rooms were in a mild or harsh environment. This issue remained unresolved in Revision 1 of the applicant's response (see the discussions below on Revision 2 and Revision 3 of the applicant's response to RAI 8089, Question 03.11-9, for more information and the resolution of this issue).

In Revision 1 of the response, the applicant proposed updating DCD Tier 2 Section 3.11.1.3, to clarify that equipment with a required operational time of "short-term," is required to operate only one time up to 24 hours from the start of the design basis accident. The applicant also provided examples of equipment with different required operating times. This clarified the required operational times of the equipment and therefore, the staff found the response to be acceptable.

Revision 1 of the response did not provide any additional information regarding actual structural wall and floor thicknesses used in the EQ analysis that were missing from the DCD. This issue remained unresolved in Revision 1 of the applicant's response (see the discussions below on Revision 2 and Revision 3 of the applicant's response to RAI 8089, Question 03.11-9, for more information and the resolution of this issue).

In Revision 1 of the response, the applicant proposed changing the numbering of the new fuel container laydown and inspection area (originally Room 156-A08D) to Room 156-A08B, in the RAI response and Table 3 of the technical report, which is the room number for fuel handling area. In Revision 2 of the response (ML17263A169), the applicant further clarified that Room 156-A08B, was the correct room number for the fuel handling area.

In Revision 2 of the response (ML17263A169), the applicant also proposed other changes including changing the radiation environment designations for Room 100-A24A and Room 100-A32B, from "mild" to "harsh" in DCD Tier 2 Table 3.11-2, and correcting the designation for

equipment in those rooms. However, Table 3 of the technical report still specified that the rooms were mild environments. There also appeared to be several other discrepancies for the non-radiological designations of some of the equipment in these areas. This issue remained open following the Revision 2 submittal (see the discussions below on Revision 3 to the applicant's response to RAI 8089, Question 03.11-9, for more information and the resolution of this issue).

In Revision 2 of the response, the applicant also proposed updating DCD Tier 1 Table 2.2.1-1, to provide structural wall and floor thicknesses and information for shielding walls which were not previously included in the DCD. The staff reviewed the information and the thicknesses appeared appropriate for the dose rates being estimated, however, some of the thicknesses for walls associated with demineralizer and filter areas were not clearly specified. This issue remained open following the Revision 2 submittal (see the discussions below on Revision 3 to the applicant's response to RAI 8089, Question 03.11-9, for more information and the resolution of this issue).

In Revision 3 of the response (ML17331A315), the applicant proposed to correct Table 3 of the technical report to specify that Room 100-A24A and Room 100-A32B, are a harsh environment. This is consistent with information elsewhere in the DCD and technical report, as discussed above, and is therefore, acceptable.

In Revision 3, the applicant also proposed to update DCD Tier 1 Table 2.2.1-1, to clarify the wall thicknesses for demineralizer and filter areas which were not clear previously. The staff reviewed these changes and found the thicknesses to be consistent with the minimum shielding thicknesses provided in Chapter 12, Table 12.3-4 of the DCD and to be appropriate for the EQ TID values calculated. Based on the staff's confirmatory review, which included Microshield calculations for selected high dose rate areas, the staff found the thicknesses to be acceptable.

In addition, in Revision 3 of the response, the applicant also proposed to update Appendix A of APR1400-E-X-NR-14001 to clarify how the normal operating doses and TIDs for rooms without radiation sources in the radiologically controlled area were calculated. The applicant specified that the TIDs were based on the radiation zone maps provided in Chapter 12, of the DCD which is multiplied by 4, because the Chapter 12, radiation zone maps are based on an assumed 0.25 percent failed fuel, while the EQ TID values are based on 1 percent failed fuel, consistent with RG 1.89. The TID values are based on 60 years of operation and also include a 10 percent uncertainty margin and 20 percent of additional margin. This provides additional margin beyond the 10 percent margin recommended in RG 1.89. Based on this, the staff finds the methodology for calculating TIDs to areas without radiation sources, in the radiologically controlled areas to be acceptable.

In Revision 4 of the response (ML17349B005), the applicant re-analyzed the accidental EQ TIDs for penetration areas at a dose point 30 cm away from the penetrations, and proposed changes to Table 3 of APR1400-E-X-NR-14001 to provide updated TID values for these rooms. The staff finds that revising the calculations to provide the dose rate 30 cm away from the penetrations provides a more accurate estimate of the maximum doses that equipment within the room could be exposed to. Therefore, the staff finds the new approach and revisions to doses in penetration areas to be acceptable.

Regarding the response to Question 03.11-11, Revision 1, and the associated application changes describing the methodology for calculating the TID during accident conditions, the staff noted that while the applicant assumed a leakage rate from ESF components of 0.285 cubic feet per hour (cft/hr) in accordance with RG 1.183, the applicant did not provide any justification for how the leakage rate of 0.285 cubic feet per hour was determined.

In Revision 2 of the response to Question 3.11-11 (ML17004A039), the applicant proposed updating Appendix B of APR1400-E-X-NR-14001 to clarify that the allowed ESF leakage rate for EQ of 0.285 cft/h was based on the assumed leakage rates from valves and pumps specified in the response. As previously indicated, the allowed leakage rate of 0.285 cft/h, is doubled to 0.57 cft/h, in accordance with RG 1.183. In Revision 3 of the response to Question 3.11-11 (ML17152A016), the applicant proposed to update DCD Tier 2, Section 15.6.5.5.1.2, and Appendix B of APR1400-E-X-NR-14001 to clarify that while the DCD Chapter 15, accident analysis used a different assumed leak rate of 18.9 L/hour (0.667 cft/h), doubled to 37.8 L/h (1.335 cft/h), the EQ analysis was based on 0.285 cft/h, which is doubled to calculate TID valves. The staff found the ESF leakage values used in the EQ analysis to be acceptable because the 0.285 cft/h, is based on conservative leakage assumptions and it is the maximum leakage allowed. If the value were to be exceeded, the applicant would have to evaluate the impacts on the equipment and take appropriate action. The assumptions for ESF leakage in Chapter 15, are extra conservative because they assume a leakage rate beyond what is allowed. As a result of the above analysis, the staff found the proposed responses to RAI 8089, Questions 3.11-9 and 3.11-11, to be acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8089, Question 3.11-9 and RAI 8089, Question 3.11-11, are resolved and closed.

DCD Section 3.11.5.2, indicated that for normal operations, the TID is calculated based on an assumed 1 percent fuel failure defect and 60 years of operation, which is consistent with RG 1.89 and is therefore acceptable. DCD Tier 2 Section 3.11.5.2, also indicated that for the equipment used only during refueling operation, the normal operation TID was calculated assuming that the radiation sources affect the equipment only during refueling periods. It was unclear to staff why only dose during refueling was considered, since components will still be exposed to the radiological environment in which they are located (for example, normal operation containment conditions), when they are not being used. The staff issued RAI 8218, Question 03.11-16 (ML15295A506), requesting the applicant to provide this information.

In its response to RAI 8218, Question 03.11-16 (ML15324A452), the applicant indicated that the equipment used only during refueling operation includes the fuel transfer tube and equipment in the cask loading pit and that the normal operation (non-refueling) dose to this equipment is expected to be very minimal during normal operation (non-refueling), because these areas are zoned radiation Zone 2 during normal operation (less than or equal to 0.025 mSv/hour). As a result, the applicant concluded that the normal operating dose to these components is negligible. Specifically, the applicant considers a one month refueling period for every 18 months of normal operation (40 months of refueling during the assumed 60 year life of the plant). The applicant also indicated that while normal TID plus accident TID is considered for safety-related systems and components, the fuel transfer tube and cask loading pit are not designed to perform any safety related functions. As a result, the applicant stated it is not necessary to include the accident TID for this equipment. Finally, the applicant also proposed DCD changes to Section 3.11.5.2 to explain that, since the equipment does not perform a safety related function, the dose contribution from accidents was not considered. The staff concludes

that it is reasonable to assume that the normal (non-refueling) dose to these areas will be negligible, due to the low dose rate in these areas during normal operation (non-refueling) operation. Likewise, if the equipment is not needed during accident conditions, it is not necessary for the applicant to consider accident TID for this equipment. Therefore, the response is acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8218, Question 03.11-16, is resolved and closed.

SRP Section 3.11 indicates that the equipment should be designed to have the capability of performing its design safety functions under all AOOs and normal, accident, and post-accident environments, and for the length of time for which its function is required. The application did not discuss if any equipment will be required to be replaced during the lifetime of the plant in order to ensure that the cumulative effects of normal operation and the limiting potential design basis accident would not result in exceeding the equipment's designed environmental limits and including the cumulative effects of designed pressure, temperature, relative humidity, radiation dose, and chemical limitations (as applicable). In addition, if replacement of components is required, the application does not discuss how environmental conditions will permit workers to access these areas in order to replace equipment during accident conditions and the radiation doses that a worker would receive in replacing the components. The staff issued RAI 8089, Question 03.11-10 (ML15252A562), requesting the applicant to provide this information.

In its response to RAI 8089, Question 03.11-10 (ML15345A208), the applicant added information in DCD Section 3.11.2.2, specifying that with the inclusion of the cumulative effects of the normal operating conditions that each piece of equipment has received, the qualification program will ensure that the replacement of equipment will be made before the worst case design basis accident condition would result in exceeding design limits for each piece of equipment. This is in accordance with SRP Section 3.11 and is therefore acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 8089, Question 03.11-10, is resolved and closed.

As a result of a Chapter 12 shielding audit, it was determined that the 1 percent failed fuel source term of the boric acid concentrator package, provided in the applicant's Calculation No. 1-321-N376-012, was incorrect, by a factor of 10. During the audit, the applicant indicated that the source term incorrectly assumed a concentration factor of 10 instead of 100. Since the 1 percent failed fuel source term is used in the EQ analysis, the staff issued RAI 8577, Question 03.11-17 (ML16112A015), requesting that the applicant correct this error. In its response to Question 03.11-17 (ML16190A338), the applicant corrected the source term. The applicant also indicated that its response to RAI 8089, Question 03.11-9, would include the corrected TID information for the boric acid concentrator. The staff reviewed the source term and the TID value for the boric acid concentrator room in Table 3 of APR1400-E-X-NR-14001, and verified that the TID value provided was consistent with the corrected source term. Since the applicant updated the source term as was requested, the response to RAI 8577, Question 03.11-17, is acceptable. Therefore, RAI 8577, Question 03.11-17, is resolved and closed. It is noted that additional evaluations of the boric acid concentrator are discussed in Chapter 12 of this SER. Mainly as it relates to the responses to RAI 8353, Question 12.02-21, and RAI 8420, Question 12.02-22. These questions did not result in any changes to the equipment qualification source terms or doses beyond those discussed above. The staff concludes that the radiological aspects of the EQ information meet the applicable acceptance criteria in SRP Section 3.11, the

guidance in RGs 1.89 and 1.183, and the requirements of 10 CFR Part 50, Appendix A, GDC 4, and 10 CFR 50.49.

3.11.5 Combined License Information Items

Per 10 CFR 52.79(a)(10), a COL application must include a “description of the program, and its implementation, required by § 50.49(a) “...for the environmental qualification of electric equipment important to safety and the list of electric equipment important to safety that is required by 10 CFR 50.49(d).” DCD Tier 2, Section 3.11.7, “Combined License Information,” specifies action items for COL applicants related to generic APR1400 EQ of mechanical and electrical equipment programs and plant-specific components, as indicated in the following table.

Table 3.11.5 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.11(1)	The COL applicant is to identify and qualify the site-specific mechanical, electrical, I&C, and accident monitoring equipment specified in RG 1.97.	3.11.1.1
COL 3.11(2)	The COL applicant is to identify the nonmetallic parts of mechanical equipment in the procurement process.	3.11.2
COL 3.11(3)	The COL applicant is to address operational aspects for maintaining the environmental qualification status of components after initial qualification.	3.11.2.2
COL 3.11(4)	The applicant is to provide a full description of the environmental qualification program of mechanical and electrical equipment.	3.11.2.2
COL 3.11(5)	The COL applicant is to document the qualification test results and qualification status in an auditable file for each type of equipment in accordance with the requirements 10 CFR 50.49(j).	3.11.3
COL 3.11(6)	The COL applicant is to describe the EQP implementation milestones based on the APR1400 EQP.	3.11.3
COL 3.11(7)	The COL applicant is to provide room number designation for those unidentified rooms in Table 3.11-2.	3.11.7

DCD Tier 2, Section 3.11.2.2, “Environmental Qualification during and after a Design Basis Accident,” states that the COL applicant is to address aspects for maintaining the EQ status of components after initial qualification. However, this COL item is not listed in DCD Tier 2 Section 3.11.7. The staff issued RAI 115-8066, Question 3.11-07 (ML15208A456), requesting the applicant to address this COL item in DCD Tier 2, Section 3.11.7 and enhance the specificity of its description in DCD Tier 2, Section 3.11.2.2. In its response to RAI 115-8066, Question 3.11-07 (ML15349A795), the applicant proposed to revise DCD Tier 2, Section 3.11-7

and Table 1.8-2 for the COL applicant to address operational aspects for maintaining the EQ status of components after initial qualification. The applicant also proposed to revise DCD Tier 2, Section 3.11.2.2 to describe the operational aspects for a COL applicant to address when developing the operational program to maintain the EQ status of components. The staff confirmed that DCD Tier 2, Revision 1, dated March 10, 2017 was revised as committed in the response to RAI 115-8066, Question 03.11-07. The staff considers the applicant's response acceptable because it describes the operational aspects and the COL item, and is consistent with the guidance in SRP Section 3.11. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 115-8066, Question 03.11-07, is resolved and closed.

The SRM for Commission paper SECY-02-0067 stated that ITAAC for an operational program are unnecessary if the program and its implementation are fully described in a COL application and found to be acceptable by the NRC. In its SRM for SECY-04-0032, the Commission defined "fully described" as when the program is clearly and sufficiently described in terms of the scope and level of detail to allow a reasonable assurance finding of acceptability. However, DCD Tier 2, Section 3.11.7, does not specify a COL item for the COL applicant to provide a full description of the EQ of mechanical and electrical equipment program. The staff issued RAI 115-8066, Question 3.11-08 (ML15208A456), requesting the applicant to include a COL item for a full description of the EQ program. In its response to RAI 115-8066, Question 3.11-08 (ML15356A727), the applicant proposed to revise DCD Tier 2, Section 3.11-7, and Table 1.8-2, to add a COL item for the COL applicant to provide a full description of the EQ of mechanical and electrical program. The applicant also proposed to revise DCD Tier 2, Section 3.11.2.2 to specify that the applicant is to provide a full description of the EQ of mechanical and electrical program. The staff considers the applicant's response acceptable because the COL item fully describes the EQ program, and is consistent with the guidance in SRP Section 3.11. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 115-8066, Question 03.11-08, is resolved and closed.

3.11.6 Conclusion

As set forth above, the staff has reviewed all of the relevant information that is applicable to DCD Tier 2, Section 3.11, for EQ of mechanical and electrical equipment and evaluated for compliance with the requirements of 10 CFR 52.47(a)(3)(i)-(iii) (addressing reasonable assurance that the design will conform to the design bases with an adequate margin for safety), 10 CFR 52.47(a)(13) (requiring the application for a standard DC to include list of electric equipment important to safety that is required by 10 CFR 50.49(d)), applicable 10 CFR Part 50, Appendix B, Quality Assurance Criteria, conformance with applicable RGs, and standards committed to by the applicant. The staff also reviewed the COL information items in DCD Tier 2, Table 1.8-2 for the COL applicant.

The staff concludes that the provisions in the DCD and technical report for the EQ of mechanical and electrical equipment in the APR1400 design are acceptable and meet the applicable NRC requirements and are consistent with guidance. This conclusion is based on the applicant having specified provisions in the DCD and technical report that mechanical, electrical, and I&C equipment, including digital I&C equipment designated as important to safety, addressed in the EQ program is capable of performing its design functions under all normal environmental conditions, AOOs, and accident and post-accident environmental conditions.

3.12 ASME Code Class 1, 2, and 3 Piping Systems, Piping Components and their Associated Supports

3.12.1 Introduction

This section covers the design and structural integrity of piping systems and supports used in seismic Category I and non-seismic Category I piping systems whose failure could potentially affect seismic Category I systems. The staff's evaluation considered the adequacy of the structural integrity as well as the functional capability of piping systems. The review includes piping designed in accordance with ASME BPV Code Section III, Subsections NB, NC, and ND, as incorporated by reference in 10 CFR 50.55a (also referred to as ASME Class 1, 2, and 3, or Quality Group A, B, and C, respectively).

The review also includes buried piping, instrumentation lines, and interaction of non-seismic Category I piping with seismic Category I piping. The following sections of this report provide the staff's evaluation of the adequacy of the APR1400 piping analysis methods, design procedures, acceptance criteria, and verification of the design.

The staff's evaluation included the following:

- Regulatory criteria
- Applicable codes and standards
- Methods to be used in the piping design
- Modeling of piping systems
- Pipe stress analysis criteria
- Pipe support design criteria

3.12.2 Summary of Application

In DCD Tier 2, Section 3.12, "Piping Design Review," the applicant provided the methods of piping analysis and addressed the design of piping systems for loadings due to normal operating conditions, system operating design transients, postulated pipe breaks, and seismic events. Loading combinations for piping analysis were also included.

Additionally, DCD Tier 2, Section 14.3.2.3, "ITAAC for Piping Systems and Components," describes the use of a graded approach in completing detailed APR1400 piping analysis at the design certification stage and identifies the scope of the graded approach. For ASME Class 1 piping, it includes the RCS main loop, PZR surge line (SL), direct vessel injection (DVI) line and shutdown cooling (SC) line. For ASME Class 2 and 3 piping systems, it includes the main steam (MS) and main feedwater (FW) piping located inside containment extended up to and including the anchor restraint beyond the outboard containment isolation valve.

The concept of employing a graded approach for the piping design analysis in the design certification application is consistent with the staff's discussion on level of detail for design certification in SECY-90-377 (ML003707892), "Requirements for Design Certification under 10

CFR Part 52,” and the staff’s white paper (ML14065A067), which provides guidance in accordance with SECY-90-377, in utilizing a graded approach for the staff’s review of the piping design analysis. Additional evaluation of this approach and review of ITAAC applicable to piping is presented in Section 14.3.3, “Tier 1, Chapter 3: Interface Requirements,” of this SER.

3.12.3 Regulatory Basis

The applicant’s piping and pipe support design criteria, including the analysis methods and modeling techniques, are acceptable if they meet codes and standards and are consistent with regulatory guidance documents, commensurate with the safety function to be performed. This will ensure that the piping design criteria meet the relevant requirements in 10 CFR Part 50, and 10 CFR Part 52.47 to ensure structural integrity and pressure boundary leakage integrity of piping and components, as well as structural integrity of pipe supports in nuclear power plants. The acceptance criteria are based on meeting the relevant requirements of the following regulations for piping systems, piping components, and their associated supports, as described below.

- Section 50.55a of 10 CFR, and GDC 1, as they relate to piping systems, pipe supports, and components being designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.
- Appendix B to 10 CFR Part 50, which sets quality assurance requirements for safety-related systems structures and components.
- GDC 2, and Appendix S to 10 CFR Part 50, with regard to design transients and resulting load combinations for piping and pipe supports to withstand the effects of earthquakes combined with the effects of normal or accident conditions.
- GDC 4, with regard to piping systems and pipe supports important to safety being designed to accommodate the effects of, and to be compatible with, the environmental conditions of normal as well as postulated events, such as a LOCA, and dynamic effects.
- GDC 14, with regard to the reactor coolant pressure boundary (RCPB) being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.
- GDC 15, with regard to the RCS and associated auxiliary, control, and protection systems being designed with sufficient margin to ensure that the design condition of the RCPB is not exceeded during any condition of normal operation, including anticipated operational occurrences.
- Section 52.47 of 10 CFR, which requires that a DC application must contain a level of design information sufficient to enable the Commission to judge the applicant’s proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted.

- Section 52.47(b)(1) of 10 CFR, which requires that a DC 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, a plant that incorporates the DC has been constructed and will operate in accordance with the DC, the provisions of the Atomic Energy Act of 1954, and the NRC's regulations.

In addition, the staff in its review utilized SECY-90-377 (ML003707892), in which the Commission addressed the use of a graded approach for the level of detail in design certifications required under 10 CFR Part 52. In its review, the staff also utilized the NRO staff white paper (ML14065A067), which provides guidance in accordance with SECY-90-377, in utilizing a graded approach for the staff's review of piping design analysis.

The NRC established requirements in 10 CFR Part 50 to ensure the pressure boundary leakage integrity of the piping components and structural integrity of the pipe supports in nuclear power plants. Detailed acceptance criteria are given in SRP Section 3.12, "ASME Code Class 1, 2, and 3 Piping Systems, Piping Components and their Associated Supports," Revision 1, dated April 2014.

3.12.4 Technical Evaluation

The staff used SRP Section 3.7.2, "Seismic System Analysis," Revision 3, issued March 2007; SRP Section 3.7.3, "Seismic Subsystem Analysis," Revision 3, issued March 2007; SRP Section 3.9.1, "Special Topics for Mechanical Components," Revision 3, issued March 2007; SRP Section 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," Revision 3, issued March 2007; SRP Section 3.9.3, "ASME Code Class 1, 2, and 3 Components and Component Supports, and Core Support Structures," Revision 3, issued April 2014; and SRP Section 3.12, "ASME Code Class 1, 2, And 3 Piping Systems, Piping Components and Their Associated Supports," Revision 1, issued April 2014, to evaluate the piping and pipe support design information in the DCD. Interfaces with the staff's reviews associated with these other SRP sections are presented in the sections below. The staff evaluated the design, materials, fabrication, erection, inspection, testing, and in-service surveillance of piping and pipe supports using the industry codes and standards, regulatory guides, and staff technical reports listed in the SRP. The staff also considered industrial practice and programs during the review process.

In the SRM associated with SECY-90-377, the Commission addressed the use of a graded approach for the level of detail in design certifications required under 10 CFR Part 52, and approved the staff's proposal to develop regulatory guidance, which will clarify the definition of an "essentially complete design," in terms of the scope and depth of design, including a description of the structures, systems, and components to be included in the application for design certification and COL. The Commission also stated that such regulatory guidance should be incorporated into the SRP and RG 1.70, or into a separate guide(s) as staff deems appropriate. In the interim, the staff prepared such guidance, for utilizing a graded approach for the review of piping design analysis in design certification applications, in NRO staff white paper (ML14065A067).

As mentioned above in Section 3.12(B), Summary of Application, the applicant used the graded approach to perform piping design analyses in the design certification stage of the application.

According to SECY-90-377 (ML003707892) and NRO staff white paper (ML14065A067), the level of detail of the piping design review is to be commensurate with the importance of the safety function to be performed. DCD Tier 2, Section 3.12, Revision 0, primarily addressed the methodology for piping analysis but did not discuss the graded approach for piping analysis. To ensure that sufficient information is provided to support a safety determination and meet the applicable requirements of 10 CFR 52.47, the staff issued RAI 35-7955, Question 03.12-2 (ML15168A283), requesting the applicant to revise DCD Tier 2, (Section 3.12 to reference DCD Tier 2 Section 14.3.2.3, for the selection of certain piping systems based on the graded approach and to include additional information on system selection, the approach to the analyses and results of analyses completed at the design certification stage.

In its final revised response to RAI 35-7955, Question 03.12-2 (ML16211A384), the applicant submitted its DCD markups. The DCD markups add new DCD Tier 2 Section 3.12.7, "Graded Approach of Piping Systems," add three additional references to the DCD Section 3.12 (References 33, 34 and 35), and modify DCD Tier 2, Table 1.6-2, "List of Technical Reports," to include these references in the table and also modify DCD Tier 2, Section 14.3.2.3 accordingly. The added DCD Tier 2 Section 3.12.7, discusses the ASME Code Class 1, 2 and 3 piping systems of the APR1400 design. It shows that the selection of piping systems that are included in the graded approach, which were evaluated and completed in the design certification (DC) stage, is consistent with the staff's discussion on level of detail for design certification in SECY-90-377 and the staff's guidance presented in the staff's white paper (ML14065A067). It also shows that the selection of these systems for performing piping analyses is based on the safety function, integrity, piping size and layout. Piping evaluations of these systems were made available to the staff for audit. The applicant indicated that the references to be added to the APR1400 DCD Tier 2 Section 3.12, will contain results summaries and discussion of the structural evaluations to show how the APR1400 piping design adequately meets the requirements of applicable regulations (10 CFR 50.55A; 10 CFR Part 50, Appendix A, GDC-1, GDC-2, GDC-4, GDC-14 and GDC-15; and 10 CFR Part 50, Appendix S). The staff finds the applicant's response is in accordance with the graded approach in SECY-90-377 and follows the staff's White Paper guidance and, therefore, is acceptable. The references added to DCD Subsection 3.12.7 are reviewed as part of the piping audit discussed later in this section. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 35-7955, Question 3.12-2, is resolved and closed.

3.12.4.1 Codes and Standards

GDC 1, requires that structures, systems, and components important to safety be designed, fabricated, erected, tested, and inspected 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. In 10 CFR 50.55a, the NRC requires that certain systems and components of boiling- and pressurized-water-cooled nuclear power reactors must meet certain requirements of the ASME BPV Code. The regulation specifies the use of the latest edition and addenda endorsed by the NRC and any limitations discussed in the regulations. In RG 1.84, "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III," the staff lists acceptable ASME BPV Code, Section III cases for design and materials acceptability and any conditions that apply to them.

In DCD Tier 2, Section 1.9, “Conformance with Regulatory Criteria,” and Section 3.2, “Classification of Structures, Systems, and Components,” the applicant lists applicable codes and standards used for the design of ASME Class 1, 2, and 3, pressure-retaining components and their supports. Table 1.9-1, “APR1400 Conformance with Regulatory Guides,” identifies RG applicability. Table 1.9-2, “APR1400 Conformance with the Standard Review Plan,” identifies SRP applicability. Table 1.9-3, “APR1400 Conformance with Generic Issues (NUREG-0933),” identifies Generic Issues applicability. Table 3.2-1, “Classification of Structures, Systems, and Components,” identifies applicable ASME and other code editions. In DCD Tier 2, Section 5.0, Table 5.2-4, “ASME Section III Code Cases,” identifies ASME BPV Code cases that are applicable to the RCPB components, including piping and pipe supports.

3.12.4.1.1 *ASME Boiler and Pressure Vessel Code*

DCD Tier 2, Section 3.12.2.1, “ASME Boiler and Pressure Vessel Code,” indicates that safety-related piping is designed using the ASME BPV Code, Section III, 2007 edition with 2008 addenda. The applicant stated that for socket weld leg dimensions, ASME BPV Code, Section III, Footnote 11, to Figure NC/ND-3673.2(b)-1, in the 1989 Edition is used for socket weld with leg size less than $1.09t_n$ instead of Footnote 13 from 2007 Edition and 2008 Addenda to Figures NC/ND- 3673.2(b)-1. This statement is consistent with the 10 CFR 50.55a(b)(1)(ii), limitation for socket welds in Subarticles NC-3600 and ND-3600, for ASME Class 2 and 3 piping. The applicant though did not discuss 10 CFR 50.55a requirements for ASME Class 1 socket weld dimensions. Therefore, the staff issued RAI 40-7958, Question 05.02.01.01-2, requesting the applicant to provide this information.

In its revised response to RAI 40-7958, Question 05.02.01.01-2 (ML15254A337), the applicant provided a markup for DCD Tier 2, Subsection 3.12.2.1, which shows that for ASME Class 1 weld leg dimensions, the requirements of Subparagraphs NB-3683.4(c)(1) and NB-3683.4(c)(2) are not applied for weld leg size less than $1.09t_n$. As modified, the information in the application meets the requirements in 10 CFR 50.55a(b)(1), for socket welds and, therefore, the staff finds the applicant’s response acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 40-7958, Question 05.02.01.01-2 is resolved and closed. RAI 40-7958, Question 05.02.01.01-2, is further discussed in SER Section 5.2.1.1.

3.12.4.1.2 *ASME Code Cases*

DCD Tier 2, Section 3.12.2.2, “ASME Code Cases,” states that ASME BPV Code Cases N-122-2, N-71-18 and N-249-14, are applicable for the design of the piping system and the piping supports of the APR1400 design and that other ASME BPV Code cases may be used if they are conditionally or unconditionally approved in RG 1.84. In Revision 36 of RG 1.84, dated August 2014, the staff accepted ASME BPV Code Cases N-122-2, N-71-18, and N-249-14. The staff also agrees that other code cases can be used in the design if they are approved in RG 1.84. Because RG 1.84 is incorporated by reference in 10 CFR 50.55a, the staff finds that the ASME BPV Code cases proposed by the applicant for the APR1400 design are acceptable. Additional staff evaluation of ASME Code cases is presented in SER Section 5.2.1.2.

3.12.4.1.3 *Design Specifications*

Section III of the ASME BPV Code, requires that design specifications be prepared for ASME Class 1, 2, and 3, components such as pumps, valves, and piping systems. The design specification is intended to become a principal document governing the design and construction of these components and should specify loading combinations, design data, and other design inputs. The Code also requires a design report for ASME Class 1, 2, and 3, piping and components at the completion of detailed design.

DCD Tier 2, Section 3.12.2.3, "Piping System Design Specification and Design Report," states that the design specifications and the design reports are to be developed in accordance with the ASME BPV Code, Section III. The staff reviewed four piping system design specifications along with piping stress analysis reports based on the scope of the graded approach during piping audits in September 2015, and June 2016, in order to verify that the applicant is implementing the design in accordance with the ASME BPV Code requirements. The staff identified and related to the applicant areas where the specifications were inconsistent with the DCD and also identified various errors in the pipe stress analysis reports that were available for audit. In addition, the staff identified that the applicant had omitted piping evaluations that included two sections of the feedwater (lines FW209 and FW219) from the containment penetration to the MSVH wall penetration. The staff also identified that the applicant had overlooked the environmentally assisted fatigue (EAF) evaluation of the reactor coolant loop piping. The applicant responded that it will update the specifications and correct stress reports and will also complete missing piping structural evaluations. The applicant also responded that it will reference RG 1.207, "Guidelines for Evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components Due to the Effects of the Light-Water Reactor Environment for New Reactors," dated March 2007 in the piping design specifications. During the 2017 APR1400 piping audit (ML18074A088), the staff audited the updated stress and fatigue analyses, as well as the resolution of observations from the September 2015, and June 2016, audits and found that the applicant has successfully updated its piping design specifications and calculation reports for identified errors and missing piping evaluations. In addition, the staff found that the applicants piping design structural evaluations follow NRC general guidance, meet ASME Section III and 50.55a requirements, and are consistent with relevant industry standards. Therefore, this issue is resolved and closed.

3.12.4.1.4 *Conclusions Regarding Codes and Standards*

Based on its review, as set forth above, the staff concludes that the piping systems important to safety are designed to quality standards commensurate with their importance to safety. The staff's conclusion is based on the following:

- The applicant satisfied the requirements of GDC 1 and 10 CFR 50.55a by specifying appropriate codes and standards for the design and construction of safety-related piping and pipe supports.
- The applicant identified ASME BPV Codes and Code cases that may be applied to ASME Class 1, 2, and 3 piping and pipe supports, which are acceptable to the staff because they are endorsed in RG 1.84.

3.12.4.2 *Piping Analysis Methods*

3.12.4.2.1 *Experimental Stress Analysis Method*

In DCD Tier 2, Section 3.12.3.1, “Experimental Stress Analysis Method,” the applicant stated that experimental stress analysis methods will not be used to qualify piping for the APR1400 design. The staff finds this acceptable per acceptance criterion II.A.i in SRP Section 3.12.

3.12.4.2.2 *Modal Response Spectrum Method*

DCD Tier 2, Section 3.12.3.2, “Modal Response Spectrum Method,” states that the modal response spectrum method consists of either the uniform support motion (USM) or the independent support motion (ISM) techniques.

The staff evaluated the modal response spectrum method and documented the results of this evaluation in the following sections.

Peak Broadening Method

DCD Tier 2, Section 3.12.3.2.2, “Floor Response Spectrum,” states that the peak broadened floor response spectra is generated according to RG 1.122, “Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components,” Revision 1, issued February 1978. SRP Section 3.7.2, “Seismic System Analysis,” Section II.5.C.(3a) provides the acceptance criteria for development of in-structure response spectra (ISRS) and states that the ISRS should be smoothed and broadened in accordance with the provisions of RG 1.122 to account for uncertainty.

Because the applicant’s peak broadening method is in accordance with the SRP recommendation, the staff finds this acceptable.

Further evaluation of the he applicant’s response spectra broadening method is presented in SER Section 3.7.2.

Uniform Support Motion Method

DCD Tier 2, Section 3.12.3.2.3, “Uniform Support Motion Method,” states that piping systems supported by structures located at multiple elevations within one or more buildings may be analyzed using USM. This analysis method applies a single set of spectra at all support locations, which envelopes all of the individual response spectra for these locations. The enveloped response spectrum is developed and applied in the two mutually perpendicular horizontal directions and the vertical direction. SRP Section 3.7.3, “Seismic Subsystem Analysis,” Section II.9 indicates that the USM method is a conservative and acceptable approach for analyzing component items supported at two or more locations to calculate the maximum inertial response of the component. Therefore, the staff finds the USM method is an acceptable method.

Modal Combination

DCD Tier 2, Section 3.12.3.2.4, “Modal Combination,” states that modal responses from individual modes are calculated and combined using Revisions 1 and 3, of RG 1.92, “Combining

Modal Responses and Spatial Components in Seismic Response Analysis.” For piping systems with no closely spaced modes, the representative maximum responses are obtained by taking the square root of the sum of the squares (SRSS). This is acceptable to the staff because the applicant’s position of combining modal responses with no closely spaced modes is in conformance with the staff’s recommendation in RG 1.92.

DCD Tier 2, Section 3.7.2.7, “Combination of Modal Responses,” shows that the combination of modal responses is performed in accordance with the latest (2012) revision of RG 1.92, which is Revision 3. DCD Tier 2, Section 3.7.1.2, “Percentage of Critical Damping Values,” shows that damping values are based on RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, dated March 2007. In contrast, DCD Tier 2, Section 3.12.3.2.4 states that RG 1.92, Revision 1, dated February 1976, and Revision 3, dated October 2012, are used for combination of modal responses. The staff issued RAI 311-8278, Question 03.12-8 (ML15320A349), requesting the applicant to provide a justification for the difference between DCD Tier 2, Sections 3.7.2.7 and Section 3.12.3.2.4, and an explanation for the different combinations of revisions of RG 1.61, and RG 1.92.

DCD Tier 2, Section 3.12.3.2.1, “General,” states that the response spectra analysis for piping will use damping values from the 2007 RG 1.61 Revision 1, which specifies 4 percent safe-shutdown earthquake (SSE) damping for piping. According to RG 1.92, Revision 3, Section C.1.1.1(2), for 4-percent damping, closely spaced modes are considered those that are within 20 percent of each other. DCD Tier 2 Section 3.12.3.2.4, shows that closely spaced modes are only those that are within 10 percent of each other and its proposed method for combining closely spaced modes when using a 4 percent damping does not include modes up to 20 percent of each other. The staff issued RAI 311-8278, Question 03.12-8 (ML15320A349), requesting the applicant also to provide additional information to justify using a definition for closely spaced modes different than that provided in staff guidance, such that the requirements of 10 CFR 50.55a can be demonstrated to be met.

In summary, the issue that the staff has identified and related to the applicant is that when seismic analysis is performed utilizing response spectrum analysis for piping, the DCD Tier 2 Section 3.12.3.2.4, specified method for combining modal responses does not follow NRC guidance and acceptance criteria. The applicant was requested to either follow NRC guidance or provide a technical justification which validates the method it used. In its revised response to RAI 311-8278, Question 03.12-8 (ML17058A177), the applicant chose to reevaluate the structural integrity of the piping using the methodology acceptable in the NRC guidance and criteria for seismic response spectrum analysis in RG 1.92, Revision 3, and provided DCD mark-ups. The staff finds the applicants response acceptable because the methodology to be used for piping seismic analysis is in accordance with applicable NRC guidance. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 311-8278, Question 03.12-8, is resolved and closed.

Directional Combination

DCD Tier 2, Section 3.12.3.2.5, “Directional Combination,” states that the responses due to each of the three spatial components of earthquake motion are combined using the SRSS method as provided in Regulatory Position C2.1 of RG 1.92, Revision 1. Because the applicant’s position is in conformance with staff’s recommendation in RG 1.92, the staff finds this acceptable.

Seismic Anchor Motion Analysis Method

The staff notes that, for piping systems that are anchored and restrained to floors and walls of structures that have differential movements during a seismic event, additional forces and moments due to the differential supporting structure movements are induced in the system.

DCD Tier 2, Section 3.12.3.2.6, "Seismic Anchor Motion Analysis Method," indicates that the maximum relative support displacements are obtained from the structural response calculations and that support displacements are then imposed in a conservative manner on the supported piping in the most unfavorable combination using the static analysis method for each of the three orthogonal directions with all dynamic pipe supports active. This is known as seismic anchor movement (SAM) analysis. DCD Tier 2, Section 3.12.3.2.6 shows that to obtain the cumulative effect of pipe support displacements, responses from the three orthogonal components are combined by the SRSS method, which is recommended in SRP Section 3.9.2. It also shows that for the USM method of analysis, the results of the SAM analysis are combined with the results of the dynamic SSE inertia analysis by the absolute sum method, which is also in accordance with SRP Section 3.9.2 guidance and, therefore, the staff finds it acceptable.

Independent Support Motion Method

The response spectra analysis is performed using either the USM method or the ISM method. DCD Tier 2, Section 3.12.3.3, "Independent Support Motion Method," describes the ISM method. The applicant stated that this method may be used when there is more than one supporting structure. In the analysis, the supports are divided into support groups. A support group is defined by supports that have the same time-history input. This usually means all supports located on the same floor (or portions of a floor) of a structure. The applicant stated that when the ISM method is used, damping values per RG 1.61, Revision 1, are utilized, which, therefore, is acceptable to the staff. The applicant stated that the responses caused by each support group are combined by the absolute summation method. The staff finds this acceptable because when this methodology is applied, each support group can be in a random-phase relationship to the other support groups. In DCD Tier 2, Section 3.12.3.3 the applicant specifies that the combinations of modal and directional responses for piping analyzed using ISM are performed in conformance to the recommendations of Section 2 in NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee," Volume 4, dated December 1984. Since this position meets the current staff position on ISM method of analysis presented in SRP Section 3.7.3, the staff finds this acceptable. Additional related staff evaluation on this subject is found in SER Section 3.7.3.

Time History Method

DCD Tier 2, Section 3.12.3.4, "Time-History Method," states that the time-history method may be used for dynamic analyses of piping systems subjected to hydraulic transient loadings induced by fluid flow transients or forcing functions induced by postulated pipe breaks. The applicant indicated that the time-history analysis may be performed using the modal superposition method. The modal superposition technique for time history analysis is used for linear elastic dynamic analysis. DCD Tier 2, Appendix 3.9B states that gaps in the support systems of the RCL are modeled in the RCL piping analysis model, which, due to the geometric nonlinearities of the gaps, requires nonlinear time-history analysis. This section, however, does

not specify the type of time-history analysis technique used (modal superposition method, direct integration method in the time domain or the complex frequency response method in the frequency domain). The staff issued RAI 334-8373, Question 03.12-10 (ML15348A120), requesting the applicant to identify which piping systems are evaluated using the time history analysis and specify the time-history analysis technique used.

In DCD Tier 2, Section 3.7.2.1.2, "Time-History Methods," for the modal superposition method, the applicant refers to ASCE Standard 4-98. As stated in RG 1.92, Revisions 2 and 3, as well as in further detail in NUREG/CR-6926, "Evaluation of the Seismic Design Criteria in ASCE/SEI Standard 43-05 for Application to Nuclear Power Plants," dated March 2007, this ASCE standard is not completely consistent with current NRC guidance and staff positions. ASCE 4-98, discusses an alternate method for considering the number of modes in a modal superposition analysis and states that the number of modes included shall be sufficient to ensure that inclusion of all remaining modes does not result in more than a 10 percent increase in the total response of interest. The current NRC technical position, as described in RG 1.92, Revisions 2 and 3, is that this approach is "non-conservative and should not be used." In RAI 334-8373, Question 03.12-10, the staff also requested the applicant to verify that when modal superposition time history analysis is used, its use is in conformance with the guidance described in RG 1.92, Revision 2 or 3, or justify an alternative approach.

In its response to RAI 334-8373, Question 03.12-10, Revision 3 (ML17087A453), the applicant provided the following. For the evaluation of specific dynamic loads, the main steam, the feedwater, and the safety injection/shutdown cooling lines were evaluated using the time-history analysis technique of the linear modal superposition method. The surge line was evaluated for branch line pipe break loads using the time-history analysis technique of the linear direct integration method. The RCL piping was evaluated using the time-history analysis technique of the linear complex frequency response method for seismic loads and the time-history analysis technique of the linear direct integration method for IRWST discharge loads. Nonlinear analysis was only performed for the RCL piping analysis due to branch line pipe break loads and it used the time-history analysis technique of the nonlinear direct integration method. The applicant stated in its response that in this analysis the material was considered as linear elastic using the material properties of ASME Code Section II. The applicant's response shows that the analyses were either linear elastic or in the case of the RCL piping the nonlinear analysis was performed on an elastic basis. This is acceptable to the staff on the basis that SRP Section 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," requires the staff to verify that piping system analyses are performed by the applicant on an elastic basis.

The applicant's response also stated that the nonlinear analysis of the RCL piping was due to the modeling of the gaps in the RCS component supports. Gaps in the component supports in the RCL piping analysis model are applied to the RPV, SG and PZR supports. These are critical gaps and are considered to be hot gaps that are required to be met at normal operating conditions. The applicant's response revised DCD Tier 2 Section 5.4.15.2, "Description," to show that the gaps in the RPV, SG and PZR supports are checked, recorded and adjusted by machining shims during the RCS hot functional test. The applicant's response also revised DCD Tier 2, test 14.2.12.1.51, "Pre-Core Reactor Coolant System Expansion Measurements", to address the control and verification of the component support design gaps. The applicant's response also revised DCD Tier 2, Section 3.12.3.4, to clarify the time history method was used for the piping systems. As requested by the staff's RAI, the applicant also verified that the modal superposition time history analysis method to evaluate the piping systems is used in

accordance with RG 1.92, Revision 3. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 334-8373, Question 03.12-10, is resolved and closed.

According to SRP Sections 3.7.1, 3.7.2, and 3.7.3, as well as RG 1.92, the time history method for dynamic analysis is acceptable to the staff. DCD Tier 2, Section 3.7.2, "Seismic System Analysis," provides descriptions of the dynamic analysis methods. The complete staff evaluation of the time-history analysis methods is presented in Section 3.7.2 of this SER report.

Inelastic Analyses Method

DCD Tier 2, Section 3.12.3.5, "Inelastic Analyses Method," states that inelastic analysis methods are not used to qualify piping and pipe supports for the APR1400 design. The applicant's decision not to use inelastic analysis methods is consistent with SRP Subsection 3.12, Subsection II.A.v and therefore acceptable to the staff.

Small Bore Piping Method

DCD Tier 2, Section 3.12.3.6, "Small-Bore Piping Method," states that for small-bore piping, either the equivalent static load method or the modal response spectrum method is used. The modal response spectrum method is evaluated in SER Section 3.12.4.2.2. According to SRP Section 3.9.2, Section II.2.A(ii), an equivalent static load method is acceptable if certain criteria are met. The applicant described its equivalent static load method of analysis. The applicant stated that to obtain an equivalent static load of a small-bore piping system, which is represented by a simple model, a factor of 1.5 is applied to the peak acceleration of the applicable floor response spectrum. The staff finds that this load factor is consistent with the equivalent load factor recommended in SRP Section 3.9.2, Section II.2.A(ii)(3) and, therefore, is acceptable.

The staff issued RAI 334-8373, Question 03.12-11 (ML15348A120), requesting the applicant to provide justification that, when the equivalent static load method is used, the use of a simplified model is realistic and the results are conservative, as described SRP Section 3.9.2, Section II.2.A(ii)(1). The staff also requested the applicant to clarify in the DCD that, when the equivalent static load method is used, the design and simplified analysis account for the relative motion between all points of support, as described in SRP Section 3.9.2, Section II.2.A(ii)(2). Finally, the staff requested that the applicant revise DCD Tier 2, Section 3.12.3.6, "Small-Bore Piping Method," to describe how the provisions of SRP Section 3.9.2, Section II.2.A(ii), are addressed or to justify an alternative approach.

In its response to RAI 334-8373, Question 03.12-11 (ML16050A533) and DCD Tier 2, Subsection 3.12.3.6 markup, the applicant showed that when the equivalent static load method is used for piping seismic analysis, it is applied based on SRP Section 3.9.2.II.2.A(ii), and added SRP Section 3.9.2 to its DCD Section 3.12 references. Because the applicant's DCD static seismic piping analysis is based on NRC guidance, the staff finds the applicant's response acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 334-8373, Question 03.12-11, is resolved and closed.

Non-seismic/Seismic Interaction

DCD Tier 2, Section 3.12.3.7, “Non-seismic/Seismic Interaction (II/I),” states that in the design of the APR1400 piping, the primary method of protecting seismic Category I piping is its isolation from piping that is not required to be designed to seismic Category I requirements. If isolation of the Category I piping system is not feasible or practical, adjacent non-Category I piping is classified by the applicant as seismic Category II and is analyzed in accordance with the same seismic design criteria applicable to the seismic Category I piping and pipe supports. Because the applicant’s position is consistent with SRP Section 3.9.2, Subsection II.2.K, the staff finds the applicant’s position acceptable.

Category I Buried Piping

According to the applicant’s response to RAI 88-8046, Question 03.05.02-4 (ML15240A210), the APR1400 design has no seismic Category I buried piping. The staff confirmed that the APR1400 DCD has incorporated the RAI response (ML15240A210) regarding Category I buried piping in DCD Tier 2, Section 3.12.3.8, which states “The APR1400 design has no seismic Category I buried piping.” Therefore, the staff finds that the applicant’s response (ML15240A210) regarding Category I buried piping has been properly incorporated in DCD Tier 2 Section 3.12.

3.12.4.2.3 Conclusions Regarding Piping Analysis Methods

Based on its review, as set forth above, the staff concludes that the structural evaluations of seismic Category 1 piping systems, as well as non-seismic Category I piping systems that are important to safety, are acceptable because they satisfy the requirements of GDC 2, by specifying appropriate analysis methods for designing piping and pipe supports to withstand seismic loads.

3.12.4.3 Piping Modeling Technique

3.12.4.4 Computer Codes

DCD Tier 2, Section 3.12.4.1, “Computer Codes,” lists the computer programs used in the design of APR1400 piping. Piping-related computer programs include PIPESTRESS, ANSYS, RELAP5/MOD3.3, GTSTRUDL, and RELAP5/MOD3.1. These computer programs have been accepted for use in past design certifications reviewed by the staff. In addition, during piping Audits in September 2015, and June 2016, it was revealed that computer codes AFPOST and NOZPROG have also been used in the APR1400 piping evaluation. All these programs are further described in DCD Tier 2, Section 3.9.1.2, “Computer Programs Used in Stress Analyses,” and the applicant’s use of these programs is evaluated by the staff in SER Section 3.9.1.

3.12.4.4.1 Dynamic Piping Model

In DCD Tier 2, Section 3.12.4.2, “Dynamic Piping Model,” the applicant provided its description for analytical modeling of piping systems. The applicant states that in the dynamic mathematical model, the distributed mass of the system, including pipe, contents, and insulation weight, is represented as lumped masses located at each node, which is designated as a mass point. Nodes are provided at points that define piping geometry, lump mass locations, locations

of structural or load discontinuities, flange locations, locations of concentrated weights, and at other locations of interest along the piping system.

The applicant also provided the formula used by the PIPESTRESS program for automatic lump mass modelling to determine the maximum spacing between two successive mass points. The formula is based on a simply supported beam that would produce a natural frequency equal to a preselected cut-off-frequency. The staff confirmed that the formula is derived from a simply supported beam dynamic evaluation.

The applicant also stated that if the distance between mass points exceeds one half of the span length for the simply supported beam when the automatic mass modeling is used, then additional mass points are generated. The staff confirmed this by comparing the formula stated in DCD Tier 2 Section 3.12.4.2, with the PIPESTRESS User's Manual. The PIPESTRESS program is a staff-accepted program for piping analysis and has been used in past DCDs that the staff has approved (see NUREG-1793). The purpose of its automatic mass modeling is to ensure that there are sufficient number of mass points for an accurate dynamic model.

The staff compared the applicant's description of dynamic pipe modeling to acceptance criteria provided in SRP Section 3.9.2, Section II.2, and found it acceptable because the applicant's use of modeling techniques, including the use of the PIPESTRESS program, provides reasonable assurance that the acceptance criteria for dynamic analysis provided in SRP Section 3.9.2, Section II.2.A(i), are met.

The staff notes that in some instances under deadweight and dynamic loadings, including seismic, the piping is supporting the mass of certain supports in the unrestraint direction of the support. Therefore, the staff issued RAI 311-8278, Question 03.12-7 (ML15320A349), requesting that the applicant describe how this situation is accounted for in the analysis and design of the APR1400 piping. In its response to RAI 311-8278, Question 03.12-7 (ML16020A507), and in DCD Tier 2 Section 3.12.4.2, the applicant showed that the weight added by the component support is included in the piping analysis as a lumped mass at the support point when it is greater than ten percent of the total mass of the adjacent pipe span including pipes, contents, insulation, and in-line components. The staff finds this acceptable because it is in accordance with the staff approved EPRI NP-5639, and past DCDs that the staff has approved (see NUREG-1793); therefore, RAI 311-8278, Question 03.12-7, is resolved and closed.

3.12.4.4.2 *Piping Benchmark Program*

DCD Tier 2, Section 3.12.4.3, "Piping Benchmark Program," states that piping benchmark problems in NUREG/CR-1677, Volume 1 and 2, issued August 1980, are used to validate the PIPESTRESS computer program used in piping stress analysis. The Staff finds this acceptable because it is in conformance with SRP Section 3.12, Subsection II.B.iii, and the acceptance criteria provided in SRP Section 3.9.1, Section II.2. The acceptability of all computer programs used in piping design, including the ones discussed in DCD Tier 2 Section 3.12.4.1, is evaluated by the staff in SER Section 3.9.1.

3.12.4.4.3 *Decoupling Criteria*

SRP Section 3.12, specifies that when a piping system is to be broken up into two parts with the input from the larger piping system used to analyze the smaller piping system, the acceptance decoupling criteria provided in SRP Section 3.7.2, is applicable. DCD Tier 2, Sections 3.7.2.3.2, “Decoupling Criteria for Subsystems,” and 3.7.2.3.3, “Modeling of Safety-related Structures,” specify decoupling criteria for piping similar to SRP Section 3.7.2. DCD Tier 2, Section 3.12.4.4, “Decoupling Criteria,” specifies a choice of two decoupling criteria for piping that are both different than those provide in the staff’s guidance in SRP Section 3.7.2 and those specified in DCD Tier 2, Section 3.7.2.3.2. Therefore, the staff issued RAI 311-8278, Question 03.12-6 (ML15320A340), requesting the following.

- If the branch piping geometry is known, the applicant should clarify whether the branch piping is included in the piping analysis model with the header. Otherwise, the applicant should provide a justification for decoupling the branch from the header.
- For branch piping with known geometry for which decoupling is justified based on the item above, the applicant should apply consistent decoupling criteria in accordance with those in DCD Tier 2, Section 3.7.2.3.2 or justify why the decoupling criteria in DCD Tier 2 Section 3.7.2.3.2, cannot be applied.
- DCD Tier 2, Section 3.12.4.4, includes as one of the decoupling criteria that, if only the size of the branch pipe is known, the branch pipe may be decoupled from the run pipe if the ratio of run to branch pipe moment of inertia is 25 to 1 or more. The Welding Research Council (WRC) Bulletin (BL) 300, “Technical Position on Damping and on Industry Practice,” provides the technical justification for using the moment of inertia ratio of 25 for decoupling with exceptions, which has been accepted by the NRC in past design certification applications (see NUREG-1793). Since this decoupling criterion is in DCD Tier 2, Section 3.12.4.4, the applicant is requested to refer to and add WRC BL 300 in the DCD Tier 2, Section 3.12 list of references and also show in DCD Tier 2, Section 3.12.4.4 that, as shown in WRC BL 300, if either of the following two factors apply, piping cannot be decoupled. If an alternative approach is selected, the applicant is requested to provide a technical justification.
 - a. If an anchor or fixed restraint on the branch pipe is located near the run pipe and significantly restrains the movement of the run pipe, the branch pipe should be included with the model of the run pipe, up to the anchor (or up to and including the series of fixed restraints that effectively permits termination of the problem at some point remote from the run pipe).
 - b. The branch pipe should be included in the computer model of the run pipe if more precise magnitudes of reactions are required at terminal points (i.e., equipment, penetrations, etc.) to determine their (the reactions) acceptability.

In its revised response to RAI 311-8278, Question 03.12-6 (ML16148B206), and its attached DCD markup, the applicant showed that in general, the large bore (LB) piping systems are designed when the geometry of the branch piping systems has not been determined. In these cases, the decoupling criteria and exclusions of WRC BL 300 will apply. In the case that the branch piping geometry is known, the decoupling of branch piping will be in accordance with

DCD Tier 2, Sections 3.7.2.3.2 and 3.7.2.3.3, which specify decoupling criteria for piping similar to SRP Section 3.7.2. Hence, based on its review, the staff determined that the applicant has successfully resolved the branch piping decoupling issues identified by the staff. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 311-8278, Question 03.12-6, is resolved and closed.

DCD Tier 2 Section 3.12.4.4, also shows that when the pipe run seismic analysis is performed without the decoupled branch, the branch mass effect is considered when the mass of half the span of the branch pipe is greater than 10 percent of the mass of the pipe run span. The staff reviewed this position and determined that the mass effect position is consistent with the position recommended in SRP Section 3.7.2, Section II.3.B.iii.

3.12.4.4.4 Conclusions Regarding Piping Modeling Technique

Based on its review, as set forth above, the staff concludes that the applicant has met Appendix B to 10 CFR Part 50, and GDC 1, by submitting information that demonstrates the applicability and validity of the design methods and computer programs used for the design and analysis of seismic Category I piping designated as ASME Code Class 1, 2, and 3.

3.12.4.5 Piping Stress Analysis Criteria

3.12.4.5.1 Seismic Input

In DCD Tier 2, Section 3.12.5.1, "Seismic Input Envelope vs. Site-Specific Spectra," the applicant states that the seismic input envelope and site-specific spectra of the APR1400 are described in DCD Tier 2, Subsection 3.7.2.5, "Development of In-Structure Response Spectra." In this section, the applicant described the development of floor response spectra for the APR1400 design. It stated that the time-history analysis using a complex frequency response method was used to generate the floor response spectra at wall and floor locations in the finite element models of the buildings and that the spectra are generated in accordance with the procedure given in RG 1.122. The staff's evaluation and acceptance of DCD Tier 2, Section 3.7.2.5 is documented in SER Section 3.7.2.

3.12.4.5.2 Design Transients

DCD Tier 2, Section 3.12.5.2, "Design Transients," states that RCS design transients used in the design and fatigue analysis of ASME Class 1 piping systems and supports are identified in DCD Tier 2, Table 3.9-1, "Transients Used in Stress Analysis." DCD Tier 2, Table 3.9-1 lists the design transients for various plant operating conditions and the number of cycles for each event, all of which are used in the stress analysis of ASME Class 1 and Class CS components of the primary system. The staff's evaluation of this information is documented in SER Section 3.9.1.

3.12.4.5.3 Loadings and Load Combinations

The loadings and load combinations presented in the application should be sufficiently defined to provide the basis for piping design for all applicable conditions. The acceptability is based on comparisons with positions in Appendix A to SRP Section 3.9.3, NUREG-0484, and ASME Section III. DCD Tier 2, Section 3.12.5.3, "Loadings and Load Combination," discusses the loads and load combinations used for the structural evaluation of ASME Class 1, 2 and 3

pipng. In DCD Tier 2, Section 3.12.5.3.10, "Load Combinations," the applicant states that in evaluating pipe stresses for APR1400 piping, it used the ASME BPV Code methodology and equations, which include evaluations for service levels A, B, C, and D, as well as testing. DCD Tier 2, Table 3.12-1, "Loading Combinations and Acceptance Criteria for ASME Section III, Class 1 Piping," and DCD Tier 2, Table 3.12-2, "Loading Combinations for Acceptance Criteria for ASME Section III Class 2 and 3 Piping," tabulate this information for the referenced piping systems.

In DCD Tier 2, Section 3.12.5.3, the applicant states that dynamic loads, other than high energy line breaks and SSE loads, are combined considering time phasing of the events and relationships considering the time phasing of the events. The applicant also states that when the time phasing relationship can be established, dynamic loads may be combined by the SRSS method, provided it is demonstrated that the non-exceedance criteria given in NUREG-0484, are met. When the time phasing relationship cannot be established, or when the non-exceedance criteria in NUREG-0484, are not met, dynamic loads are combined by absolute sum. The applicant also stated that SSE and high-energy line break loads are always combined using the SRSS method. The staff finds that the applicant's dynamic loads combination methods conform to the recommendations provided SRP Section 3.9.3. Therefore, the staff finds that the applicant's dynamic loads combination methods are acceptable.

The staff reviewed the proposed loads, load combinations, and stress limits given in the DCD Tier 2 sections and tables, discussed above, and concludes that appropriate combinations of normal operating transients and accident loadings are specified to provide a conservative design envelope for the design of piping systems. The load combinations and stress limits conform to the guidelines provided in SRP Section 3.9.3, and the Commission position in item 9 of the Staff Requirements Memorandum (SRM) on SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and ALWR Designs," regarding elimination of the OBE. Therefore, the staff finds that the load combinations for the ARP1400 piping design acceptable. Additional evaluation of these loading combinations with respect to analysis of other components is presented in SER Section 3.9.3.

The staff also compared the listed condition loadings, equations, and stress limits of DCD Tier 2, Tables 3.12-1 and 3.12-2, with the condition loadings, equations, and stress limits of ASME BPV Code, Section III, and concluded that the applicant's position is in compliance with the requirements of ASME BPV Code, Section III, as incorporated by reference into 10 CFR 50.55a. On this basis, the staff finds this acceptable.

In DCD Tier 2, Section 3.12.5.3.3, "Thermal Expansion," and Section 3.12.5.3.4, "Seismic," the applicant indicates that thermal anchor movements (TAMs) and seismic anchor movements (SAMs) less than 1.6 mm (1/16 inch) may be excluded from the piping analysis. The staff issued RAI 311-8278, Question 03.12-4 (ML15320A349), and RAI 334-8373, Question 03.12-13 (ML15348A120), requesting that the applicant provide additional information on its approach to demonstrate that when the piping analysis has excluded pipe restraint movement(s), adequate gap(s) exist in the as-built pipe supports to accommodate the excluded movement(s), including addressing applicable additive loads.

In its responses to RAI 311-8278, Question 03.12-4 and RAI 334-8373, Question 03.12-13 (ML16195A537 and ML16050A533, respectively), the applicant provided DCD markups that delete sentences from DCD Tier 2, Sections 3.12.5.3.3 and 3.12.5.3.4 for excluding TAMs and

SAMs less than 1.6 mm (1/16 inch), which is acceptable to the staff. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 311-8278, Question 03.12-4 and RAI 334-8373, Question 03.12-13, is resolved and closed.

DCD 3.12.5.3.5, Fluid Transient Loads, discusses piping loads due to water hammer and states that water hammer loads are considered in Level B, or D service load combinations. The staff issued RAI 549-8856, Question 03.12-19 (ML17188A454), requesting the applicant to discuss how potential cavitation effects and vibration, originating from the operation of the safety injection tank and its fluidic device (SIT-FD), have been taken into account in the structural design evaluation of the SIT, its discharge piping and pipe supports. The staff also requested the applicant to discuss whether the operation of the SIT with its FD can result in other phenomena, such as water hammer, and how their effects have been accounted for in the structural design of the safety injection tank, discharge piping and pipe supports.

In its response to RAI 549-8856, Question 03.12-19 (ML17332A108), the applicant provided pertinent pipe stress and pipe support calculations. The applicant evaluated fluid dynamic loads, which included water hammer loads that could potentially occur in the safety injection line due to the safety injection pump operation and due to the safety injection tank discharge. The staff reviewed the derivation of these fluid dynamic loads and found them acceptable due to the conservatism in the method used. The applicant incorporated these fluid dynamic loads in the load combinations for pipe stress and pipe support design to evaluate the structural integrity of piping and its supports. The staff reviewed the applicant's work presented in the RAI response along with pertinent pipe stress and pipe support calculations that the staff had audited. With the inclusion of water hammer and/or fluid dynamic loads the pipe stresses are shown to be within their ASME Section III allowable values and the pipe supports are found to be within their rated capacity. Therefore, the staff found the applicant's response acceptable regarding the effects of fluid dynamic loads, including water hammer loads on the structural integrity of the safety injection piping and pipe supports. Regarding vibration effects on piping and pipe supports due to the operation of the safety injection tank, the applicant in its response modified the Safety Injection Tank Subsystem Test, DCD Tier 2 Section 14.2.12.1.22, to assure that vibration levels are within acceptable limits. Because the applicant's response and modified DCD test show that the vibration levels will be evaluated for acceptability in accordance with the ASME OM-SG Part 3, the staff finds the applicant's response regarding vibration effects acceptable. Based on its review, summarized above, the staff finds that RAI 549-8856, Question 03.12-19, has been successfully resolved. In addition, based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 549-8856, Question 03.12-19, is resolved and closed.

3.12.4.5.4 *Damping Values.*

DCD Tier 2, Section 3.12.5.4, "Damping Values," states that damping values used in the seismic analysis of the APR1400 piping systems are in accordance with Table 3 of RG 1.61, Revision 1. The applicant also addresses use of the USM response spectra method of seismic analysis, which uses an envelope of response spectra at all support points. When this method is used, the applicant states that frequency-dependent damping values shown in Figure 1 of RG 1.61, Revision 1, may also be used in the analysis, provided the five restrictions identified in the staff's regulatory position C.2 of RG 1.61, Revision 1 are maintained. Because the applicant's position is in conformance with staff's recommendations in RG 1.61, Revision 1, the staff finds this acceptable.

3.12.4.5.5 *Combination of Modal Responses*

DCD Tier 2, Section 3.12.5.5, "Combination of Modal Responses," states that seismic responses to each mode are calculated in accordance with the method described in RG 1.92, Revision 1 and combined with other responses. The staff's evaluation of the applicant's combination of modal responses is documented in SER Section 3.12.4.2.2.

DCD Tier 2, Section 3.12.3.2.4, "Modal Combination," shows that closely spaced modes are combined with the grouping method of RG 1.92, Revision 1. The grouping method is described in Subsection C.1.2.1 of RG 1.92, Revision 1. The same statement about the grouping method is made in DCD Tier 2, Section 3.9.2.2.6, "Combination of Modal Responses." In contrast, DCD Tier 2, Section 3.12.5.5, shows that closely spaced modes are combined with the 10-percent method of RG 1.92, Revision 1. The 10-percent method is described in Section C.1.2.2 of RG 1.92, Revision 1. The staff issued RAI 334-8373, Question 03.12-14 (ML15348A120), requesting the applicant to explain this difference and revise the DCD as appropriate.

In its response to RAI 311-8278, Question 03.12-8 (ML15320A349), the applicant had chosen to reevaluate the structural integrity of the piping following proper NRC guidance and criteria for seismic response spectrum analysis. In its revised response to RAI 334-8373, Question 03.12-14 (ML17058A191) and in the DCD Tier 2, Section 3.12.3.6 markup, the applicant committed to delete the entire discussion contained in DCD Tier 2, Section 3.12.5.5, after the piping analyses have been completed. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above and via its piping audit has verified that the DCD seismic methodology has been followed in the piping analyses; therefore, RAI 334-8373, Question 03.12-14, is resolved and closed.

3.12.4.5.6 *High-Frequency Modes*

In DCD Tier 2, Section 3.12.5.6, "High-Frequency Modes," the applicant shows that that response of high frequency rigid modes is considered in the response of the piping system either by the ANSYS computer program, which uses the missing-mass correction method, or by the PIPESTRESS computer program, which uses the left-out-force method.

The staff reviewed the above two methods presented by the applicant. The missing-mass method used in ANSYS is a method contained in guidance of RG 1.92, Revision 3, and therefore, is acceptable to the staff. The use of the left-out-force method in PIPESTRESS is also acceptable to the staff, as it is consistent with past precedent for new reactor piping analysis, such as the staff's evaluation documented in NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design," dated September 2004, Section 3.12.5.6, "High-Frequency Modes."

3.12.4.5.7 *Fatigue Evaluation for ASME Class 1 Piping*

In DCD Tier 2, Section 3.12.5.7, "Fatigue Evaluation of ASME Code Class 1 Piping," the applicant states that ASME Class 1, piping is to be evaluated for the effects of fatigue due to thermal and pressure transients, thermal stratification, and other cyclic events including earthquakes.

In Note 7 of DCD Tier 2, Table 3.12-1, the applicant shows that for fatigue analysis of Class 1 piping, if the earthquake inertial load is taken as the peak SSE inertial load, then 20 cycles of earthquake loading are considered. If the earthquake inertial load is taken as one-third of the peak SSE inertial load, then the number of cycles to be considered for earthquake loading is the equivalent number of 20 full SSE cycles. The staff reviewed the applicant's position and found it acceptable, as it is consistent with the staff's guidance in SRP Section 3.7.3, Revision 4, and the position on elimination of the OBE documented in the SRM on SECY-93-087.

DCD Tier 2, Section 3.12.5.7 shows that the applicant accounts for the environmental effects of the reactor coolant in the fatigue evaluation of ASME Class 1 piping in accordance with the guidance presented in RG 1.207. The staff finds this acceptable because the methodology conforms to the NRC guidance.

3.12.4.5.8 Fatigue Evaluation for ASME Class 2 and 3 Piping

In DCD Tier 2, Section 3.12.5.8, "Fatigue Evaluation of ASME Code Class 2 and 3 Piping," the applicant shows that ASME Class 2 and 3 piping is evaluated for thermally induced fatigue by following the requirements of the ASME BPV Code, Section III. The applicant also indicates that it is not required to meet the limits of Equation 10(a) in NC/ND-3653.2. This is acceptable to the staff because per NC/ND-3653.2, in satisfying the requirements for thermal expansion either eq. (10a) or eq. (11), and eq. (10b) must be met. The staff finds this acceptable because the proposed fatigue evaluation meets the requirements of the ASME BPV Code, as incorporated by reference in 10 CFR 50.55a.

3.12.4.5.9 Thermal Oscillations in Piping Connected to the Reactor Coolant System

Thermal stratification, cycling, and striping (TASCS) are thermal mechanisms that have caused significant damage to power plant pressure boundary components—most commonly fatigue cracking of piping. NRC BL 88-08, "Thermal Stresses in Piping Connected to Reactor Cooling Systems," issued June 22, 1988, requested licensees to identify and evaluate the piping systems connected to the RCS that were susceptible to TASCS to ensure that the piping will not be subjected to unacceptable thermal stresses. The bulletin recommended nondestructive examinations of potentially affected pipes to assure that no flaws exist, as well as the development and implementation of a program to provide continuing assurance of piping integrity. Ways to provide this assurance include designing the system to withstand the cycles and stresses from valve leakage, instrumenting the piping to detect adverse temperature distributions and establishing appropriate limits, and providing a means to monitor pressure differentials that may indicate valve leakage.

While the applicant was not an addressee of this bulletin, the operating experience described in the bulletin should be incorporated in the design in accordance with 10 CFR 52.47(a)(22). As such, SRP Section 3.12, includes criteria related to this bulletin, to the extent that the issue applies to a given design.

In DCD Tier 2, Section 3.12.5.9, "Thermal Oscillations in Piping Connected to the Reactor Coolant System," the applicant indicated that APR1400 conforms to the provisions in BL 88-08, for all piping connected to the RCS and that data available from the reference plant have been evaluated and incorporated into the design of the APR1400.

The staff issued RAI 334-8373, Question 03.12-15 (ML15348A120), requesting the applicant to provide the following additional information to support the staff's finding related to this provision in SRP Section 3.12, and the requirement in 10 CFR 52.47(a)(22), related to operating experience. To the extent that the response addresses programmatic or operational activities that are outside the scope of design certification, the applicant was requested to describe these and include in the DCD a provision for COL applicants to describe these activities.

- Identify all piping connected to the RCS susceptible to TASCs and discuss the methodology followed for evaluating the effects of TASCs.
- Discuss features in the design that provide assurance against thermal stratification and thermal oscillation.
- Discuss whether a program has been established to monitor temperature distributions in affected piping and establish appropriate temperature limits.
- Discuss means to monitor pressure differentials that may lead to valve leakage.
- Identify the "reference plant," mentioned in DCD Tier 2, Section 3.12.5.9 and discuss its similarities to the APR1400.
- Discuss the data collected from the reference plant and the methodology followed in using these data for the evaluation of TASCs in the APR1400 design.

Licensees of U.S. nuclear plants customarily use guidance found in the EPRI Materials Reliability Program (MRP) report MRP-146, "Management of Thermal Fatigue in Normally Stagnant Non-Isolable Reactor Coolant System Branch Lines," to address NRC BL 88-08. In its response to RAI 334-8373, Question 3.12-15 (ML16050A533), the applicant utilized the EPRI MRP-146, to assess and investigate which lines are susceptible to TASCs issues addressed in BL 88-08 and discussed design features in APR1400 piping that could potentially preclude TASCs susceptibility. Such design features in APR1400 include:

- Safety injection lines through the direct vessel injection (DVI) nozzle intersect at a side orientation.
- No charging lines that are not in service.
- RCS drain lines are 2 inches and are not susceptible to TASCs because of the long length of vertical line.
- No excess letdown lines.
- Common lines for shutdown cooling (SDC) suction lines and safety injection lines to hot leg injection intersect at the bottom orientation.

As a result of its assessment, the applicant determined that the following lines connected to the RCS are considered to be still susceptible to TASCs:

- Safety injection (SI) lines through the DVI nozzle.

- Shutdown cooling suction (SCS) lines.

The applicant stated that because the SI system has a dedicated safety injection pump (no connection lines from the charging pump), the pressure in the SI system is always lower than the normal RCS operating pressure and, therefore, no actual in-leakage to the RCS from the safety injection lines is expected. It assumed though, a small amount of in-leakage to the RCS from the SI lines, which provides conservative results for the SI lines. In evaluating the effects of thermal stratification on the piping, the applicant determined the temperature distribution for the SI lines and SCS lines inside the piping were determined by performing thermal hydraulic analysis using computational fluid dynamics. The applicant applied the temperature distribution data to the piping model to determine stress intensities. Because the APR1400 design precludes in-leakage to the RCS, as indicated above, the applicant concluded that pressure differences and temperature monitoring is not necessary. The staff finds this acceptable because according to BL 88-08 stratification could potentially exist, and needs to be monitored, only when in-leakage to the RCS can occur from unisolable piping. The applicant stated that the piping layout of the APR1400 is the same as the Shin-Kori Units 3 and 4, in Korea and that the primary system operating parameters of the APR1400 are identical to those of Shin-Kori Units 3 and 4. Therefore, the applicant used the temperature distributions from Shin-Kori Units 3 and 4, in the piping analysis for thermal stratification of the APR1400 SIS and SCS. The staff finds this acceptable, since the operating conditions and the piping layout are the same, the temperature distributions inside the relevant piping would also be the same. Based on its review, as summarized above, the staff concludes that the applicant has adequately responded to RAI 334-8373, Question 03.12-15, which, therefore, is considered resolved and closed.

In addition, the staff verified during the piping audit in September 2015, and June 2016, that the structural evaluation of the DVI SI and SCS lines included stratification load cases. Global stratification bending moments were calculated from ANSYS and inputted into PIPESTRESS. Local thermal stratification stresses from ANSYS were converted in to NB-3600, stress equation terms (ΔT_1 , ΔT_2 and $T_a - T_b$) and input to the PIPESTRESS program. The audited calculations showed that the resulting stresses and fatigue usage (including EAF) met the requirements of NB-3600. The staff also finds that the applicant has used methodology and criteria consistent with industry practice to address NRC Bulletin 88-08.

3.12.4.5.10 *Thermal Stratification*

NRC BL 88-11, and SRP Section 3.12, discuss the potential for stresses induced by thermal stratification in the PZR SL. In particular, BL 88-11 requested that licensees at the time establish a program that would monitor the surge line for the effects of thermal stratification beginning with hot functional testing (HFT).

While the applicant was not an addressee of this bulletin, the operating experience described in the bulletin should be incorporated in the design in accordance with 10 CFR 52.47(a)(22). As such, SRP Section 3.12 includes criteria related to this bulletin, to the extent that the issue applies to a given design.

DCD Tier 2, Section 3.12.5.10, "Thermal Stratification," states that the APR1400 conforms to BL 88-11, but the APR1400 DCD does not include the description of a program to implement monitoring of the PZR SL consistent with BL 88-11, and SRP Section 3.12. The staff issued RAI 70-8027, Question 03.12-3 (ML15196A596), requesting the applicant to provide the following additional information.

- Please confirm that the structural integrity evaluation of the APR1400 PZR SL includes consideration of thermal stratification and thermal striping to ensure that fatigue and stresses are in compliance with applicable code limits.
- The presentation in DCD Tier 2, Section 3.12.5.10 on thermal stratification with regard to the PZR SL is rather general. Please revise the DCD to describe APR1400 PZR SL features and operational procedures that address the structural integrity issues raised by BL 88-11 in minimizing SL stratification.
- According to BL 88-11, thermal stratification occurs in the PZR SL during heatup, cooldown, and steady-state operations of the plant. Please discuss whether a monitoring program is planned to verify the design transients used in the structural design of the surge line or how this verification will take place. Describe the program, testing, and its implementation, consistent with BL 88-11 and SRP Section 3.12, that will demonstrate that stratification temperature measurements for the APR1400 PZR SL will be within acceptable analyzed limits, that there will not be unanalyzed thermal cycles, and that piping thermal deflections result in no adverse consequences (such as contacting the pipe whip restraints). In addition, add, or provide a technical justification for not including HFT activities in DCD Tier 2, Section 14.2, "Initial Plant Test Program," to monitor the PZR SL stratification, which should continue at least during the first cycle of plant operation.
- Given that PZR SL monitoring is the responsibility of a COL licensee, please discuss (with DCD revisions such as COL items as appropriate) what these responsibilities would be.

In its revised response to RAI 70-8027, Question 03.12-3 (ML16251A336), the applicant showed that the structural evaluation of the APR1400 PZR SL, includes consideration of thermal stratification and thermal striping and stated that the evaluation results confirmed that fatigue usage and stresses are in compliance with the ASME Code limits considering thermal stratification and thermal striping. This was also verified by the staff during the piping audit. Therefore, the staff finds that the applicant has adequately addressed RAI 70-8027, Question 03.12-3, request 1.

In horizontal lines, hotter fluid flowing over colder fluid without considerable mixing gives rise to the phenomenon of thermal stratification. The applicant's response and DCD markups for DCD Tier 2, Subsection 3.12.5.10, show that the pressurizer surge line has design features to minimize surge line thermal stratification. The horizontal section between the pressurizer and the hot leg is designed with a minimum downward slope of 1/16 inch per foot from the pressurizer. The surge line vertical length that includes the nozzle from the hot leg is of sufficient length to prevent the hot leg colder water from entering the surge line horizontal leg beyond the take-off. It is also shown that operational procedures are in place to control surge line thermal stratification. During normal power operation, a continuous bypass spray flow is

maintained to suppress turbulent penetration from the hot leg flow. The pressurizer versus hot leg temperature differential is limited during heatup and cooldown below the design temperature differential of 188.9 °C (340 °F). This is established by conservatively assuming that the pressurizer is heated up to the maximum system pressure for SCS alignment. This temperature difference is established as the design criteria for the surge line and the system operating procedure for heatup and cooldown. Differential temperature limits are specified in the operating procedures. The staff verified during the piping audits that the surge line structural evaluation included stratification load cases, including the maximum thermal stratification flow condition with temperature delta of 340 °F. Based on its review, the staff finds that the applicant has adequately addressed RAI 70-8027, Question 03.12-3, request 2.

In its response to RAI 70-8027, Question 03.12-3 (ML16251A336), the applicant included DCD markups, which provide DCD Tier 2 test modifications and additions for the PZR SL monitoring, which will be implemented during the first preoperational testing (i.e., during initial startup of each plant) and continue to be monitored during the first cycle of operation. The DCD Tier 2 markups add pre-core test No. 14.2.12.1.140, "Pre-Core Pressurizer Surge Line Stratification Test," for the COL applicant to monitor the temperature distribution on the PZR SL during APR1400 plant HFT and collect data to demonstrate that the temperature measurements due to surge line stratification are within design limits.

The DCD markups also add a power ascension test, test No. 14.2.12.4.27, to demonstrate, as stated in the test, that the Fatigue Monitoring System (FMS) functions are as designed to monitor the fatigue usages for the identified locations, including the surge line which will experience thermal stratification. Temperature monitoring of the surge line will continue using the FMS during the first cycle of operation to verify the design transients used in the structural design of the surge line. In addition, test No. 14.2.12.1.51, "Pre-Core Reactor Coolant System Expansion Measurements," is to be modified by adding the monitoring of the surge line to demonstrate that surge line movements due to stratification are within design limits. DCD Tier 2 markups also modify pertinent DCD Tier 2 tables to show the test additions and modifications. Based on its review above, the staff finds that the applicant has adequately addressed RAI 70-8027, Question 3.12-3, requests 3 and 4, pertaining to SRP Section 3.12, and BL 88-11, which requires analysis and hot functional testing to verify that piping thermal deflections result in no adverse consequence.

Based on its review shown above, the staff finds the applicant's response to RAI 70-8027, Question 3.12-3, acceptable. In addition, based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 70-8027, Question 3.12-3, is resolved and closed. It is noted that at the time of the RAI 70-8027, Question 3.12-3 response (ML16251A336), the added FMS Test was identified as test No. 14.2.12.4.27. Due to numbering changes, this test in DCD Revision 3, is identified as test No. 14.2.12.4.26.

NRC BL 79-13 addresses the effect of thermal stratification that can lead to cracking of the FW line. Thermal stratification could occur in horizontal sections of piping when the incoming FW flow rate is low and there is a large temperature difference between the incoming FW and the steam generator coolant, which results in a density difference.

DCD Tier 2, Section 3.12.5.10 states that APR1400 FW lines are designed to minimize thermal stratification. It also states that this is addressed in DCD Tier 2, Section 5.4.2.1.2.1.3, "Thermal Stratification at Feedwater Nozzle." This section refers to BL 79-13, and the effects of thermal

stratification in the FW line. It states that the FW lines are angled downward from the horizontal to minimize the potential for thermal stratification. It also states that the upward bend using a goose-neck design is incorporated to avoid the stratified flows in the piping connecting the thermal sleeve in the downcomer FW nozzle to the downcomer FW piping inside the steam generator. The staff's evaluation of this design information is documented in SER Section 5.4.2.

3.12.4.5.11 *Safety Relief Valve Design, Installation, and Testing*

In DCD Tier 2, Section 3.12.5.11, "Safety Relief Valve Design, Installation, and Testing," the applicant stated that the design and installation of safety and relief valves for overpressure protection are performed to the criteria specified in Appendix O, "Rules for the Design of Safety Valve Installations," of the ASME BPV Code, Section III, Division 1. The applicant also stated that a static method is used with a conservative dynamic loading factor (DLF) to calculate the discharge forces of safety valves and relief valves for open discharge to the atmosphere. In DCD Tier 2, Section 3.9.3.2.3, the applicant stated that this DLF is equal to 2.0.

According to SRP Section 3.9.3, Subsection II.2, for pressure relief device design and installation, the applicant should use the design criteria for pressure relief installations specified in ASME BPV Code, Section III, Division 1, Appendix O. SRP Section 3.9.3, Section II.2.C, also specifies that a DLF of 2 may be used in lieu of a dynamic analysis to determine the DLF.

Because the applicant's design for safety relief valve installation is in conformance to SRP Section 3.9.3, the staff finds the applicant's approach acceptable. The testing of valves is reviewed and documented in SER Section 3.9.6.

3.12.4.5.12 *Functional Capability*

DCD Tier 2, Section 3.12.5.12, "Functional Capability," indicates that the functional capability provisions for ASME Class 1, 2, and 3, piping systems needed to provide an adequate fluid flow path under Level D service loading conditions are consistent with the guidance of NUREG-1367, "Functional Capability of Piping Systems," dated November 1992. Since the applicant committed to satisfy the provisions of NUREG-1367, which is the current Staff guidance related to functional capability referenced in SRP Section 3.12, the staff finds this acceptable.

In addition, NUREG-1367 was developed to address concerns that increased ASME BPV Code Level D stress limits were high enough that the functional capability of piping subject to such stresses was called into question. The staff observes that where the ASME BPV Code of record for a given plant is before the 1992 Edition with 1994 Addenda or after the 2004 Edition with 2005 Addenda, the Level D stress limits in the ASME BPV Code are considered sufficient to ensure piping functional capability consistent with NUREG-1367. Therefore, the applicant's use of the ASME BPV Code, 2007 Edition with 2008 Addenda, is in itself sufficient to address the primary concern related to this acceptance criterion within SRP Section 3.12. The applicant's adherence to NUREG-1367, Section 9.1 of which includes several additional provisions to confirm functional capability, provides additional confidence that functional capability will be maintained.

3.12.4.5.13 *Combination of Inertial and Seismic Anchor Motion Effects*

DCD Tier 2, Section 3.12.5.13, "Combination of Inertial and Seismic Anchor Motion Effects," states that the inertial effects and anchor movement effects due to an earthquake are analyzed separately. The results from these two separate analyses are combined by the absolute summation method when the enveloped USM method is used in the dynamic analysis, per SRP Section 3.7.3. When the independent support motion method is used in the dynamic analysis, the inertial effects and anchor movement effects due to an earthquake are combined using the SRSS method, per NUREG-1061. Since the applicant's approach is consistent with the staff guidance, the staff finds this acceptable.

3.12.4.5.14 *Operating-Basis Earthquake as a Design Load*

In DCD Tier 2, Section 3.12.5.14, "Operating-Basis Earthquake as a Design Load," the applicant states that for the APR1400 piping design the earthquake load used is described in DCD Tier 2, Section 3.7. It also states that because the OBE has been set as 1/3 of the SSE it is not considered explicitly in the seismic design. The staff reviewed the applicant's position for eliminating the OBE from the piping design and found it acceptable, as it is in accordance with the staff's guidance in SRP Section 3.7.3, Revision 4, and the Commission position in the SRM on SECY-93-087. The staff's position on the use of a single earthquake is also discussed in SER Section 3.12.4.4.3 and 3.12.4.4.7. The staff's evaluation of DCD Tier 2 Section 3.7, is documented in SER Section 3.7.

3.12.4.5.15 *Welded Attachments*

In some cases, welded pipe attachments are needed to transfer pipe loads to pipe supports. In DCD Tier 2, Section 3.12.5.15, "Welded Attachments," the applicant states that when integral welded pipe attachments are used in the pipe restraint design of the APR1400, they are evaluated in accordance with Appendix Y, "Evaluation of the Design of Rectangular and Hollow Circular Cross Section Welded Attachments on Class 1, 2, and 3 Piping," of ASME BPV Code, Section III.

Although the non-mandatory appendices to ASME BPV Code, Section III, are not incorporated by reference into 10 CFR 50.55a, the staff observes that the technical provisions for welded attachments of Appendix Y are the same as those provided in the following ASME BPV Code Cases: N-122-2, N-318-5, N-391-2, and N-392-3. ASME annulled these code cases after Appendix Y was added to ASME BPV Code, Section III, but they remain accepted by the staff without conditions in RG 1.84, Revision 36, which is currently incorporated by reference in 10 CFR 50.55a. The staff finds the use of ASME BPV Code, Section III, Appendix Y, for the evaluation of integral pipe welded attachments acceptable, given that this appendix provides industry-accepted guidance for ensuring the quality of these welded attachments and that the staff previously approved the technical content of this appendix in RG 1.84, which was incorporated by reference into 10 CFR 50.55a.

3.12.4.5.16 *Modal Damping for Composite Structures*

In DCD Tier 2, Section 3.12.5.16, "Modal Damping for Composite Structures," the applicant states that the composite modal damping for coupled building and piping systems is used for piping systems that are coupled to concrete building structures, if applicable. The applicant's

composite modal damping is addressed in DCD Tier 2, Section 3.7.2.14, "Determination of Dynamic Stability of Seismic Category I Structures." The staff's evaluation of DCD Tier 2, Section 3.7.2.14, is documented in SER Section 3.7.2.

3.12.4.5.17 *Minimum Temperature for Thermal Analyses*

In DCD Tier 2, Section 3.12.5.17, "Minimum Temperature for Thermal Analyses," the applicant states that the stress-free state temperature [zero thermal load] is 21.1 °C (70 °F). Piping with an operational temperature of greater than 65 °C (150 °F) or less than 4 °C (40 °F) is evaluated to assess the effects of thermal expansion or contraction. The stress-free reference temperature is identical to that provided in SRP Section 3.12 and is acceptable to the staff. In addition, the temperature values above and below which thermal effects are evaluated are those typically used by the industry and the staff finds this acceptable.

3.12.4.5.18 *Intersystem Loss-of-Coolant Accident*

An intersystem loss-of-coolant accident (ISLOCA) is defined in NRC Information Notice (IN) 92-36, as "a class of accidents in which a break occurs in a system connected to the reactor coolant system (RCS), causing a loss of the primary system inventory." In DCD Tier 2, Section 3.12.5.18, "Intersystem Loss-of-Coolant Accident," the applicant stated that the design features of low-pressure piping systems that interface with (RCPB are described in DCD Tier 2, Appendix 5A, "Evaluation of the APR1400 Design and Intersystem Loss-of-Coolant Accident Challenges."

In DCD Tier 2, Appendix 5A, the applicant stated that the design responses to ISLOCA challenges described in this appendix are evaluated against acceptance criteria consistent with the guidance in IN 92-36. Because the applicant's position follows the NRC guidance, the staff finds it acceptable within the review scope of this section. In addition, DCD Tier 2, Appendix 5A states that the evaluation approach is to assume that the system design incorporates all of the requirements necessary to satisfy the GDC and then to consider the exposure of a low-pressure system to full RCS pressure. This provides reasonable assurance of compliance with the applicable NRC design requirements and, therefore, the staff finds it acceptable within the review scope of this section. Additional evaluation of this topic is provided in SER Chapter 5.

3.12.4.5.19 *Effects of Environment on Fatigue Design*

DCD Tier 2, Section 3.12.5.7 states that the fatigue evaluation of ASME Class 1, piping takes into consideration the effects of the reactor coolant environment and follows the guidance presented in RG 1.207. SRP Section 3.12, Subsection II.C.xix indicates that the guidance provided in RG 1.207, is an appropriate means of characterizing the effects of environment on fatigue design. Because the APR1400 piping design addresses the effects of environment on fatigue life in conformance with the guidance in RG 1.207, the staff finds this acceptable.

3.12.4.5.20 *Piping Evaluation For High Frequency Seismic Input*

The seismic analysis and design of the APR1400 standard plant are based on the CSDRS. Additionally, the APR1400 standard plant is evaluated for the potential effects of hard rock high frequency (HRHF) seismic response spectra.

DCD Tier 2, Section 3.7B.7.3, "Piping System," shows that ASME Class 1, 2, and 3, piping systems are evaluated for HRHF seismic response spectra. DCD Tier 2 Section 3.7B.1, identifies that the HRHF response spectra exceed the CSDRS for frequencies above approximately 10 Hz. DCD Tier 2 Section 3.7B.7, "Evaluation," discusses the HRHF evaluation of selected SSCs. DCD Tier 2, Sections 3.7B.1, "Overview," and 3.7B.6, "General Selection Screening Criteria," show that piping is among the SSCs that were selected to be evaluated for the effects of HRHF as part of the design certification application. DCD 3.7B.7.3 though shows that HRHF effects are to be evaluated by the COL applicant. Therefore, the staff issued RAI 311-8278, Question 03.12-9 (ML15320A349), requesting the applicant to provide a justification for this inconsistency. In addition, the staff requested the applicant to provide a technical justification for not having evaluated the piping that was selected in the graded approach identified in DCD Tier 2, Section 14.3.2.3 for HRHF seismic effects.

In its revised response to RAI 311-8278, Question 03.12-9 (ML16148B206), the applicant stated that since the graded approach is applied to the piping design, the HRHF evaluation of piping systems within the scope of the graded approach will be performed by KHNP.

In its second revised response to RAI 311-8278, Question 03.12-9 (ML17174B269), the applicant presented its evaluation for the HRHF spectra for piping systems in the scope of the graded approach and included the Class 1 RCS main loop, pressurizer surge line, direct vessel injection line, and shutdown cooling lines. For class 2 piping, it included the main steam and main feedwater piping inside containment and in the main steam valve housing. The HRHF response spectra evaluation for piping is included in Technical Report, APR1400-E-S-NR-14004, Revision 2, "Evaluation of Effects of HRHF Response Spectra on SSCs." Applicable sections of this report to the graded approach for piping are included in the RAI 311-8278, Question 03.12-9, revised response as well as DCD markups for DCD Tier 2, Table 1.8-2, "Combined License Information Items," Subsections 3.7B.7.3 and 3.7B.8, "Combined License Information." The staff reviewed the applicant's HRHF piping evaluation and found it acceptable because it meets the ASME Section III Code, allowable stress limits. Based on the review of the DCD and Technical Report PR1400-E-S-NR-14004, Revision 3, the staff has confirmed incorporation of the changes described above; therefore, RAI 311-8278, Question 03.12.-09, is resolved and closed.

The staff's acceptance evaluation of the CSDRS and HRHF are presented in SER Section 3.7.1.

3.12.4.5.21 *Conclusions Regarding Piping Stress Analysis Criteria*

Based on its review, as set forth above, and upon successful resolution of the confirmatory items discussed above, the staff concludes that the applicant has met the following requirements with regard to piping stress analysis criteria:

- GDC 1 and 10 CFR 50.55a, with regard to piping systems being designed, fabricated, constructed, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed and with appropriate quality control.
- GDC 2 and 10 CFR Part 50, Appendix S, with regard to design transients and resulting load combinations for piping and pipe supports to withstand the effects of earthquakes combined with the effects of normal or accident conditions.

- GDC 4, with regard to piping systems important to safety being designed to accommodate the effects of, and to be compatible with, the environmental conditions of normal and accident conditions.
- GDC 14, with regard to the RCPB of the primary piping systems being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapid propagating failure, and of gross rupture.
- GDC 15, with regard to the reactor coolant piping systems being designed with specific design and service limits to assure sufficient margin that the design conditions are not exceeded.

3.12.4.6 *Piping Support Design Criteria*

3.12.4.6.1 *Applicable Codes*

In DCD Tier 2, Section 3.12.6.1, “Applicable Codes,” the applicant provides the piping support design criteria requirements. It is indicated that seismic Category I and safety-related pipe supports are designed in accordance with Subsection NF of the ASME BPV Code, Section III. In addition, the design uses for Service Level D the stress limits included in the non-mandatory Appendix F of the ASME BPV Code, Section III. SRP Section 3.12, Section II.D.i, states that the design of ASME Class 1, 2, and 3, piping supports should comply with the design criteria requirements of ASME BPV Code, Section III, Subsection NF. ASME BPV Code, Section III, Subsection NF, states that Appendix F, is used for the stress limit factors for Service Level D. Because the applicant’s pipe support design codes are in conformance with the SRP recommendation, the staff finds this acceptable.

DCD Tier 2, Section 3.12.6.1, also states that non-seismic Category I piping supports are designed in accordance with the requirements of ASME/ANSI B31.1, “Power Piping,” specifically Paragraph 120, for loads on pipe supporting elements and Paragraph 121, for design of pipe supporting elements. It also states that structural elements are designed using guidance from the AISC 360-05, “Specification for Structural Steel Buildings.” The staff recognizes that these methods provide reasonable assurance for the standard piping design and have been used in piping and piping support design in current nuclear plants. Based on past precedent, the staff finds that the design criteria included in the DCD for the non-seismic Category I piping supports are acceptable.

3.12.4.6.2 *Jurisdictional Boundaries*

According to DCD Tier 2, Section 3.12.6.2, “Jurisdictional Boundaries,” the jurisdictional boundary between a pipe and its support structure follows the requirements in ASME BPV Code, Section III, Subsections NB-1132, NC-1132, or ND-1132, depending on the class of piping. The staff recognizes that the referenced subsections provide the jurisdictional boundaries between piping and attachments, which may be part of the piping support. Because the applicant position follows the ASME BPV Code position, which is part of the portion of the code mandated in 10 CFR 50.55a, for Quality Group A, B, and C components, the staff finds this acceptable.

DCD Tier 2, Section 3.12.6.2 also states that the jurisdictional boundaries between the pipe support and the building structure follow the requirements of Subsection NF-1130, of the ASME BPV Code, Section III. Because the jurisdictional boundaries between piping supports and interface attachment points is in conformance with the criteria recommended in SRP Section 3.12, Section II.D.ii, the staff finds the applicant's approach acceptable.

3.12.4.6.3 *Loads and Load Combinations*

SRP Section 3.9.3, Section II.1, provides acceptance criteria for component and component support design. This SRP section states that the design and service loading combinations should be sufficiently defined to provide the basis for the design of ASME Class 1, 2, and 3, components and component supports for all conditions. This SRP section also states that the acceptability of the combination of design and service loadings applicable to the design of ASME Class 1, 2, and 3, components and component supports is judged by comparison with positions stated in Appendix A of SRP Section 3.9.3.

DCD Tier 2, Section 3.12.6.3, "Loads and Load Combinations," states that the pipe support loads and load combinations are described in DCD Tier 2, Section 3.12.5.3 and it also refers to DCD Tier 2, Table 3.9-10, "Loading Conditions and Load Combinations Requirements for ASME Section III Class 1, 2, and 3, Piping Supports." The staff compared the loads and load combinations listed by the applicant with those presented in SRP Section 3.9.3. Overall, the staff finds the applicant's loads and load combinations consistent with SRP Section 3.9.3 but requested clarification of the following subjects in RAI 334-8373, Question 03.12-16 (ML15348A120). The content of this question also relates to RAI 319-8360, Question 03.9.3-2, which is discussed further in SER Section 3.9.3.

- The applicant was requested to identify the loads in category termed "Dynamic system loads," which are included in the loading combination for the emergency operating condition shown in DCD Tier 2 Tables 3.9-10, 3.12-1 and 3.12-2.
- The applicant was requested to describe how loads caused by design basis pipe breaks and LOCAs are included in the loads presented in DCD Tier 2, Table 3.9-10, Table 3.12-2 and other related tables or DCD descriptions.
- The applicant was requested to revise DCD Tier 2, Section 3.12.6.3 to clarify how the loading combinations for piping supports are addressed. DCD Tier 2, Section 3.12.6.3 states that loading combinations for piping supports are shown in DCD Tier 2, Section 3.12.5.3. The load combinations discussed in DCD Tier 2, Section 3.12.5.3 are discussed in the context of the pipe stress evaluation and not for pipe support design.

In its revised responses to RAI 334-8373, Question 03.12-16, request 1, and RAI 319-8360, Question 03.9.3-2 (ML17191B170 and ML16232A613, respectively), the applicant clarified the DCD to delete Service Level C loads, including dynamic system loads. Thus, the staff determined that the applicant has adequately responded to request 1.

From reviewing responses to RAI 334-8373, Question 03.12-16 and RAI 319-8360, Question 03.9.3-2 and related DCD markups, the staff determined that for the APR1400 design the reactor coolant makeup system can compensate for the loss of coolant from breaks in Class 1 branch lines up to a 5.56 mm (7/32 in.) internal diameter. SRP Section 3.9.3 classifies

these type of breaks as DBPBs. Generally, SRP Section 3.9.3 specifies loads from DBPBs to be combined with sustained loads in the loading combination for the emergency operating condition. SRP Section 3.6.2 does not require the postulation of breaks in one-inch nominal diameter piping and smaller. Based on this, the applicant stated that loads from DBPBs are not considered in load combinations for the APR1400 piping design and DCD Tier 2 will be revised to delete Service Level C loads for piping. The applicant also stated that loads caused by LOCAs are included only in the Service Level D load combination, and are indicated as “pipe break loads” in Tables 3.9-10, 3.12-2 and other related tables. The staff notes that this is in accordance with SRP Section 3.9.3. The statement, “pipe break loads include loads due to LOCA,” will be added as a note in the associated DCD tables. The applicant’s response is acceptable because it is in accordance with the staff’s guidance. From the above, the staff determined that the applicant has adequately addressed request 2.

In its response to RAI 334-8373, Question 03.12-16, (ML17191B170), the applicant provided a DCD markup which shows that DCD Tier 2, Section 3.12.6.3 will be revised. The statement that refers to Section 3.12.5.3 for pipe support loads and load combinations is deleted and is replaced by referring to Table 3.9-10 for applicable pipe support loads and load combinations, which follows guidance in SRP Section 3.12 and SRP Section 3.9.3 and, therefore, is acceptable. The staff has thus determined that the applicant has adequately addressed request 3. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 334-8373, Question 03.12-16, is resolved and closed. Resolution of RAI 319-8360, Question 03.09.03-2, is tracked in SER Section 3.9.3.

3.12.4.6.4 Pipe Support Baseplate and Anchor Bolt Design

In DCD Tier 2, Section 3.12.6.4, “Pipe Support Baseplate and Anchor Bolt Design,” the applicant discusses that it expects to minimize the use of base plates in pipe support designs. In cases where these designs are needed, concrete evaluations are performed using ACI-349, Appendix B, considering the limitations of RG 1.199. The applicant also stated that all aspects of the anchor bolt design, baseplate flexibility, and factors of safety will be addressed as identified in BL 79-02, “Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts,” Revision 2, issued November 8, 1979. The staff reviewed DCD Tier 2, Section 3.12.6.4 using the criteria provided in SRP Section 3.12, Section II.D.iv, which states that the design of the pipe support baseplates and anchor bolts should conform to guidance provided in BL 79-02, Revision 2. Because the APR1400 pipe support anchor bolt design, baseplate flexibility, and factors of safety will be in conformance with BL 79-02, Revision 2 per the SRP recommendations, the staff finds the applicant’s approach acceptable.

3.12.4.6.5 Use of Energy Absorber and Limit Stops

SRP Section 3.12, Section II.D.iv, provides piping analysis guidance in circumstances when energy absorbers and limit stops are used. DCD Tier 2, Section 3.12.6.5, “Use of Energy Absorber and Limit Stops,” states that energy absorbers and limit stops are not used as piping supports in the APR1400 design. Because energy absorber and limit stops are not part of the APR1400 design, the staff finds that this portion of the SRP Section 3.12 is not applicable to the APR1400.

3.12.4.6.6 *Use of Snubbers*

Snubbers are used in piping systems to restrain pipe movements due to cyclic events such as seismic and fluid transient events (water and steam hammer) while allowing pipe movements due to thermal expansion. Snubbers are not used to counteract vibration or support gravity loads. In DCD Tier 2, Section 3.12.6.6, "Use of Snubbers," the applicant stated that snubbers can be either hydraulic or mechanical in operation. The staff's evaluation of snubber design, qualification, and functional capability is documented in SER Sections 3.9.3 and 3.9.6.

3.12.4.6.7 *Pipe Support Stiffness*

In DCD Tier 2, Section 3.12.6.7, "Pipe Support Stiffness," the applicant states that the actual stiffness of variable spring supports may be used in the piping analysis. If the actual support stiffness is used for any support, other than variable spring supports, all supports within the piping model use the actual support stiffness. The staff notes that, in general, rigid pipe supports are modeled in the piping analysis model with a very high "rigid" stiffness. The applicant stated that when the "rigid" stiffness is used, a check is performed on support deflection to verify the rigidity. Each support modeled as rigid is checked with the deflection in the restrained directions to a maximum of 1.6 mm (1/16 inch) for SSE loadings, and a maximum of 3.2 mm (1/8 inch) for other loadings.

The staff reviewed the applicant's procedure for pipe support stiffness presented in DCD Tier 2, Section 3.12.6.7, and determined that it is reasonable and consistent with industry practices documented in WRC BL 353 and, therefore, found it acceptable.

3.12.4.6.8 *Seismic Self-Weight Excitation*

In DCD Tier 2, Section 3.12.6.8, "Seismic Self-Weight Excitation," the applicant shows that the pipe support structure is considered as a self-weight excitation when SSE loading is considered in the pipe support analysis. The support self-weight SSE response and the piping inertial load SSE response are to be combined by absolute summation. Damping values for welded and bolted structures are taken from the RG 1.61, Revision 1. The staff reviewed the information presented in DCD Tier 2 Section 3.12.6.7, and found it acceptable because it is the same method that the staff approved in past design certification applications, as documented in NUREG-1793, Section 3.12.6.8. The same method that was also approved for the AP600. This method results in consideration of service loading combinations resulting from postulated events and the designation of appropriate service limits for pipe support seismic loads and is consistent with SRP Section 3.9.3, and is, therefore, acceptable.

3.12.4.6.9 *Design of Supplementary Steel*

In DCD Tier 2, Section 3.12.6.9, "Design of Supplementary Steel," the applicant states that all seismic Category I pipe supports for the APR1400 are designed to ASME BPV Code, Section III, NF. For non-seismic Category I pipe supports, AISC 360-05, is used for the supplementary steel and the main support structure. As stated in Section 3.12.4.6 (1), "Applicable Codes," because ASME BPV Code, Section III, Subsection NF is recommended by SRP Section 3.12 for seismic Category I pipe support evaluation and because the use of AISC 360-05 provides reasonable assurance that the structural adequacy of the non-seismic

Category I pipe supports is maintained, the staff finds the applicant's approach to the design of supplementary steel in pipe supports acceptable.

3.12.4.6.10 *Consideration of Friction Forces*

In DCD Tier 2, Section 3.12.6.10, "Consideration of Friction Forces," the applicant presents its approach for the consideration of frictional forces on pipe supports, which are generated when the pipe slides on its supports during heat-up and cooldown. The forces due to pipe friction on supports are normal to the direction of movement and are considered under combined deadweight and thermal loads. The method the applicant uses to calculate these friction forces, if the pipe movement in the unrestraint direction is greater than 1.6 mm (1/16 inch), is to multiply the combined force in the direction normal to the direction of pipe movement by a coefficient of friction. The applicant used a coefficient of friction of 0.3 for steel-to-steel friction and 0.1 for low-friction slide-bearing plates. The staff reviewed the applicant's method for consideration of friction forces acting on pipe supports presented in DCD Tier 2, Section 3.12.6.10 and determined that it is reasonable and consistent with industry practices documented in WRC BL 353 and past design certifications (see NUREG-1966 and NUREG-1793) the staff has approved and, therefore, found it acceptable.

3.12.4.6.11 *Pipe Support Gaps and Clearances*

In DCD Tier 2, Section 3.12.6.11, "Pipe Support Gaps and Clearances," the applicant presents its approach for considering pipe gaps and clearances in guide type restraints, such as frame boxed-type supports built around the pipe. The applicant uses small gaps that should allow pipe rotation and should not restrain radial thermal expansion, thereby avoiding thermal binding. The applicant stated that the normal design practice for the APR1400 is to use a nominal cold condition gap of 1.6 mm (1/16 inch) on each side of the pipe in the restrained direction. The staff reviewed the applicant's approach for consideration of pipe gaps and clearances in guide type restraints presented in DCD Tier 2 Section 3.12.6.11, and determined that overall it is reasonable and consistent with SRP Section 3.12, and standard industry practice documented in WRC BL 353 and past design certifications (see NUREG-1793 and NUREG-1966), the staff has approved and, therefore, found it acceptable.

Although the staff found the applicant's overall approach acceptable, the staff requested clarification on specific topics in RAI 311-8278, Question 03.12-5 (ML15320A349), and RAI 334-8373, Question 03.12-17 (ML15348A120). Therefore, the staff issued RAI 311-8278, Question 03.12-5 (ML15320A349), requesting the applicant to show that, when the restraint is intended to support the weight of the pipe, there is no clearance between the pipe and its support. The staff issued RAI 334-8373, Question 03.12-17 (ML15348A120), requesting the applicant to discuss, consistent with SRP Section 3.12, Section II.D.xi, how the specified pipe support gap will be checked against the maximum combined radial growth of the pipe due to temperature and pressure to assure that adequate clearance exists to avoid thermal binding. To the extent that the response addresses programmatic or operational activities that are outside the scope of design certification, the applicant was requested to describe these and include in the DCD a provision for COL applicants to describe these activities.

In its response to RAI 311-8278, Question 03.12-5 (ML15365A559), and in DCD Tier 2 Section 3.12.6.11 markup, the applicant showed that, as the staff requested, in deadweight supports the pipe will be in contact with the support member in the direction of gravity. The staff accepted

the applicant's response and verified that the DCD has incorporated these changes; therefore, RAI 311-8278, Question 03.12-5, is resolved and closed.

In its revised response to RAI 334-8373, Question 03.12-17 (ML16230A109), the applicant stated that if designs of frame type supports are needed on the large diameter high temperature piping, the gap considering the diametrical expansion of the pipe will be specified on each pipe support design drawing. This also is reflected in the DCD Tier 2, Section 3.12.6.11 markup provided with the applicant's response. Because adequate gap between the pipe and its support will be provided by design, sufficient to allow pipe radial growth and pipe rotation to avoid binding and unanalyzed local stresses, as required by SRP Section 3.12, Section II.D.xi, the staff finds the applicant's approach acceptable. Based on the review of the DCD, the staff has confirmed incorporation of the changes described above; therefore, RAI 334-8373, Question 03.12-17, is resolved and closed.

3.12.4.6.12 *Instrumentation Line Support Criteria*

In DCD Tier 2, Section 3.12.6.12, "Instrumentation Line Support Criteria," the applicant states that the design loads, load combinations, and acceptance criteria for instrumentation line supports are similar to those used for pipe supports. Design loads include deadweight, thermal, and seismic loads (where appropriate).

The staff notes that the use of pipe support design criteria for instrumentation line supports provides a conservative design and uses standards developed by professional societies, which as shown in Section 3.12.4.5 above are acceptable to the staff.

3.12.4.6.13 *Pipe Deflection Limits*

In DCD Tier 2, Section 3.12.6.13, "Pipe Deflection Limit," the applicant states that manufacturers' recommendations for the limitations in their hardware are followed for those piping supports that use standard manufactured components. Such limitations include travel limits for spring hangers; stroke limits for snubbers; swing angles for rods, struts, and snubbers; alignment angles between clamps or end brackets with their associated struts and snubbers; and the variability check for variable spring supports. The staff finds the applicant's approach acceptable because its approach to use manufacturers' recommendations to limit pipe deflection provides confidence that pipe deflection will not cause the failure of the supports or cause an unanalyzed condition in the piping stress analysis. In addition, the applicant shows that allowances are made in the initial designs for tolerances on the manufacturers' recommended limits. The purpose of allowances for tolerances on limits in the initial designs is to avoid exceedance of manufacture's recommended limits. This provision is especially important for snubber and spring design, in which the function of the support may be changed by an exceeded limit. The staff finds these additional tolerances acceptable, because they provide additional confidence that the component movement will remain within intended design limits of the component supports, thus ensuring the functionality of supports.

3.12.4.6.14 *Conclusions Regarding Piping Support Design Criteria*

Based on its review, as set forth above, the staff concludes that the applicant has met the following requirements regarding piping support design criteria:

- GDC 1, and 10 CFR 50.55a, by specifying methods and procedures for the design and construction of safety-related pipe supports in conformance with these requirements and general engineering practice.
- GDC 2 and 4, by designing and constructing the safety related pipe supports to withstand the effects of normal operation, as well as postulated accidents such as LOCAs and effects resulting from the SSE.
- GDC 14, by following the ASME BPV Code requirements with regard to the RCPB of the primary piping systems being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapid propagating failure, and of gross rupture.
- GDC 15, by following the ASME BPV Code requirements with regard to the reactor coolant piping systems being designed with specific design and service limits to assure sufficient margin that the design conditions are not exceeded.
- Part 50 of 10 CFR, Appendix S, by providing reasonable assurance that the safety-related piping systems are designed to withstand the effects of earthquakes with an appropriate combination of other loads of normal operation and postulated accidents with an adequate margin for ensuring their safety functions.

3.12.5 Combined License Information Items

The applicant in its letter, dated June 1, 2015, (ML15152A248), provided a proposed revision to the list of COL items in DCD Tier 2, Section 3.12.7 and Table 1.8-2. The staff has verified that the DCD has incorporated these changes.

It is noted that in accordance with RAI 35-7955, Question 3.12-2 response (ML16211A384), DCD Revision 1, added new DCD Tier 2 Subsection 3.12.7, "Graded Approach of Piping Systems," see above in Section 3.12..2, "Summary of Application." Therefore, DCD Revision 0, Section 3.12.7, "Combined License Information," became Section 3.12.8 in DCD Revision 1.

Table 3.12.5 Combined License Items Identified in the DCD

Item No.	Description	Section
COL 3.12(1)	Safety related piping systems of ASME Class 1, 2, and 3 are designed within the wind/tornado protected structure. If COL applicant finds it necessary to route the piping systems outside the structure, the wind and/or tornado load must be included in the plant design basis loads considering the site-specific loads.	3.12.5.3.6
COL 3.12(2)	The COL Applicant will implement pre-core test No. 14.2.12.1.140, Pre-Core Pressurizer Surge Line Stratification Test and continue to	3.12.5.10

Item No.	Description	Section
	monitor by using the fatigue monitoring system during the first cycle of operation to verify the design transients used in the structural design of the surge line.	

The staff evaluated the above COL item and concluded that the applicant appropriately lists the information that will be provided by the COL applicant for the APR1400 plant.

3.12.6 Conclusion

Based on its review of the information provided in DCD Tier 2, Section 3.12, the staff concludes, for the reasons set forth above, that the applicant has established an acceptable basis for the structural integrity and functional capability of APR1400 ASME Class 1, 2, and 3, piping and its pipe supports. Based on the above, the staff further concludes that the applicant has provided reasonable assurance that safety related piping and its pipe supports are structurally adequate to perform their intended design function and be in compliance with 10 CFR 50.55a; 10 CFR 52.47(b)(1); 10 CFR Part 50, Appendix S; and GDC 1, 2, 4, 14, and 15.

3.13 Threaded Fasteners for ASME Code Class 1, 2, and 3 Components

3.13.1 Introduction

The purpose of this section is to review and evaluate the adequacy of the applicant's criteria with regard to selection of materials, design, inspection, and testing of its threaded fasteners (i.e., threaded bolts, studs, etc.) prior to initial service and during service. The scope in this review is limited to threaded fasteners in ASME B&PV Code Class 1, 2, or 3, systems.

3.13.2 Summary of Application

DCD Tier 2, Section 3.13, describes the use of threaded fasteners (e.g., threaded bolts, studs) and specifies requirements pertaining to selection of materials, design, inspection, and testing prior to and during service. Detailed enumeration of ASME Code, Section III subarticles is provided in DCD Tier 2, Tables 3.13-1 and 3.13-2, identifying the appropriate subarticles concerning material selection; material test coupons and specimens for ferritic steel materials; fracture toughness requirements; examination criteria; certified material test report criteria; specific bolting inspections; and system pressure tests. DCD Tier 2, Section 3.13.1.2 also identifies that threaded fasteners are to be cleaned in accordance with RG 1.28, "Quality Assurance Program Criteria (Design and Construction)."

3.13.3 Regulatory Basis

The following regulatory requirements provide the basis for the acceptance criteria for the staff's review:

- GDC 1, requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

- Section 50.55a of 10 CFR, relates to the design, fabrication, erection, construction, testing, and inspection of components and systems. It requires the systems and components of both boiling- and pressurized-water-cooled nuclear power reactors to meet the requirements of the ASME Code, and SSCs must be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed.
- GDC 4, requires that SSCs important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs.
- GDC 14, requires that components that are part of the RCPB be designed, fabricated, erected, and tested to ensure an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture.
- GDC 30, requires that components which are part of the RCPB shell be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage.
- GDC 31, requires in part that the RCPB shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized.
- Part 50 of 10 CFR, Appendix B, requires that measures be established to control the handling, storage, shipping, cleaning, and preservation of material and equipment to prevent damage or deterioration.
- Part 50 of 10 CFR, Appendix G, specifies fracture toughness requirements for ferritic materials of pressure-retaining components of the reactor pressure boundary of light-water nuclear power reactors to provide adequate margins of safety during any condition of normal operation, including AOOs and system hydrostatic tests, to which the pressure boundary may be subjected over its service lifetime.

3.13.4 Technical Evaluation

The staff reviewed the information included in the DCD Tier 2, Section 3.13, in accordance with the guidance provided in SRP Section 3.13, "Threaded Fasteners – ASME Code Class 1, 2, and 3," issued March 2007. The purpose of the review was to determine the adequacy of threaded fasteners (e.g., threaded bolts, studs) with respect to the selection of materials, design, inspection, and testing prior to and during anticipated service. The staff notes that DCD Tier 2, Table 1.9-2, which summarizes the differences between the DCD application and SRP Chapter 3, included references to SRP Section 3.13, and stated that the APR1400 conforms to SRP Section 3.13. The staff's review of DCD Tier 2, Section 3.13, follows.

DCD Tier 2, Section 3.13 states that material used for threaded fasteners complies with the requirements of ASME Code, Section III, Subsections NB, NC, or ND. DCD Tier 2, Section 3.13 also states that the criteria of ASME Code, Section III, rather than the material specification

criteria applicable to the mechanical testing, should be applied if there is a conflict between the two sets of criteria. For ASME Code, Section III, Class 1, 2, and 3, component fasteners, certified material test reports are part of the ASME Code records that are provided when the parts are shipped and are part of the required records that are maintained at the site. The staff finds these requirements acceptable because the ASME Code, Section III imposes appropriate requirements consistent with SRP Section 3.13.

The applicant also addressed the use of lubricants and/or surface treatments in mechanical connections secured by threaded fasteners and the compatibility of these materials with the threaded fasteners. As stated in DCD Tier 2, Section 3.13, lubricants are to be selected in accordance with NUREG-1339, "Resolution of Generic Safety Issue 29: Bolting Degradation or Failure in Nuclear Power Plants." Specifically Loctite N-5000, Neolube, and Never Seez Pure Nickel Special Nuclear Grade, are enumerated as acceptable in the guidance. Additionally, lubricants containing molybdenum sulfide (disulfide or polysulfide) are forbidden from use for any safety-related application. The staff finds these requirements acceptable because the lubricants are selected in accord with the guidance found in SRP Section 3.13. Based on conformance to the NUREG, the staff finds that controls imposed on threaded fasteners satisfy the requirements of 10 CFR Part 50, Appendix B, Criterion XIII, "Handling, Storage and Shipping," with respect to controls for cleaning of materials and components. Additionally, the lubricants and sealants are compatible with the threaded fastener materials.

The applicant stated in the DCD that fracture toughness testing is performed in accordance with ASME Code, Section III, Subarticles NB-2300, NC-2300, or ND-2300, as appropriate. Testing for mechanical properties is required on samples representing each heat treat lot in accordance with ASME Code, Section III, Paragraph NB-2345. Inspection of the threaded fastener materials complies with ASME Code Section III, Subsubarticles NB-2580, NC-2580, or ND-2580, as applicable. In addition ferritic bolts, studs, and nuts used in RCPB applications are specified to meet the fracture toughness requirements of 10 CFR Part 50, Appendix G. The staff finds these requirements acceptable because the selection of threaded fastener materials and their inspection, testing, and certification are in accordance with ASME Code, Section III, criteria for Code Classes 1, 2 and 3 as referenced by SRP Section 3.13; and 10 CFR Part 50, Appendix G.

DCD Tier 2, Section 3.13 states that preservice and inservice inspections of threaded fasteners are performed in accordance with ASME Code, Section III and Section XI, respectively. Preservice inspections per ASME Code, Section III, Subsubarticles NB-2580, NC-2580, and ND-2580 require visual and magnetic particle or liquid penetrant examinations as appropriate to the Class and size of the subject bolting. The preservice and inservice inspection programs for ASME Section III, Classes 1, 2, and 3 are to be submitted as COL 3.13(2). The staff finds these requirements acceptable because threaded fasteners must meet the requirements of ASME Code, Sections III and XI as referenced by SRP Section 3.13. Compliance with the requirements of ASME Code, Section XI, also satisfies the regulatory requirements of 10 CFR 50.55a. In addition to ASME Code, Section III and Section XI requirements discussed above, the reactor vessel closure studs also follows the guidance provided in RG 1.65, "Materials and Inspections for Reactor Vessel Closure Studs," without exceptions, as detailed in DCD Tier 2, Section 5.3.1.7. Following the guidance provided in RG 1.65 ensures that the reactor vessel studs will perform as designed. The staff finds these requirements acceptable as they are in accordance with the ASME Code, Sections III and XI criteria for Code Classes 1, 2, and 3, as referenced by SRP Section 3.13.

The ASME Code, Section III, Subsubarticles NB-2160, NC-2160, and ND-2160 require consideration of material degradation in service to ensure that the threaded fasteners will perform in service as designed. However, because the ASME Code, Subsubarticle NB-2160 does not clearly specify how the owner should consider service conditions for bolting, DCD Tier 2, Section 3.13.1 specifies that threaded fasteners which are part of the RCPB or are in contact with primary coolant, except the stud bolts for the reactor vessel head and reactor coolant pump casings, are to be made of primary water corrosion resistant materials. In addition the design of threaded fasteners is to include consideration of galvanic corrosion potential except where the adequacy of design or material has already been demonstrated in the Korean OPR 1000 plants, where primary coolant leakage can automatically be identified if it occurs, or where periodic inspections for leakage and verification of integrity of the threaded fasteners are performed as a countermeasure for leakage. In a public meeting dated June 17, 2015 (ML15168A18), the applicant provided details concerning the location, material, and size of bolting used in the APR1400 and OPR 1000, demonstrating a direct and complete correspondence between the two designs with regards to material specifications. Additionally, the applicant stated that OPR 1000 operational experience with the listed materials occurred “without any material issues.” The staff concluded that the information presented was sufficient to support the determination that the applicant had adequately supported their DCD assertion citing operating experience. Finally DCD Tier 2 Section 3.13.2, states that threaded fasteners are designed and fabricated to minimize stress corrosion cracking or other forms of material degradation. The staff finds the above acceptable as it meets the intent of ASME Code, Section III and is therefore consistent with SRP Section 3.13.

3.13.5 Combined License Information Items

There are no Combined License Information (COL) items in this section.

3.13.6 Conclusion

The staff concludes that the selection of materials, design, inspection, testing and recording are in accordance with ASME Code, Section III criteria for Code Classes 1, 2, and 3 threaded fasteners and ensure application of quality standards commensurate with the importance of the safety functions to be performed. Application of these ASME Code criteria also provides assurance of an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture. The DCD conforms to these ASME Code requirements as deemed acceptable by SRP Section 3.13, therefore, satisfies GDC 1, 14, and 30.

The fracture toughness tests specified in the ASME Code, as augmented by the requirements of Appendix G to 10 CFR Part 50, provide reasonable assurance that adequate safety margins against nonductile behavior or rapidly propagating fracture will be provided for threaded fastener materials used in ASME Code Class 1, 2, and 3, systems. The DCD conforms to these criteria and, therefore, is consistent with SRP Section 3.13, and meets the requirements of 10 CFR 50.55a(c), (d), and (e) and GDC 31, “Fracture prevention of reactor coolant pressure boundary.”

The DCD identifies special processes used for threaded fasteners. Since the DCD certifies compliance with the materials and fabrication criteria of Section III of the ASME Code, the staff considers the special processes used to be acceptable because they are consistent with SRP Section 3.13.

The threaded fastener materials need to be compatible with the materials of the components being joined. Lubricants and sealants need to be compatible with the materials of the components being joined and with the piping system fluids. Following the criteria of the ASME Code, Section III ensures that the level of general corrosion of threaded fasteners will be acceptable and in accordance with SRP Section 3.13. The threaded fasteners are also compatible with the materials being joined and with the piping system fluids as discussed above, and therefore, the DCD meets the requirements of GDC 4, relative to compatibility of components with the environmental conditions.

The DCD controls to avoid contamination that could lead to stress corrosion cracking conform to the recommendations of RG 1.28. These controls satisfy the requirements of 10 CFR Part 50, Appendix B, Criterion XIII, with respect to the cleaning of materials and components. The staff concludes that the preservice and inservice programs for threaded fasteners specified in the DCD are acceptable and meet the criteria of ASME Code, Section XI and the requirements of 10 CFR 50.55a.