3. DESIGN OF STRUCTURES, SYSTEMS AND COMPONENTS

3.8 Design of Category I Structures

3.8.4 Other Seismic Category I Structures

3.8.4.1 *Introduction*

U.S. EPR Final safety evaluation report (FSAR) Tier 2, Section 3.8 describes the Seismic Category I structures and their foundations, but it does not describe safety-related Seismic Category I structures classified as mechanical equipments in FSAR Tier 1, Section 2.2.2, Table 2.2.2-1 such as trash racks (TRs), retaining baskets (RBs), and sump strainers (SSs) that are part of the U.S. EPR emergency core cooling system (ECCS) recirculation system, collectively and interchangeably called debris interceptor-collector structures (DICSs) and designated as TR_RB_SS. The function of these structures is to intercept and collect the debris and prevent the sump pumps from clogging.

In the case of a loss-of-coolant accident (LOCA) within the containment of a pressurized-water reactor (PWR), break-jet impingement will dislodge piping thermal insulation and other materials surrounding the break area. The steam and water flows induced by the break and the containment sprays will transport dislodged insulation and other materials such as paint chips, paint particulates, and concrete dust, collectively called debris, to the containment floor. Some of this debris will eventually be transported to and accumulate on the recirculation sump suction screens. Debris accumulation on the sump screens may challenge the sump's capability to perform its safety function adequately and to provide adequate, long-term cooling water to the emergency core cooling system (ECCS) and the containment spray pumps.

NUREG-0800, Section 6.2.2.I.8, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (SRP), states that to address the effects of accident-generated debris, including an assessment for the potential loss of long-term cooling capability resulting from LOCA-generated and latent debris, the staff issued Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR Sump Performance," which relates to debris-induced PWR sump clogging. The U.S. Nuclear Regulatory Commission (NRC) may develop additional guidance for the review of information in applications on the performance of ECCS strainers and downstream components such as pumps, valves, and nuclear fuel. Until such time and in the absence of a separate Standard Review Plan (SRP) section on the effects of debris, SRP Section 6.2.2, "Containment Heat Removal Systems," Revision 5, March 2007, addresses the functional performance of these structures and issues based on information currently available. However, the staff reviews the structural design, performance, and integrity of the DICS to withstand the loads and load combinations during the severe accident events, and to protect the ECCS sump pumps from clogging, in accordance with SRP Section 3.8.4, "Other Seismic Category I Structures," Revision 3, issued May 2010. Accordingly, Section 3.8.4.4 of this safety evaluation report will discuss this review.

Background

NUREG/CR-6762, “Assessment of Debris Accumulation on PWR Sump Performance," August 2002, addresses the issue of debris generation, transport, and accumulation on the PWR sump screen and its subsequent impact on ECCS performance during long-term reactor core cooling.

AREVA NP Inc., issued Revision 4 of Technical Report ANP-10293, “U.S. EPR Design Futures to Address GSI-191,” in November 2011. (Unless otherwise noted, references in this report to the technical report are to Revision 4 of ANP-10293.) The technical report documents and describes the U.S. EPR design with respect to GSI-191. The report also evaluates the U.S. EPR design with respect to Regulatory Guide (RG) 1.82, “Water Sources for Long-term Recirculation Cooling Following a Loss-of-Coolant Accident,” Revision 3, November 2003, and Generic Letter (GL) 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors,” September 13, 2004.

Section 1 of the technical report introduces an overview of the study results and discusses the general design concept of the U.S. EPR DICSs and the three steel structures collectively designated as TR_RB_SS, including the functional performance of the overall system and DICSs.

Section 2 of the technical report describes the in-containment refueling water storage tank (IRWST) as the key feature of the U.S. EPR design important to resolving post-accident debris blockage. The applicant’s technical report indicates that the IRWST is functionally equivalent to the external refueling water storage tank found in the current fleet of PWRs. The IRWST contains a large volume of borated water that is monitored for a homogeneous concentration, level, and temperature. The IRWST serves as a water source, heat sink, and return reservoir for ECCS. The two important tiered barrier structures such as retaining baskets and sump strainers (total of four each) are located in IRWST area. Further, in Section 2 of the technical report, the defense-in-depth strategy, the details of the sump blockage mitigation design features and the type of insulation materials used in the RCS piping and other components to mitigate the consequences of a LOCA and prevent sump pump blockage are described.

Section 3 of the technical report presents the design bases for the ECCS sump recirculation design features which are discussed in detail in the “Applicable U.S. EPR Design Bases” section of this report,

In Section 4, of the technical report, the applicant provided a regulatory overview, including GSI-191, RG 1.82 Revision 3, and GL 2004-02, that are detailed in Appendix A and B of the technical report. The last two sections (5 and 6) present conclusions and references.

The staff reviewed FSAR Revision 2, Section 6.2.2, on the ECCS recirculation system, to ensure conformance with the requirements of General Design Criterion (GDC) 38, “Containment Heat Removal,” GDC 39, “Inspection of Containment Heat Removal System,” and GDC 40, “Testing of Containment Heat Removal System,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, “Domestic Licensing of Production and Utilization Facilities,” and 10 CFR 50.46(b)(5). The staff conducted its review in accordance with SRP Section 6.2.2 to evaluate the overall system and the functional performance of the DICSs as part of the heat removal system. As part of the FSAR Tier 2, Section 6.2.2 review, the staff also raised some concerns regarding the structural design and analysis of the DICSs in RAI 259, Question 06.02.02-32. Since the structural integrity, design, and analysis of these types of structures are the responsibility of a structural engineer, therefore, this issue was transferred to the Structural Engineering Branch 2 (SEB2). The SEB2 staff reviewed the structural integrity and acceptability of the design in accordance with SRP Section 3.8.4. Since FSAR Revision 2 did not contain a section providing a detailed design description of the DICSs, the staff based its review on the available Technical Report ANP-10293, which mainly addresses the general issues of GSI-191, RG 1.82, and GL 2004-2.

This report discusses the technical adequacy of the conceptual structural design, analysis, and design approach of AREVA NP Inc., to determine the structural capacity and integrity of the DICSs to withstand the loads and load combinations during the design-basis accident conditions (i.e., a LOCA combined with a seismic event and to protect the ECCS sump pumps from clogging). The scope of this report does not include consideration of the functional performance of the ECCS recirculation DICSs in terms of the debris blockage.

3.8.4.2 Summary of Technical Information

U.S. EPR Emergency Core Cooling System Recirculation Debris Interceptor-Collector Structures

Technical Report ANP-10293 indicates that the U.S. EPR ECCS recirculation DICSs design is based on a defense-in-depth strategy that it contains three steel structures to be located in the reactor coolant system (RCS) and IRWST area to intercept and collect all debris induced after the accident. The DICSs are designed and composed of austenitic steel structural elements as of box-type structures, which are covered with appropriate sizes of heavy-duty screens or steel mesh to intercept and collect the various type of debris in the event of a LOCA. The technical report summarizes that the defense-in-depth philosophy considers a multibarrier defense strategy against the consequences of the accident, and it demonstrates that debris blockage does not affect the functionality of the sump pumps, which are the source of long-term water for the core cooling system. Section 3.8.4 of this report reviews and evaluates the physical structural design and analysis of the DICSs with respect to the structural performance and integrity of the subject structures to ensure that they will withstand the loads and load combinations in the event of an accident and will still be able to perform their intended safety functions. The sections below give a summary description of the system and each debris structure. (The respective sections of Technical Report ANP-10293 provide detailed descriptions of the system performance analyses.)

Defense-in-Depth Strategy in the U.S. EPR ECCS Debris Interceptor-Collector Structural Design

Technical Report ANP-10293 indicates that the U.S. EPR design took advantage of the in-containment physical arrangement to develop a tiered defense-in-depth strategy against ECCS sump suction clogging. The technical report briefly describes the three primary DICSs (i.e., TR_RB_SS) as the three-step defense strategy. In addition to these physical barriers, the design also considered other factors contributing to defense-in-depth strategy. These additional factors are large area of RCS loop vaults, large volume and area of the IRWST and low flow velocity, and approximately 1.6-foot gap between the top of the retaining basket and the bottom of the heavy floor for the overflow of water into the IRWST. These factors support the tiered defense-in-depth design of the U.S. EPR ECCS system in terms of the ability of the DICSs to perform its intended safety functions and prevent sump suction clogging. The following sections discuss the physical debris interceptor collector structures.

Debris Interceptor-Collector Structures

The applicant indicated that for the U.S. EPR DICSs, the design considered four units of three types of stainless steel structures (i.e., TR_RB_SS), which act as a multibarrier system. These structures will be constructed in the RCS and IRWST area to mitigate the consequences of debris generated by a LOCA. Each structure is briefly described below in a sequence of their locations as the steps of defense-in-depth concept as follows:

Trash Racks

Technical Report ANP-10293 indicates that the trash racks are heavy-duty box-type mesh structures made of stainless steel elements covered with a steel mesh opening of 4x4 inches (in.) and 22 in. high. The four trash racks are designed to be constructed over the top of heavy floor openings of approximately 50 square feet (ft^2) each in the RCS area. The trash racks act as the first interceptor-collector barrier and are intended to collect most of the large debris. A 2-inch-high concrete weir (curb) protects the perimeters of the openings by promoting debris settlement on the floor of the RCS loop vault.

Retaining Baskets

As indicated by the applicant, the retaining baskets are designed from austenitic stainless steel elements with attached screens. The screen size is approximately 2x2 millimeters (mm) (0.08x0.08 in.). The retaining baskets are supported and anchored to the basemat. Two of the four retaining baskets are double-compartment designs with larger capacities and two are single-compartment designs with smaller capacities. The retaining baskets collect all small and fine debris that bypasses the trash racks.

The four retaining baskets are located directly under each weir and trash rack port in the IRWST area, overlapping the perimeter of the opening by approximately 1.5 ft so that ECCS recirculation flow falls within the retaining basket, enabling it to catch and retain any small debris that is carried through the trash racks by ECCS recirculation flow. The retaining baskets are the second barrier for the collection of debris.

Sump Strainers

The third barrier for the collection of debris is the sump strainer also located in the large area of the IRWST. The applicant indicated that four sump suction pumps will be located in the IRWST area, and four separate strainers will be constructed over each pump. The sump strainer will be manufactured from austenitic stainless steel elements with inverted sides. The screen size of the sump strainer and retaining baskets (both 0.08x0.08 in.) is designed to minimize fine debris that may bypass the strainer and obstruct downstream clearance in the ECCS flow path (including flow through the core). The inverted side screens on the sump suction strainers promote the gravitational release of debris beds in low-flow or no-flow conditions to the floor of IRWST. Technical Report ANP-10293 indicates that the retaining baskets and ECCS strainers are sized so that each set is sufficient to accommodate the anticipated debris load resulting from the worst case LOCA.

<u>Applicable U.S. EPR Design Bases</u>

Section 3 of Technical Report ANP-10293 describes the bases for the design and sizing of the U.S. EPR ECCS recirculation DICSs. The applicant stated that the judicious selection and control of insulating materials for piping and equipment inside containment minimizes the quantity of insulation debris known to be highly deleterious to post-LOCA ECCS function and effectively resolves the strainer clogging issue.

The applicant indicated that the design is such that in a LOCA, the collected debris will not cause a significant loss of net positive suction head (NPSH) for the ECCS pumps, which is based on design assumptions such as conservative LOCA debris estimation using guidance of RG 1.82, Revision 3 and information presented in Nuclear Energy Institute (NEI) 04-07, and that all debris is transported to the IRWST and deposited into one retaining baskets. These assumptions form the underlying technical basis for the U.S. EPR strainer design. The applicant indicates that the results of the strainer test program validate the design of the U.S. EPR ECCS recirculation system.

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In Section 3.1 of the technical report, the applicant indicated that the technical basis for the ECCS sump recirculation design features is based on studies that demonstrate the effectiveness of the sump recirculation design features. This section and its subsections provide information on the technical basis for the ECCS sump recirculation design features, including (1) debris transport (2) debris source term, (3) chemical effects, and (4) ECCS Strainer Performance. The applicant summarizes the design bases assumptions by stating that beside the multiple LOCA return flow paths and a tiered defense-in-depth debris retention structures and system, a conservative approach is applied in the debris transport evaluation by assuming that all LOCA debris transported through one floor opening to enter one retaining basket or deposited on one strainer, which in addition to other loads and load combination is the bases for sizing of these structures. In Appendices C through E, the applicant provided detailed description and calculations for the above technical basis. Thus, the sizing of the ECCS DICSs located in the RCS and IRWST is based on the assumption that these structures should collect all the debris that can reach the IRWST in the event of a LOCA. The applicant also provided the quantity of debris in both volumetric and weight units to calculate the load on the structures.

Section 3.2 of Technical Report ANP-10293 takes into consideration other factors such as NPSH assessment, strainer vortexing, submergence, flashing, and deaeration assessment, the IRWST cleanliness, strainer mechanical integrity and water holdup detailed in Appendix F and G.

In Section 5 of the technical report, the applicant concludes that the three-tiered debris retention design of the U.S. EPR ECCS recirculation system is an effective solution to post-accident ECCS pump strainer clogging. The combination of weirs/trash racks and retaining baskets are effective in retaining most of the debris. As a result, very little debris will reach the ECCS strainers. The ECCS strainers have a large screen surface area to accommodate the small amount of debris that will reach them. The test results using a conservative debris source term validate the performance of the U.S. EPR recirculation system features to prevent sump/strainer clogging.

In terms of the functional performance of the ECCS recirculation DICSs, the staff evaluation of Technical Report ANP-10293 falls under SRP Section 6.2.2 and other appropriate sections, which are not the subject of this report. The staff's technical evaluation provided in this report is related to the evaluation and acceptability of the design approach and the integrity of the physical structure and structural performance of the steel DICS, as described in the following sections.

3.8.4.3 Regulatory Criteria

The staff reviewed FSAR Revision 2 with regard to the ECCS recirculation DICSs in accordance with SRP Section 3.8.4 to ensure conformance with the regulatory requirements. The staff's acceptance of the structural design of the subject structures is based on the applicant's compliance with 10 CFR Part 50:

- 10 CFR 50.55a, "Codes and Standards," as they relate to codes and standards

- 10 CFR Part 50, Appendix A, specifically the following:

    - GDC 1, "Quality Standards and Records," as it relates to structures, systems and components being designed, fabricated, erected, constructed, and tested to quality standards commensurate with the importance of the safety function to be performed

    - GDC 2, "Design Bases for Protection against Natural Phenomena," as it relates to structures, systems, and components important to safety being designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of earthquakes

    - GDC 4, "Environmental and Dynamic Effects Design Bases," as it relates to structures, systems, and components important to safety being appropriately protected against the dynamic effects of discharging fluids

- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"

3.8.4.4 Staff Evaluation

Technical Report ANP-10293 documents the design of the U.S. EPR ECCS recirculation DICSs with respect to GSI-191, RG 1.82, and GL 2004-02. The purpose of the technical report was to address the functional performance and structural design approach for these stainless steel structures (i.e., TR_RB_SS) as a three-step tiered defense-in-depth design philosophy that would mitigate the consequences of LOCA-generated and latent debris by preventing sump suction clogging.

The staff reviewed the description of the ECCS recirculation DICSs in Technical Report ANP-10293 to ensure that it contains information sufficient to define the primary structural aspects and elements that are relied upon to maintain the integrity of the structures to enable the DICSs to perform their intended safety functions.

RAI 259, Question 06.02.02-32 and Response

During its review of FSAR Tier 2, Revision 3, Section 6.2, the staff identified a number of structural design items that were not described in sufficient detail. These included design details, inputs, and parameters for the design and analysis of DICSs. To address these concerns, in RAI 259, Question 06.02.02-32, the staff requested that the applicant (1) summarize the design codes, inputs, assumptions, loads, and load combinations used for the structural analysis of the sump debris interceptors, (2) give the structural qualification results and design margins for the various sump debris interceptors, and (3) summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy breaks (as applicable). The staff needed this information to establish the primary design codes and structural elements of the DICSs that are relied upon to transfer loads and perform their intended safety functions.

In a July 14, 2009, response to RAI 259, Question 06.02.02-32, the applicant indicated that detailed structural analysis of the debris interceptors will be performed later in the design process. In response to Part 1 of the question, the applicant identified American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC) N690-1994, Supplement 2, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," revised 2004, as the primary design code for the design of debris interceptor structures, and indicated that the acceptance criterion for these structures is that they conform to this code. The applicant also provided a list of loads to which each debris interceptor is subjected, including the following:

- dead weight of the device
- weight of debris on the device, as defined in Technical Report ANP-10293
- seismic loading on the device, including dynamic fluid pressures for those devices that are fully or partially submerged
- pressure drop across the device from the action of the safety injection pumps
- thermal loading from temperature changes within the building
- jet impingement and pipe whip on the trash racks and their associated weirs as a result of postulated breaks in lines that are not qualified based on leak-before-break criteria

The applicant also described the load combinations based on ANSI/AISC N690-1994. Dead weight, debris weight, and thermal loads will be considered as "normal" loads, per ANSI/AISC N690-1994, Table Q.1.5.7.1. When these loads are combined with seismic loads, jet impingement, and pipe whip, the load combination will be considered as "abnormal extreme," according to ANSI/AISC N690-1994, Table Q.1.5.7.1, summarized as follows:

- Normal, Stress Limit Coefficient = 1.0: Dead weight + Debris weight + Thermal loads
- Abnormal Extreme, Stress Limit Coefficient = 1.7: Dead weight + Debris weight + Thermal loads + Pipe Whip + Jet Impingement + Seismic Loads

Impactive and impulsive loads from jet impingement and pipe whip will use the ductility factors from ANSI/AISC N690-1194, Table Q.1.5.8.1.

Therefore, the staff finds the applicant's response to RAI 259, Question 06.02.02-32, Part 1 acceptable, because the use of ANSI/AISC N690-1994, Supplement 2 including Revision 2004 (R2004), for the design of debris interceptor-collector structures is acceptable for the staff, and is approved by the NRC based on the RG 1.84, "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III," Revision 33, August 2005 , which endorses American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Case N-570-2, "Alternative Rules for Linear Piping and Linear Standard Supports for Class 1, 2, 3, and MC."

The ASME approves ANSI/AISC N690-1994 as an alternative to ASME Code, Section III, and Subsection NF, which is endorsed by the NRC. The use of this code also complies with the recommendations delineated in the acceptance criteria of SRP Section 3.8.4. Regarding the loads and load combinations, the applicant based its approach on the loads and load combinations required by ANSI/AISC N690-1994, Supplement 2 (R2004), which also complies with regulatory requirements and SRP Section 3.8.4, Acceptance Criterion II.3. Therefore, the approach is acceptable.

The applicant's response to RAI 259, Question 06.02.02-32, Part 2 was not acceptable to the staff and will be discussed further in the upcoming sections.

In response to RAI 259, Question 06.02.02-32, Part 3, the applicant indicated that the only debris interceptors that are subject to the dynamic effects of pipe whip, jet impingement, and missiles are the trash racks and their associated weirs located on the heavy floor that supports the RCS. Other debris interceptors are mounted within the IRWST area, which does not contain any pressurized piping. The trash racks and weirs are not subject to missile effects because they are located within the containment building distant from any mechanism that is capable of generating missiles. The applicant indicated that a geometric investigation of the layout of the trash racks and weirs relative to piping within their vicinity identified three pipelines capable of generating pipe whip loads on the trash racks and weirs. Therefore, whip restraints are provided at appropriate locations to eliminate these pipe whip effects. These whip restraints also prevent pipe break jets from impinging directly on the trash racks and weirs, based on the postulated break locations.

Since the detailed structural analysis of the subject structures will be performed later in the design process, the applicant proposed to add Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) Items 3.3c and 3.3d to cover the design details. Therefore, the staff is not able to make a safety conclusion at this time.

For the response to RAI 259, Question 06.02.02-32, Part 2, related to structural qualification applicable to seismic response spectra and equivalent static analysis procedures, and margin of safety, the applicant referred to Part 1of its response. This is not acceptable to the staff because the response to Part 1 does not explicitly identify the structural qualification, the damping value, and the margin of safety for the subject structures.

The staff believes that the most important, safety-significant elements of the design are the structural integrity of the DICSs and the robust design of joints between screen and steel structural elements. This is specifically important for the sump strainers to perform its intended safety function which is blockage of debris to provided clean water for the ECCS during and after of LOCA event. The staff concludes that the integrity and safety of the entire emergency core cooling system depends on the integrity and solid design of the DICSs as whole. This includes the robust design of structural steel components, adequate design of screen and its joints, the appropriate number of strong supports, and an anchorage system designed to withstand design-basis loads and load combinations during LOCA or and seismic events.

FSAR Tier 2, Section 3.8.4 does not provide a specific input for the design and analysis of the subject structures. The only document that addresses all design and system analysis issues required by GSI-191 and GL 2004-02 is Technical Report ANP-10923. This report includes the design and analysis of DICSs such as trash racks, retaining baskets, and sump strainers affecting the potential for post-accident debris blockage that could interfere with the capability of the recirculation mode of the ECCS during long-term reactor core cooling or during LOCA and seismic events.

The staff's evaluated the applicant's October 14, 2009, response to RAI 259, Question 06.02.02-32, and determined that the response is only partially acceptable, because the applicant did not provided sufficient information to address all of the staff's concerns. The applicant's responses did not include a discussion regarding whether these structures are designed adequately with sufficient margin of safety to withstand the loads and load combinations during the LOCA event and to perform their intended safety functions. The more detailed review of Technical Report ANP-10293 as the primary sources of information related to the design and analysis of U.S. EPR ECCS recirculation DICSs by the staff identified several other structural issues and deficiencies for the applicant to address. For example, according to Technical Report ANP-10923, the DICSs were designed and analyzed using austenitic stainless steels with material properties consistent with ANSI/AISC N690-1994, Supplement 2 (R2004). The structural acceptance criterion for these structures is that the design does not exceed the allowable stress level given in ANSI/AISC N690-1994, Supplement 2 (R2004). The staff was mainly concerned about the primary structural design aspects of the three DICSs and its components that the stress levels should not exceed the allowable stress level. The staff also is concerned about the design of the connection of the steel structural elements to box-type structures manufactured or constructed on site; the type of steel structures (welded or bolted), which relates to the structural qualification and damping values; and the joint design between heavy-duty mesh or screens to structural steel, specifically for the sump strainers. The connection of the sump strainer screen to the structural elements is a safety-significant issue and concerns the staff, because the hydrodynamic loads combined with other loads induced by the design-basis accident could damage and pop up the screen, creating a gap. The gap could then allow the debris to bypass the strainer and clog the sump pump. The staff was also concerned about whether the design of the support and anchorage system is in accordance with acceptable codes and standards. Specifically, the staff was interested in the appropriate connection of structures to the basemat or walls or both of the IRSWT and the type of supports (fixed or flexible) to address different types of induced stresses during design-basis accident loading. Therefore, to address these concerns, in follow-up RAI 384, Questions 03.08.04-11 through 03.08.04-14, the staff requested that the applicant for additional information and to address the staff's concerns noted above. In an August 30, 2010, response RAI 384, Question 03.08.04-11 through 03.08.04-14, the applicant provided the information given below.

RAI 384, Question 03.08.04-11

With regard to the response to RAI 259, Question 06.02.02-32, discussed in the previous paragraph, the report discussed the use and acceptability of ANSI/AISC N690-1994, Supplement 2 (R2004), for the design of DICSs. In RAI 384, Question 03.08.04-11, that followed RAI 259, Question 06.02.02-32 part (a) and (b), the staff raised the issue of the applicability of ANSI/AISC N690-1994 to the design of linear-type supports, which will be employed in the strainer component design. Therefore, in RAI 259, Question 06.02.02-32, the staff requested that the applicant describe the industry codes and standards applicable to the design and analysis of supports, anchorages, and joints related to Seismic Category I structures. In addition, the staff requested that the applicant describe how the structures would be connected and anchored to the concrete walls or base for the retaining baskets and the sump strainer, as it relates to the ability of these structures to perform their intended safety functions. The staff needed this information to ensure that the design of the supports, joints, and anchorage system complies with the acceptable codes and standards, and that the integrity and structural performance of the supports, joints, and anchorage system is not impaired for the intended functions.

In a August 30, 2010 response to RAI 259, Question 06.02.02-32, the applicant replied in terms of (1) the use of ANSI/AISC N690-1994 for the design of the supports, joints, and anchorage system, (2) the applicant's commitment to the ITAAC items and its description of the design and construction of connections, and (3) the use of additional industry codes for the design and analysis of the subject structures.

Staff Evaluation of Response to RAI 384, Question 3.08.04-11

The staff finds the applicant's response to the first part of RAI 384, Question 3.08.04-11 acceptable because applicant justified the use of ANSI/AISC N690-1994, Supplement 2 (R2004), as the basis for the design of supports, joints, and anchorage system by comparing the provisions of ANSI/AISC N690 to those of the sections of ASME Code, Section III, Subsection NF, on supports and their requirements for all type of stresses induced by loadings. The comparison showed that these requirements are the same. The staff confirmed this information, and finds it acceptable.

The staff finds the response to the second part of RAI 384, Question 03.08.04-11 acceptable because the applicant categorized the subject structures as Seismic Category I mechanical components and committed that the seismic qualification and installation of these components will be covered by ITAAC Items 3.3a and 3.3b in FSAR Tier 1, Table 2.2.2-3. In Part b of the response, the applicant stated:

> Because the final design of the anchorages will be completed after the debris interceptor components are procured ITAAC Items 3.3(a) and 3.3(b) will will be added to FSAR Tier 1, Table 2.2.2.-3 to cover the structural design details and structural evaluation of the components, including the anchorages of the components to the walls or the floor and attachments of the screens.

The staff confirmed that the FSAR Tier 1, Revision 3, contains the proposed additional ITAAC Items 3.3(c) and 3.3(d). Additionally, the applicant briefly described the conceptual design of the supports, anchorage components, and screen panels using three illustrations. For example, FSAR Tier 2, Figure 3.08.04-11-1 details the ball and socket joints that will be used to minimize thermal stress and transfer the loads to the floor or walls of the IRSWT.

The applicant also indicated that each of the four strainers has six such anchorage points mounting the strainer frame to the basemat. Each of the two double-compartment retaining baskets has four anchorage points mounting the basket frame to the basemat, four anchorage points mounting the frame to the side wall, and two anchorage points mounting the top horizontal cross-braces to the side wall. Each of the two single-compartment retaining baskets has at least eight anchorage points mounting the frame to the basemat and at least 10 anchorage points mounting the frame to the two sidewalls. The anchorages to the side walls are similar to those shown in FSAR Tier 2,Figure 3.08.04-11-1 and are divided between the walls, allowing for zero-, one-, and two-direction movement in a way that minimizes thermal stresses and still allows for the complete transfer of all forces to the concrete elements.

The staff's evaluation of the conceptual design of the DICSs supports and joints agrees with the applicant's statement that this type of joint and support allows free rotation in all directions and horizontal movement in three directions, depending on the location of joints and the resisting movement system. Although the design of ball and socket joints was invented for machinery, in particular for the linkages of motor vehicle steering devices, it is also used in medicine and structural applications. The compressive, tensile, and off-center load-carrying capacity and the free movement of the joint during dynamic loading in this type of support and joint are much greater than some of the similar types of design, such as wrist pin connections. The ball seat spherical design provides less wear and less maintenance for compression and tension loading because of its larger area and superior off-center load carrying capacity.

Therefore, considering the load-carrying capacity, off-center loading, free movement in all directions, reduced wear and maintenance, as well as the number of supports and joints for each structure, the staff finds the ball and socket design and application appropriate for the DICSs design.

The staff finds the third part of the response to RAI 384, Question 03.08.04-11 acceptable because the applicant listed other applicable industry codes and NRC guidance that will be used for the design of the DICSs and components, including the ASME B&PV, Section II, Part D, 2004 edition, on the design properties of materials; American Concrete Institute (ACI) 349-01/349R-01, “Code Requirements for Nuclear Safety Related Concrete Structures and Commentary,” for the concrete anchorages; and NRC RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, March 2007, for the selection of damping values. The applicant committed to incorporate all these changes and commitments into FSAR Tier 1, Table 2.2.2-3, and FSAR Tier 2, Section 6.3.

The staff finds the ITAAC items discussed above acceptable because they require the licensee to verify that the safety-related Seismic Category I DICSs are designed and constructed as described in FSAR Tier 1 and Tier 2. In addition, the use of these codes and standards together complies with the requirements of 10 CFR 50.55a and provides reasonable assurance that the design of the subject structures, systems, and components, including the supports, joints, and anchorage system, will have sufficient margin of safety to perform their intended safety functions. Therefore, the staff finds the response to RAI 384, Question 03.08.04-11 acceptable. Accordingly, the staff considers RAI 384, Question 03.08.04-11 resolved.

<u>RAI 384, Question 03.08.04-12</u>

On the basis of applicant’s response to RAI 259, Question 06.02.02-32, the staff identified a lack of sufficient information as well as deficiencies in addressing the staff’s concerns that did not allow the staff to reach conclusions about safety. The staff’s concerns related to the acceptability criterion described in SRP Section 3.8.4, Acceptance Criterion II.4. The staff requested that the applicant describe the design and analysis procedures used for Seismic Category I structures, assumptions about boundary conditions, and the extent of compliance with ANSI/AISC N690-1994 as the primary design code. The staff also requested that the applicant describe the expected behavior under applicable loading and the methods of load transfer to and from the various elements to their supports and to the foundation of the structure. The staff was also concerned about the type of steel structures (e.g., welded or bolted), appropriate damping values, differential pressure loading parameters, and thermal expansion release mechanisms, as well as computer programs used for the DICSs design.

The staff needed this information to establish the primary design methodology, analysis procedures, boundary condition assumptions, design parameters, and computer programs acceptable to the staff to ensure that these safety-related Seismic Category I structures are designed with sufficient margin of safety to perform their intended safety functions and so that the sump pumps can provide adequate cooling water to the core during a design-basis accident in accordance with GDC 35. To address these concerns, in RAI 384, Question 03.08.04-12, the staff requested that the applicant provide additional design details for the items listed above.

In a response to RAI 384, Question 03.08.04-12, the applicant replied in terms of (1) the use and justification of ANSI/AISC N690 for the support and anchorage design and the sequence of steps involved in stress calculations and analysis, (2) the damping values and types of steel structures, (3) the description of the conceptual design of double-compartment retaining baskets, for example, and (4) the material and mechanism of load transfer.

Staff Evaluation of Response to RAI 384, Question 03.08.04-12

The staff finds the applicant's response to the RAI 384, Question 03.08.04-12, Part (a) acceptable because the applicant identified the method and methodology for the load and stress calculations and analyses and provided the detailed sequence of steps for such calculations. The applicant committed to employ the structural mechanics equations either by hand or by using commercially available mathematical programs such as MathCAD to calculate loads and stress analyses for DICSs. The applicant committed that, in case detailed structural modeling is required, such modeling will be performed using the structural, and stress analysis programs ANSYS or BWSPAN or both. FSAR Tier 2, Section 3.9.1.2 describes these programs. **RAI 384, Question 03.08.04-12 is being tracked as a confirmatory item** to finalize its safety conclusions.

In the response to RAI 384, Question 03.08.04-12, Part (a), the applicant discussed the basic approach for the double-compartment retaining basket design, as illustrated in FSAR Tier 2, Figures 3.08.04-12-1 and 3.08.04-12-2, which shows fragment of bottom-portion quadrant structural frame and a typical filter panel for the wall of the baskets. The applicant then described the steps involved in the stress calculations and analyses, which consider the combination of static and dynamic fluid pressure resulting from seismic acceleration acting on the fluid in positive and negative directions (inside and outside the basket) to calculate the stresses in the wires of the screen as a two-directional network of tension cable members. The calculations involve determining the reactions at the joints of the wires connected to the boundary elements of each filter panel and evaluating reactions in the anchorage points, considering the structural connections validated by the analysis as the standard method. In FSAR Figure 3.08.04-14, the applicant presented a photograph of a representative design of the connection of wire cloth (steel screen) to the boundary elements corresponding to a filter panel. In further steps of the stress calculations and analyses, the applicant calculated the direct bearing reactions to the inside and outside stiffeners of filter panels and checked the stresses in these stiffeners acting as flexural members. The applicant then checked the stresses in welds between stiffener pairs and between stiffeners and edge frames and checked the adequacy of the connection of inside stiffeners to basket frame members. From the preceding loads applied to the basket frame members from the filter panels, the applicant followed these loads through their load paths throughout the main beams and girders to their culmination points at the anchorage points, calculating axial and shear forces and moments in all these members and checking the adequacy of stresses. In additional steps, the applicant performed a stress check in all spliced connections between the various weld areas of the basket frame and finally performed the stress analysis for the components of all of the anchorages.

Considering the geometric configurations and sizes of DICSs and the location of these structures in the RCS and IRSWT large area, the staff determined that these structures are typical and regular-shaped structures constructed of austenitic stainless steel elements. For the design and load carrying capacity analysis of this type of structure, the staff finds the applicant's approach that, , the standard methodology sufficient for static and simple dynamic loadings. However, considering the environment in which these structures are located and the design-basis accident or seismic loading conditions, the stress analyses should be more precise, as with the use of programs such as ANSYS or BWSPAN, as indicated by the applicant. The staff confirmed the applicability of these programs and that they are in accordance with NRC requirements; thus, the response is acceptable.

For other structures such as single-compartment retaining baskets, sump strainers, and trash racks, the applicant followed the same basic approach, except that the trash racks have no screen filter and there is no need to consider the submerged fluid pressures discussed below in the response to the third part of RAI 384, Question 03.08.04-12.

The staff finds the response to RAI 384, Question 03.08.04-12, Part (b) acceptable because the applicant identified the type of structural steel and structural damping values for the analysis of DICSs in accordance with RG 1.61. The critical damping value for the retaining basket and sump strainer frames as bolted structures is 7 percent and for the trash racks as fully welded structures is 4 percent. The staff confirmed these values to be in accordance with RG 1.61, Table 1, and thus they are acceptable.

The staff finds the response to RAI 384, Question 03.08.04-12, Part (c) acceptable because the filter panels are the components that receive the direct static and dynamic pressures from the fluids inside and outside, resulting in differential pressure. The applicant stated that the design assumptions will not take credit for the open area of screen if the functional testing results reveal the screen plugging. The pressure will be applied to the full area that is bounded by the plane of the wire cloth mesh. The applicant considered all states of pressure loadings to calculate the maximum value of differential pressure loadings on both sides of the filter panels and based on maximum loadings sizes the inside and outside stiffeners. Additionally, in the response to RAI 384, Question 03.08.04-12, Part (c), the applicant presented a conceptual detailed design of a typical filter panel for the wall of a double-compartment retaining basket in Figure 03.08.01-12-2. The figure show how such panels are configured in the walls and floor of the baskets of sump strainers.

The staff finds the response to RAI 384, Question 03.08.04-12, Part (d) acceptable because, in order to accommodate the themal expansion movements in the DCISs components, the applicant indicated that all structural components of debris interceptors are fabricated from the same material, thus, they would exhibit unrestrained growth without thermal stress when exposed to higher temperature of the LOCA environment if not anchorage to the surrounding building. Therefore, to transfer their applied loads to the concrete structure, the debris interceptors are anchored to the surrounding building in some directions. However, as noted in the response to RAI 384, Question 03.08.04-12, Part (d), the anchorages have been configured to provide unlimited rotation in all directions and provide translational movement in some directions at some locations, in order to limit the restraint to thermal growth during the temperature rise. This required restraint will still result in some thermal stress within the components of the debris interceptors. This stress will be accounted for in the analysis of these components. The staff agrees with the applicant’s analysis, and since the applicant committed to account for the additional thermal stress induced by the anchorages and supports in the loading combinations, the design approach is acceptable.

Further, the applicant indicated that the structural evaluation and stress margin report will provide the detailed description of the structural design and analysis of the debris interceptor components, in accordance with the ITAAC items 3.3(c) and 3.3(d) added in response to RAI 384, Question 03.08.04-11.

Since the applicant committed to address these concerns in an ITAAC inspection in FSAR Tier 2, Section 14.3.2, the staff finds that the applicant has adequately addressed this issue. Therefore, the staff considers the response to RAI 384, Question 03.08.04-12 acceptable, but it will be tracked as a confirmatory item for ITAAC 3.3(c) and 3.3(d). **RAI 384, Question 03.08.04-12, ITAAC Items 3.3(c) and 3.3(d) are being tracked as confirmatory items**.

RAI 384, Question 03.08.04-13

In the response to the second part of RAI 259, Question 06.02.02-32, the applicant referred to the first part of its response, which did not clearly address the GL 2004-02 issue. The staff's concerns in the question related to determining the adequacy of the design assumptions and parameters for the subject structures such that they will perform their intended functions. Without this information, the staff was not able to conclude its safety evaluations. Therefore, in RAI 384, Question 03.08.04-13, the staff requested that the applicant summarize the structural qualification results and design margins for the various sump debris interceptors and to identify structures considered for analysis for structural qualification purposes under the design loads and design temperature. Alternatively, if a combined license information item or an ITAAC item is needed, the staff asked the applicant to describe this information in detail.

Staff Evaluation of Response to RAI 384, Question 03.08.04-13

Based on the applicant's response to RAI 384, Question 03.08.04-13, Part (a), the staff finds the response acceptable, because the applicant committed to provide the requested information in the structural evaluation and stress margin report, in accordance with ITAAC Items 3.3(c) and 3.3(d) added to FSAR Tier 1, Section 14.3.2, Table 2.2.2-3 in response to RAI 384, Question 03.08.04-11 in FSAR Tier 1, Table 2.2.2-3.

The staff finds the response to RAI 384, Question 03.08.04-13, Part (b), acceptable because the methodology for the qualification and design of DICSs using design-by-analysis approach based on ANSI/AISC N690--1994, Supplement 2 (R2004), is consistent with 10 CFR 50.55a and the guidance in SRP Section 3.8.4, Subsection II. In addition, the applicant indicated that the analysis will demonstrate the structural qualification of the main girders, intermediate beams, stiffeners, wire cloth, bolts, connecting welds, and other components that are part of the load-bearing structures. On this basis, the staff finds the design-by-analysis approach for the DICSs acceptable, but it will be tracked as a confirmatory item to ensure the adequacy of the ITAAC items included in the FSAR revisions. **RAI 384, Question 03.08.04-13, Part (b) is being tracked as a confirmatory item.**

RAI 384, Question 03.08.04-14

SRP Section 3.8.4, Acceptance Criterion II.4, requires the applicant to describe the design and analysis procedures, assumptions about boundary conditions, and the extent of compliance with the ANSI/AISC N690-1994 specifications for steel structures. The description should include the expected behavior under load and the mechanisms of load transfer from the various elements to their supports and to the foundations. For the U.S. EPR ECCS recirculation DICSs, the description should include anchorage and joint design, specifically for the sump strainer screen joint to the structural elements. The staff's concern is to ensure the integrity of sump strainer screen joints to withstand the stresses induced by the design-basis load combination in the event of a LOCA or safe-shutdown earthquake.

In Technical Report ANP-10293 and as part of its response to RAI 259, Question 06.02.02-32, the applicant did not address the design of joints and the attachment of the screens to the structural steel members. To address these issues in RAI 384, Question 03.08.04-14, the staff requested that the applicant describe the design of the screen joints and clarify how the screens are attached to the sump strainer structural elements to preclude the possibility of debris bypassing the screening. The staff also requested that the applicant justify the assumption that the screens will remain undamaged and that no gaps and breaches between the screens and the structural members will occur, such that the operability of the recirculation core cooling sump pump will not be affected in the event of a LOCA or safe-shutdown earthquake.

The staff needed this information to ensure that the integrity of the screen joints is not impaired, specifically for the sump strainers, which play a significant safety role in the overall integrity of the system that provides clean water for the core cooling system in the event of a design-basis accident or seismic loading. The screens and joints must withstand the design-basis loads and transfer these loads to the vertical and lateral support elements, thus avoiding the development of gaps and breaches in the screens that will cause the debris to bypass the screens and plug the sump pumps.

Staff Evaluation of Response to RAI 384, Question 03.08.04-14

The staff finds the applicant's response to RAI 384, Question 3.08.04-14 acceptable because the applicant addressed some of the staff concerns in its responses to RAI 384, Questions 03.08.04-11, 03.08.04-12, and 03.08.04-13, as referenced by the applicant. For example, the applicant addressed design and analyses methods in its responses to RAI 384, Questions 03.08.04-11 through 03.08.04-13. The applicant discussed the analytical methodology in the first part of its response to RAI 384, Question 03.08.04-12. Boundary conditions are addressed in the second part of the response to RAI 384, Question 03.08.04-11 and in the fourth part of the response to RAI 384, Question 03.08.04-12. The applicant addressed the application of software in the first paragraph of its response to RAI 384, Question 03.08.04-12. The applicant indicated that the connections between the various structural elements of the devices are standard structural connections, which are validated by analysis, and the conceptual designs are presented in Figures 3.08.04-11-1, 3.08.04-12-1, and 3.08.04-12-2 that are discussed in the first part of the response to RAI 384, Question 03.08.04-12.

In a response to RAI 384, Question 03.08.04-14, the applicant provided a photograph of the design representative of the connection of the wire cloth (screen) to the boundary elements corresponding to a filter panel. The depiction is based on a model with various components cut away for clarity and does not reflect the continuity of these components that would occur in the actual device.

Based on its evaluation of FSAR Revision 3 and the applicant's responses to RAI 384, Question 03.08.04-11 through 03.08.04-14, the staff accepted the design of the DICSs components. In its response to RAI 384, Question 03.08.04-11, August 30, 2010, the applicant committed to provide design details regarding the seismic qualification and installation of these components under ITAAC Items 3.3(a) and 3.3(b) in FSAR Tier 1, Table 2.2.2-3. Further, the applicant added ITAAC Items 3.3(c) and 3.3(d) in FSAR Tier 1, Table 2.2.2-3 in response to RAI 384, Question 03.08.04-11 to address the design and stress margin analysis of the recirculation DICSs. Therefore, the staff concluded that the applicant provided sufficient information and reasonable assurance that the design of these structures are in accordance with the applicable codes and standards acceptable to the staff and complies with the requirements of GDC 2. In addition, the staff concluded that the design provides sufficient margin of safety to withstand the loads and load combinations during the design-basis accident and, thus, are capable of performing their intended safety functions.

However, the applicant submitted FSAR Revision 4 on November 15, 2012. In FSAR Revision 4, the staff notes that the applicant delete ITAAC Items 3.3(c) and 3.3(d) in FSAR Tier 1, Table 2.2.2-3 as well as the DICSs COL information item in FSAR Tier **X**, Section 6.2.2.2, page 6.2-237. Both the ITAAC items and the COL information items were committed to by the applicant in response to RAI 384, Questions 03.08.04-11 through 03.08.04-14 to cover the design details and stress margins analysis for the DICSs. The staff relied on these items to make its safety findings. Therefore, the deletion of ITAAC Items 3.3(c) and 3.3(d) were not acceptable to the staff.

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Accordingly, in a December 6, 2012, email, the staff requested that the applicant justify the deletion of ITAAC Items 3.3(c) and 3.3(d). In a December 19, 2012, email response, the applicant provided its justification, which the staff determined was not acceptable for the following reasons.

1. The applicant stated that the COL information item in FSAR Tier 2, Section 6.2.2 was an initial approach to respond to RAI 384, Question 03.08.04-13, and was not part of the COL information items in FSAR Tier 2, Table 1.8-2. Thus, the applicant changed their approach as reflected in FSAR Revision 4.

   The staff determined that this approach was not acceptable. However, if the applicant provides a structural evaluation including an analysis of the stress margins in the design margin report, via ITAAC 3.3(c) and 3.3(d), as the applicant committed to, then the COL information item would be considered acceptable to the staff.

2. The applicant indicated that ITAAC Items 3.3(c) and 3.3(d) were previously added in the response to RAI 384, Question 03.08.04-11 to cover structural design details and structural evaluation of the components, including the anchorages of the components to the walls or the floor, and the attachments of the screens. The applicant justified the removal of ITAAC Items 3.3(c) and 3.3(d) from FSAR Revision 4 by stating that, as part of its evaluation of ITAAC associated with the draft response to RAI 469, Question 14.03-16 (ITAAC generic wording issues), these ITAAC were deleted because they were considered redundant to the ITAAC listed in Items 3.3(a) and 3.3(b).

The staff determined that the applicant’s response is not acceptable because there is no redundancy between ITAAC Items 3.3(c) and 3.3(d) that were committed to specifically for the design and analysis of DICSs in response to RAI 384, Question 03.08.04-11, Part 2 and Question 03.08.04-13, Part (a). In addition, the applicant’s method to address the staff’s concerns contained in RAI 384, Questions 03.08.04-11 and 03.08.04-13 are deleted. If the applicant justifies the redundancy between ITAAC Items 3.3(a) and 3.3(b), and ITAAC Items 3.3(c) and 3.3(d), then the deletion of ITAAC items would be acceptable to the staff.

Based on the discussion above, **RAI 384, Questions 03.08.04-1~~1~~2 and 03.08.04-13 are being tracked as ~~open~~ confirmatory items**.

3.8.4.5 Combined License Information Item

There is no combined license information item for this section.

3.8.4.6 Conclusion

This report provides the staff's review and assessment of the U.S. EPR ECCS recirculation DICSs as described in Technical Report ANP-10293, Revision 4. The structural integrity, design and analysis of the U.S. EPR ECCS DICSs recirculatory system has been reviewed by the staff in accordance with NUREG-0800, Section 3.8.4, "Other Seismic Category I Structures." The staff's review included the applicable codes used for the analysis and design of the structures, material properties, analysis procedures used to perform the dynamic analyses of the DICSs, load and load combinations, and structural acceptance criteria to comply with GDC 1, GDC 2, and GDC 4 and other regulatory requirements listed in Section 3.8.4.3 of this report.

Based on the open items discussed above, the staff cannot find the design, as described and evaluated by the staff in this section, to be acceptable as it relates to RAI 384, Question 03.08.04-11 in accordance with the requirements of NRC regulations

References:

1. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 6.2.2, "Containment Heat Removal System," Revision 5, U.S. NRC, March 2007.

2. NUREG/CR-6762, "Assessment of Debris Accumulation on PWR Sump Performance," U.S. NRC, August 2002.

3. Technical Report ANP-10293, "U.S. EPR Design Features to Address GSI-191," Revision 3, AREVA NP Inc., February 2008.

4. RG 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 3, November 2003.

5. GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," U.S. NRC, September 2004.

6. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 3.8.4, "Other Seismic Category I Structures," Revision 2, March 2007.

7. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. NRC, 2010 Edition.

8. Response to RAI 259, Supplement 1, U.S. EPR Standard Design Certification, AREVA NP Inc., Docket No. 52-020, SRP Section 06.02.02, "Containment Heat Removal Systems Application Section: 06.02.02," July 2009.

9. ANSI/AISC N690-1994, Supplement 2, “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities,” American National Standards Institute/American Institute of Steel Construction, Revision 2004.

10. ASME B&PV Code, Case N-570-2 2008, “Alternative Rules for Linear Piping and Linear Standard Supports for Class 1, 2, 3, and MC,” Section III, Division 1, American Society of Mechanical Engineers, 2008.

11. Response to RAI 384, Supplement 4 (4350, 4351, 4469, 4498, 4527), U.S. EPR Standard Design Certification, AREVA NP Inc., Docket No. 52-020, SRP Section 03.08.04, “Other Seismic Category I Structures,” Revision 3, May 2010.

12. RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, U.S. NRC, March 2007.