C.I.3. Design of Structures, Systems, Components, and Equipment

Chapter 3 of the final safety analysis report (FSAR) should identify, describe, and discuss the principal architectural and engineering design of those structures, systems, components, and equipment that are important to safety.

C.I.3.1 *Conformance with NRC General Design Criteria*

Discuss the extent to which plant structures, systems, and components (SSCs) important to safety meet the NRC's "General Design Criteria for Nuclear Power Plants," as specified in Appendix A to 10 CFR Part 50. For each applicable criterion, provide a summary to show how the principal design features meet the general design criteria (GDC). Identify and justify any exceptions to the GDCs. In the discussion of each criterion, identify the sections of the FSAR where more detailed information is presented to demonstrate compliance with or exceptions to the GDCs.

C.I.3.2 *Classification of Structures, Systems, and Components*

C.I.3.2.1 Seismic Classification

Identify those SSCs important to safety that are designed to withstand the effects of earthquakes without loss of capability to perform their safety functions.

Plant features, including foundations and supports, that are designed to remain functional in the event of a safe shutdown earthquake (SSE, see Section 2.5) or surface deformation should be designated as Seismic Category I. Specifically, these plant features are those necessary to ensure the following characteristics:

(1) integrity of the reactor coolant pressure boundary

(2) capability to shut down the reactor and maintain it in a safe shutdown condition

(3) capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR 50.34(a)(1)

Guidance for identifying Seismic Category I SSCs is provided in Regulatory Guide 1.29, "Seismic Design Classification." Provide a list of all Seismic Category I items, and indicate whether the recommendations of Regulatory Guide 1.29 are being followed. If only portions of structures and systems are Seismic Category I, they should be listed and, where necessary for clarity, the boundaries of the Seismic Category I portions should be shown on piping and instrumentation diagrams. The portions of SSCs for which continued functioning is not required, but whose failure could reduce the functioning of any Seismic Category I plant feature to an unacceptable safety level or could result in incapacitating injury to control room occupants, should also be identified and designed and constructed so that the SSE would not cause such failure. Identify differences from the recommendations of Regulatory Guide 1.29, and discuss the proposed classification. Guidance for determining the seismic design of SSCs of radioactive waste management facilities is provided in Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants." Identify the radioactive waste management SSCs that require seismic design considerations and discuss differences from the recommendations of Regulatory Guide 1.143.

Guidance for determining the seismic design of instrument sensing lines is provided in Regulatory Guide 1.151, "Instrument Sensing Lines." Identify the instrument sensing lines that require seismic design considerations and discuss differences from the recommendations of Regulatory Guide 1.151.

List or otherwise clearly identify all SSCs or portions thereof that are intended to be designed for an operating basis earthquake (OBE).

C.I.3.2.2 System Quality Group Classification

Identify those fluid systems or portions thereof that are important to safety, as well as the applicable industry codes and standards for each pressure-retaining component.

Section 50.55a of 10 CFR Part 50 specifies quality requirements for the reactor coolant pressure boundary, and Regulatory Guide 1.26 describes a quality group classification system and relates it to industry codes for water- and steam-containing fluid systems. Guidance regarding system quality group classification and/or codes and standards is also provided in Regulatory Guide 1.143, for radioactive waste management systems, and Regulatory Guide 1.151, for instrument sensing lines. Indicate the extent to which the recommendations of Regulatory Guide 1.26, Regulatory Guide 1.143, and Regulatory Guide 1.151 are followed. Identify any differences, and justify each proposed quality group classification in terms of the reliance placed on those systems that:

(1) Prevent or mitigate the consequences of accidents and malfunctions originating within the reactor coolant pressure boundary,

(2) Permit reactor shutdown and maintenance in the safe shutdown condition, or

(3) Contain radioactive material.

For such systems, specify the proposed design features and measures that would be applied to attain a quality level equivalent to the level of the Regulatory Guide 1.26 and Regulatory Guide 1.143 classifications, including the quality assurance programs that would be implemented. Discuss group classification boundaries of each safety-related system. The classifications should be marked/noted on drawings at valves or other appropriate locations in each fluid system where the respective classification changes in terms of the NRC group classification letters (for example, from A to B, B to C, C to D, as well as other combinations) or, alternatively, in terms of corresponding classification notations that can be referenced with those classification groups in Regulatory Guide 1.26 Regulatory Guide 1.143.

C.I.3.3 *Wind and Tornado Loadings*

C.I.3.3.1 Wind Loadings

Define the design-basis wind loadings of Seismic Category I structures:

(1) Present the design wind velocity and its recurrence interval, the importance factor, and the exposure category.

(2) Describe the methods used to transform the wind velocity into an effective pressure applied to surfaces of structures, and present the results in tabular form for plant SSCs. Provide current references for the basis, including the assumptions.

C.I.3.3.2 Tornado Loadings

Define the design-basis tornado loadings on structures that must be designed to withstand tornadoes:

(1) Present the design parameters applicable to the design-basis tornado, including the maximum tornado velocity, the pressure differential and its associated time interval, and the spectrum and pertinent characteristics of tornado-generated missiles.

(2) Describe the methods used to transform the tornado loadings into effective loads on structures:

   (a) Discuss the methods used to transform the tornado wind into an effective pressure on exposed surfaces of structures, including consideration of geometrical configuration and physical characteristics of the structures and the distribution of wind pressure on the structures.

   (b) If venting of a structure is used, describe the methods employed to transform the tornado-generated differential pressure into an effective reduced pressure.

   (c) Describe the methods used to transform the tornado-generated missile loadings, which are considered impactive dynamic loads, into effective loads.

   (d) Identify the various combinations of the above individual loadings that will produce the most adverse total tornado effect on structures.

Present information showing that the failure of any structure or component that is not designed for tornado loads will not affect the ability of other structures to perform their intended safety functions.

C.I.3.4 *Water Level (Flood) Design*

C.I.3.4.1 Flood Protection

Describe the flood protection measures for SSCs whose failure could prevent safe shutdown of the plant or result in uncontrolled release of significant radioactivity. The information provided in this section of the FSAR should be consistent with the information provided in Sections C.I.2.4 and C.I.2.5 for safe shutdown ground motion, as well as Section C.I.3.8.4 for seismic design, which should be referenced as appropriate:

(1) Identify the safety- and non-safety-related SSCs that should be protected against external flooding resulting from natural phenomena, and internal flooding resulting from failures of non-seismic tanks, pressure vessels, and piping. Guidance is provided in Regulatory Guide 1.59, "Design-Basis Floods for Nuclear Power Plants," and Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."

(2) For structures housing safety-related systems or equipment, describe their capabilities to withstand flood conditions. Show the relationship between structure elevation and flood elevation, including waves and wind effects as defined in Section 2.4 of the FSAR and exterior access openings and penetrations that are below the design flood levels.

(3) If flood protection is required, discuss the means of providing flood protection (e.g., external barriers, enclosures, pumping systems, stoplogs, watertight doors and penetrations, drainage systems) for equipment that may be vulnerable because of its location and the protection provided to cope with potential in-leakage from such phenomena as cracks in structure walls, leaking water stops, and effects of wind wave action (including spray). Identify (on plant layout drawings) individual compartments or cubicles that house safety-related equipment and act as positive barriers against possible flooding.

(4) Discuss the measures taken to protect SSCs important to safety from flooding attributable to postulated failures of non-Seismic Category I and non-tornado-protected tanks, vessels, piping, and other process equipment, backflow through floor drains, and operation of the fire protection system.

(5) Describe the capability of roofs designed for safety-related structures to withstand the effects of maximum precipitation events in accordance with Regulatory Position 3 of Regulatory Guide 1.102.

(6) If all safety-related SSCs are not protected by permanent structural provisions, describe the procedures and implementation times required to bring the reactor to a cold shutdown for the flood conditions identified in Section 2.4.14. Guidance is provided in Regulatory Position 2 of Regulatory Guide 1.59 and Regulatory Position 2 of Regulatory Guide 1.102. Compare these procedures and implementation times with those required to implement flood protection requirements as identified in Section 2.4.14.

(7) Identify those systems or components important to safety, if any, that are capable of normal function while completely or partially flooded.

Describe any permanent dewatering system provided to protect SSCs important to safety from the effects of ground water:

(1) Provide a summary description of the dewatering system. Describe all major subsystems, such as the active discharge subsystem and the passive collection and drainage subsystem.

(2) Describe the design bases for the functional performance requirements for each subsystem, along with the bases for selecting the system operating parameters.

(3) Provide a safety evaluation demonstrating how the system satisfies the design bases, the system's capability to withstand design-basis events, and its capability to perform its safety function assuming a single active failure with the loss of offsite power. Evaluate protection against single failure in terms of piping arrangement and layout, selection of valve types and locations, redundancy of various system components, redundancy of power supplies, redundant sources of actuation signals, and redundancy of instrumentation. Demonstrate that the dewatering system is protected from the effects of pipe breaks and missiles.

(4) Describe the testing and inspection to be performed to verify that the system has the required capability and reliability, as well as the instrumentation and controls necessary for proper operation of the system.

C.I.3.4.2 Analysis Procedures

Describe the methods and procedures by which the static and dynamic effects of the design-basis flood or groundwater conditions identified in Section 2.4 of the FSAR that are applied to seismic Category I structures that are identified as providing protection against external flooding. For each seismic Category I structure that may be affected, summarize the design-basis static and dynamic loadings, including consideration of hydrostatic loadings, equivalent hydrostatic dynamically induced loadings, coincident wind loadings, and the static and dynamic effects on foundation properties (Section 2.5 of the FSAR).

Describe any physical models used to predict prototype performance of hydraulic structures and systems. Guidance is provided in Regulatory Guide 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants."

C.I.3.5 *Missile Protection*

C.I.3.5.1 Missile Selection and Description

C.I.3.5.1.1 *Internally Generated Missiles (Outside Containment)*

Identify all structures, systems (or portions of systems), and components (SSCs) that are to be protected against damage from internally generated missiles. These are the SSCs that are necessary to perform functions required to attain and maintain a safe shutdown condition or to mitigate the consequences of an accident. Regulatory Guide 1.117, "Tornado Design Classification," provides guidance on the SSCs that should be protected. Missiles associated with over speed failures of rotating components (e.g., motor-driven pumps and fans), failures of high-pressure system components, and gravitational missiles (e.g., falling objects resulting from a non-seismically designed SSC during a seismic event) should be considered. The design bases should consider the design features provided for either continued safe operation or shutdown during all operating conditions, operational transients, and postulated accident conditions.

Provide the following information for those SSCs outside containment that require protection from internally generated missiles:

(1) locations of the SSCs

(2) applicable seismic category and quality group classifications (may be referenced from Section 3.2)

(3) sections of the FSAR in which descriptions of the items may be found, including applicable drawings or piping and instrumentation diagrams

(4) missiles to be protected against, their sources, and the bases for their selection for analysis

(5) missile protection provided

Evaluate the ability of the SSCs to withstand the effects of selected internally generated missiles. The protection provided should meet the guidance of Regulatory Position 3 of Regulatory Guide 1.115, "Protection Against Low-Trajectory Turbine Missiles."

C.I.3.5.1.2 ***Internally Generated Missiles (Inside Containment)***

Identify all plant SSCs inside containment that should be protected from internally generated missiles. These are the SSCs whose failure could lead to offsite radiological consequences, or those required for safe plant shutdown to a cold condition assuming an additional single failure. Missiles associated with over speed failures of rotating components (e.g., pumps, fans, compressors), primary and secondary failures of high-pressure system components (e.g., reactor vessel, steam generator, pressurizer, core makeup tanks, accumulators, reactor coolant pump castings, passive residual heat exchanger, piping), gross failure of a control rod drive mechanism, hydrogen explosion inside containment, and gravitational effects (e.g., falling objects resulting from the movement of a heavy load or a non-seismically designed SSC during a seismic event, secondary missiles caused by a falling object striking a high-energy system) should be identified.

Provide the following information for those SSCs important to safety inside containment that should be protected against internally generated missiles:

(1) location of the SSCs

(2) missiles to be protected against, their sources, and the bases for their selection for analysis

(3) missile protection provided (identify SSCs protected by physical barriers and, for those protected by redundancy, demonstrate the separation and independence)

(4) an evaluation demonstrating the ability of the SSCs to withstand the effects of selected internally generated missiles

C.I.3.5.1.3 ***Turbine Missiles***

Provide the following information to demonstrate that SSCs important to safety have adequate protection against the effects of potential turbine missiles. (Regulatory Guide 1.117, "Tornado Design Classification," describes examples of SSCs important to safety that should be protected):

(1) Indicate whether the orientation of the turbine is favorable or unfavorable relative to the placement of the containment and other SSCs important to safety. Favorably oriented turbine generators are located such that the containment and all, or almost all, SSCs important to safety located outside containment are excluded from the low-trajectory hazard zone described in Regulatory Guide 1.115, "Protection Against Low-Trajectory Turbine Missiles." Provide the following information to justify the turbine's orientation (information provided in other sections may be referenced as appropriate):

    (a) dimensioned plant layout drawings (plan and elevation views) with the turbine and containment buildings clearly identified

    (b) barriers, including structural wall material strength properties and thickness

    (c) SSCs important to safety in terms of location, redundancy, and independence

    (d) all turbine-generator units (present and future) in the vicinity of the plant being reviewed

    (e) a quantitative description of the turbine-generator in terms of rotor shaft, wheels/buckets/blades, steam valve characteristics, rotational speed, and turbine internals pertinent to turbine missile analyses

    (f) postulated missiles in terms of missile size, mass, shape, and exit speed for design over speed and destructive over speed in postulated turbine failures (describe the analysis used in estimating the missile exit speeds, and identify the direction of rotation with respect to each turbine-generator under consideration)

(2) Provide the methods, analyses, and results for the turbine missile generation probability calculations.

(3) Describe the inservice inspection and testing program that will be used to maintain an acceptably low missile generation probability.

(4) Demonstrate the structural capability of any barriers (or structures used as barriers) that protect SSCs to withstand turbine missiles in the event of a turbine failure.

C.I.3.5.1.4 ***Missiles Generated by Tornadoes and Extreme Winds***

Identify all missiles generated as a result of high-speed winds such as tornadoes, hurricanes, and any other extreme winds. For selected missiles, specify the origin (including height above plant grade), dimensions, mass, energy, velocity, trajectory, and any other parameters required to determine missile penetration. Guidance for selecting the design-basis tornado-generated missiles is provided in Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants."

C.I.3.5.1.5 ***Site Proximity Missiles (Except Aircraft)***

Identify all missile sources resulting from accidental explosions in the vicinity of the site, based on the nature and extent of nearby industrial, transportation, and military facilities (other than aircraft) identified in Sections 2.2.1–2.2.3 of the FSAR. The following missile sources should be considered with respect to the site:

(1) train explosions (including rocket effects)
(2) truck explosions
(3) ship or barge explosions
(4) industrial facilities (where different types of materials are processed, stored, used, or transported)
(5) pipeline explosions
(6) military facilities

Identify the SSCs listed in Section 3.5.2 of the FSAR that have the potential for unacceptable missile damage, and estimate the total probability of the missiles striking a vulnerable critical area of the plant. If the total probability is greater than an order-of-magnitude of 10^{-7} per year, missile effects on the SSCs should be accompanied by a specific missile description, including missile size, shape, weight, energy, material properties, and trajectory.

C.I.3.5.1.6 ***Aircraft Hazards***

Provide an aircraft hazard analysis for each of the following:

(1) Federal airways, holding patterns, or approach patterns within 3.22 kilometers (2 miles) of the nuclear facility

(2) all airports located within 8.05 kilometers (5 statute miles) of the site

(3) airports with projected operations greater than $193d^2$ ($500d^2$) movements per year located within 16.10 kilometers (10 statute miles) of the site and greater than $386d^2$ ($1000d^2$) outside 16.10 kilometers (10 statute miles), where d is the distance in kilometers (statute miles) from the site

(4) military installations or any airspace usage that might present a hazard to the site [for some uses, such as practice bombing ranges, it may be necessary to evaluate uses as far as 32.19 kilometers (20 statute miles) from the site]

Hazards to the plant may be divided into accidents resulting in structural damage and accidents involving fire. These analyses should be based on the projected traffic for the facilities, the aircraft accident statistics provided in Section 2.2, and the critical areas described in Section 3.5.2 of the FSAR.

The aircraft hazard analysis should provide an estimate of the total aircraft hazard probability per year. Aircraft accidents that could lead to radiological consequences in excess of the exposure guidelines of 10 CFR 50.34(a)(1) with a probability of occurrence greater than an order-of-magnitude of 10^{-7} per year should be considered in the design of the plant. Provide and justify the aircraft selected as the design-basis impact event, including its dimensions, mass (including variations along the length of the aircraft), energy, velocity, trajectory, and energy density. Resultant loading curves on structures should be presented in Section 3.5.3 of the FSAR.

All parameters used in these analyses should be explicitly justified. Wherever a range of values is obtained for a given parameter, it should be plainly indicated and the most conservative value used. Justification for all assumptions should also be clearly stated.

C.I.3.5.2 Structures, Systems, and Components To Be Protected from Externally Generated Missiles

Identify the SSCs that should be protected from externally generated missiles. These are the SSCs that are necessary for safe shutdown of the reactor facility and those whose failure could result in a significant release of radioactivity. Structures (or areas of structures), systems (or portions of systems), and components should be protected from externally generated missiles if such a missile could prevent the intended safety function, or if as a result of a missile impact on a non-safety-related SSC, its failure could degrade the intended safety function of a safety-related SSC. Any failure of a non-safety-related SSC that could result in external missile generation should not prevent a safety-related SSC from performing its intended function. Guidance on the SSCs that should be protected against externally generated missiles is provided in Regulatory Position 2 of Regulatory Guide 1.13, “Spent Fuel Storage Facility Design Basis”; Regulatory Positions 2 and 3 of Regulatory Guide 1.27, “Ultimate Heat Sink for Nuclear Power Plants”; Regulatory Position C.1 of Regulatory Guide 1.115, “Protection Against Low Trajectory Turbine Missiles”; and Regulatory Positions 1–3 and the appendix to Regulatory Guide 1.117, “Tornado Design Classification.”

C.I.3.5.3 Barrier Design Procedures

Provide the following information concerning the design of each structure or barrier to resist the missile hazards previously described:

(1) methods used to predict local damage in the impact area, including estimation of the depth of penetration

(2) methods used to estimate barrier thickness required to prevent perforation

(3) methods used to predict concrete barrier potential for generating secondary missiles by spalling and scabbing effects

(4) methods used to predict the overall response of the barrier and portions thereof to missile impact, including assumptions on acceptable ductility ratios and estimates of forces, moments, and shears induced in the barrier by the impact force of the missile

C.I.3.6 *Protection Against Dynamic Effects Associated with Postulated Rupture of Piping*

Describe design bases and design measures used to ensure that the containment vessel and all essential equipment inside or outside the containment, including components of the reactor coolant pressure boundary, have been adequately protected against the effects of blowdown jet and reactive forces and pipe whip resulting from postulated rupture of piping located either inside or outside of containment.

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

Describe the plant design for protection against high- and moderate-energy fluid system piping failures outside containment to ensure that such failures would not cause the loss of needed functions of systems important to safety and ensure that the plant could be safely shut down in the event of such failures:

(1) Identify systems or components important to plant safety or shutdown that are located proximate to high- or moderate-energy piping systems and that are susceptible to the consequences of failures of these piping systems:

  (a) Relate the identification to predetermined piping failure locations in accordance with Section C.I.3.6.2. Provide drawings indicating typical piping runs with failure points.

  (b) Identify those conditions for which operation of the component will not be precluded.

  (c) Indicate the design approach taken to protect the systems and components identified above.

(2) Provide a listing of high- and moderate-energy lines:

  (a) Submit a description of the layout of all piping systems where physical arrangement of the piping systems provides the required protection.

  (b) Provide a description of the design basis of structures and compartments used to protect nearby essential systems or components.

  (c) Describe the arrangements to ensure the operability of safety features where neither separation nor protective enclosures are practical.

(3) Describe the failure mode and effects analyses to verify that the consequences of failures of high- and moderate-energy lines do not affect the ability to safely shut down the plant:

  (a) Identify the locations and types of failures considered (e.g., circumferential or longitudinal pipe breaks, through-wall cracks, leakage cracks) and the dynamic effects associated with the failures (e.g., pipe whip, jet impingement). The potential effects of secondary missiles should also be considered.

  (b) Explain the assumptions made in the analyses with respect to the following:

    - availability of offsite power
    - failure of single active components in systems used to mitigate the consequences of the piping failure
    - special provisions applicable to certain dual-purpose systems
    - use of available systems to mitigate the consequences of the piping failure

(c) Describe the effects of piping failures in systems not designated to Seismic Category I standards on essential systems and components, assuming concurrent failure of a single active component and a loss of offsite power.

(d) Describe the environmental effects of pipe rupture (e.g., temperature, humidity, pressure, spray-wetting, flooding), including potential transport of the steam environment to other rooms or compartments, and the subsequent effects on the functional performance of essential electrical equipment and instrumentation.

(e) Describe the effects of postulated failures on habitability of the control room and access to areas important to safe control of post-accident operations.

C.I.3.6.2 Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping

Describe the criteria for determining the location and configuration of postulated breaks and cracks in high- and moderate-energy piping inside and outside of containment; the methods used to define the jet thrust reaction at the break or crack location and the jet impingement loading on adjacent safety-related SSCs; and the design criteria for pipe whip restraints, jet impingement barriers and shields, and guard pipes.

C.I.3.6.2.1 ***Criteria Used to Define Break and Crack Location and Configuration***

Provide the criteria used to determine the location and configuration of postulated breaks and cracks in those high- and moderate-energy piping systems for which separation or enclosure cannot be achieved. In the case of containment penetration piping, in addition to the material requested above, provide details of the containment penetration identifying all process pipe welds, access for inservice inspection of welds, points of fixity, and points of geometric discontinuity. Discuss the implementation of criteria for defining pipe break and crack locations and configurations. Provide the resulting number and location of design-basis breaks and cracks. Also provide the postulated rupture orientation (such as circumferential and/or longitudinal break) for each postulated design-basis break location.

C.I.3.6.2.2 ***Guard Pipe Assembly Design Criteria***

Describe the details of protective assemblies or guard pipes to be used for piping penetrations of containment areas. (A guard pipe is a device to limit pressurization of the space between dual barriers of certain containments to acceptable levels.) Discuss whether such protective assemblies provide an extension of containment, prevent over-pressurization, or both. Identify where moment-limiting restraints are used at the extremities or within the protective assembly. Provide the design criteria for the process pipe within the protective assembly, fluid heads and bellows expansion joints, and the guard pipe that is used with the assembly. In addition, describe the method of providing access and the location of such access openings to permit periodic examinations of all process pipe welds within the protective assembly, as required by the plant's inservice inspection program. (Refer to Section 5.2.4 for ASME Class 1 systems, and Section 6.6 for ASME Class 2 and 3 systems.) Discuss the implementation of the design criteria relating to protective assemblies or guard pipes, including their final design and arrangement of the access openings that are used to examine all process pipe welds within such protective assemblies to meet the requirements of the plant's inservice inspection program.

C.I.3.6.2.3 ***Analytical Methods to Define Forcing Functions and Response Models***

Describe the analytical methods used to define the forcing functions to be used for the pipe whip dynamic analyses. This description should include direction, thrust coefficients, rise time, magnitude, duration, and initial conditions that adequately represent the jet stream dynamics and the system pressure differences. Pipe restraint rebound effects should be included if appropriate. Diagrams of typical mathematical models used for the dynamic response analysis should be provided. All dynamic amplification factors to be used should be presented and justified. Discuss the implementation of the methods used for the pipe whip dynamic analyses to demonstrate the acceptability of the analysis results, including the jet thrust and impingement functions and the pipe whip dynamic effects.

C.I.3.6.2.4 ***Dynamic Analysis Methods to Verify Integrity and Operability***

Describe the analytical methods, including the details of jet expansion modeling, that will be used to evaluate the jet impingement effects and loading effects applicable to nearby SSCs resulting from postulated pipe breaks and cracks. In addition, provide the analytical methods used to verify the integrity and operability of these impacted SSCs under postulated pipe rupture loads. In the case of piping systems where pipe whip restraints are included, the loading combinations and design criteria for the restraints should be provided along with a description of the typical restraint configuration to be used. Discuss the implementation of the dynamic analysis methods used to verify the integrity and operability of the impacted SSCs. Demonstrate the design adequacy of these SSCs to ensure that their design-intended functions will not be impaired to an unacceptable level of integrity or operability as a result of pipe whip or jet impingement loading.

C.I.3.6.2.5 ***Implementation of Criteria Dealing with Special Features***

Discuss the implementation of criteria dealing with special features, such as an augmented inservice inspection program or use of special protective devices (such as pipe whip restraints). Include diagrams showing their final configurations, locations, and orientations in relation to break locations in each piping system.

C.I.3.6.3 **Leak-Before-Break Evaluation Procedures**

Describe the analyses used to eliminate from the design basis the dynamic effects of certain pipe ruptures. Demonstrate that the probability of pipe rupture is extremely low under conditions consistent with the design basis for the piping. Adequate consideration should be given to direct and indirect pipe failure mechanisms and other degradation sources that could challenge the integrity of piping:

(1) List the piping systems included in the leak-before-break (LBB) evaluation:

- (a) Identify the types of materials and material specifications (including heat numbers) used for base metal, weldments, nozzles, and safe ends.
- (b) Provide the material properties, including the following:
  - toughness (J-R curves) and tensile (stress-strain curves) data at temperatures near the upper range of normal plant operation
  - long-term effects attributable to thermal aging
  - yield strength and ultimate strength
- (c) Identify the welding process/method (e.g.,submerged arc welding) used in the weld(s).

(2) Discuss the design-basis loads for each piping system:

(a) Provide as-built drawing(s) of pipe geometry (e.g., piping isometric drawings). Identify locations of supports and their characteristics (such as gaps). Identify the analysis nodal points.

(b) Identify locations and weights of components such as valves.

(c) Discuss snubber reliability, including applicable technical specification requirements.

(d) Identify the sources (e.g., thermal, deadweight, seismic, and seismic anchor movement), types (e.g., forces, bending and torsional moments), and magnitudes of applied loads, and the method of combination.

(3) Provide a deterministic fracture mechanics analysis. Identify the locations that have the least favorable combination of stress and material properties for base metal, weldment, and safe ends. Postulate a through wall leakage flaw at these locations. Demonstrate that the leakage flaw has sufficient safety margin with respect to the critical crack size under various loading combinations. Demonstrate that leakage flaw growth would be stable, and that the final flaw size would be limited such that a double-ended pipe break would not occur.

(4) Provide a leak rate evaluation to demonstrate that there is sufficient margin between the leak rate from the leakage flaw and the detection capability of the leak rate detection systems. Demonstrate that the leak rate detection systems are sufficiently reliable, redundant, and sensitive to provide adequate margin on the detection of unidentified leakage. Guidance on acceptable methods for detecting and identifying the location of the leakage source is provided in Regulatory Guide 1.45, "Reactor Coolant Pressure Boundary Leakage Detection Systems."

(5) Provide evaluations demonstrating that degradation by erosion, erosion/corrosion, and erosion/cavitation attributable to unfavorable flow conditions and water chemistry are not potential sources of pipe rupture.

(6) Provide a systems evaluation of potential water hammer, demonstrating that pipe rupture attributable to this mechanism is unlikely in the candidate piping system throughout the life of the plant. Identify historical water hammer frequencies, operating procedures and conditions, and design changes (e.g., J-tubes, vacuum breakers, jockey pumps) used in the evaluation.

(7) Perform an evaluation of creep and creep-fatigue, and demonstrate that the piping material is not susceptible to brittle cleavage-type failure over the full range of system operating temperatures.

(8) Demonstrate the corrosion resistence of the piping under review. Identify the measures taken to improve the corrosion resistance of the piping [such as modification to operating conditions (e.g., water chemistry, flow velocity, operating temperature, steam quality) and design changes (e.g., replacement piping material)].

(9) Demonstrate that the piping systems under LBB evaluation do not have a history of fatigue cracking or failure:

(a) Show that the potential for pipe rupture attributable to thermal and mechanical induced fatigue is unlikely.

(b) Demonstrate that there is adequate mixing of high- and low-temperature fluids so that there is no potential for significant cyclic thermal stresses.

(c) Show that there is no significant potential for vibration-induced fatigue cracking or failure.

(10) Demonstrate that the following indirect failure mechanisms (as defined in the FSAR) are remote causes of pipe failure:

- seismic events
- system over-pressurization attributable to accidents resulting from human error
- fires
- flooding causing electrical and mechanical control systems to malfunction
- missiles from equipment
- damage from moving equipment
- failures of SSCs in close proximity to the piping

(11) Describe any inspection programs developed for piping systems that are qualified for LBB.

(12) Demonstrate that the piping and weld materials are not susceptible to stress corrosion cracking (such as primary water stress corrosion cracking, intergranular stress corrosion cracking, and transgranular stress corrosion cracking).

C.I.3.7 *Seismic Design*

C.I.3.7.1 Seismic Design Parameters

Discuss the seismic design parameters (design ground motion, percentage of critical damping values, supporting media for Seismic Category I structures) that are used as input parameters to the seismic analysis of Seismic Category I SSCs for the OBE and SSE.

C.I.3.7.1.1 *Design Ground Motion*

Specify the earthquake ground motion (ground motion response spectra and/or ground motion time histories) exerted on the structure or the soil-structure interaction (SSI) system based on seismicity and geologic conditions at the site, expressed such that it can be applied to dynamic analysis of Seismic Category I SSCs. The earthquake ground motion should consider the three components of design ground motions, two horizontal and one vertical, for the OBE and SSE. For the SSI system, this ground motion should be consistent with the free-field ground motion at the site.

C.I.3.7.1.1.1 Design Ground Motion Response Spectra

Provide design ground motion response spectra for the OBE and SSE, which are consistent with those defined based on the guidelines in Section 2.5. In general, these response spectra are developed for 5-percent damping. If the ground response spectra are different from the generic ground response spectra, such as the response criteria provided in Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," provide the procedures to calculate the response spectra for each damping ratio to be used in the design of seismic Category I SSCs and the procedures for the development of target power spectral density (PSD). Provide bases to justify that the response spectra are to be applied either at the finished grade in the free field or at the various foundation locations of Seismic Category I structures.

C.I.3.7.1.1.2 Design Ground Motion Time History

Provide a description of how the earthquake ground motion time history (actual or synthetic) is selected or developed. For the time history analyses, provide the response spectra derived from actual or synthetic earthquake time-motion records. For each of the damping values to be used in the design of SSCs, submit a comparison of the response spectra obtained in the free field at the finished grade level and the foundation level (obtained from an appropriate time history at the base of the soil-structure interaction system) with the design response spectra. Alternatively, if the design response spectra for the OBE and SSE are applied at the foundation levels of Seismic Category I structures in the free field, provide a comparison of the free-field response spectra at the foundation level (derived from an actual or synthetic time history) with the design response spectra for each of the damping values to be used in the design. If the synthetic time history (three components) is to be used in the seismic analysis, demonstrate that (1) the cross-correlation coefficients between the three components of the design ground motion time histories are within the criteria of SRP Section C.I.3.7.1, and (2) the PSD calculated from these three components envelop the target PSD developed based on the guidance in Section C.I.3.7.1.1.1. Also, identify the period intervals at which the spectra values were calculated.

C.I.3.7.1.2 ***Percentage of Critical Damping Values***

Provide the specific percentage of critical damping values used for Seismic Category I SSCs and soil for both the OBE and SSE (e.g., damping ratios for the type of construction or fabrication). Also, compare the damping ratios assigned to SSCs with the acceptable damping ratios provided in Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants." Include the bases for any proposed damping ratios that differ from those given in Regulatory Guide 1.61 and for the proposed soil damping.

C.I.3.7.1.3 ***Supporting Media for Seismic Category I Structures***

For each Seismic Category I structure, provide a description of the supporting media, including foundation embedment depth, depth of soil over bedrock, soil layering characteristics, dimensions of the structural foundation, total structural height, and soil properties of each soil layer, such as shear wave velocity, shear modulus, soil material damping, and density. Use this information to evaluate the suitability of using either a finite element or lumped soil-spring approach for modeling soil foundation in the soil-structure interaction analysis.

C.I.3.7.2 Seismic System Analysis

Discuss the seismic system analyses applicable to Seismic Category I SSCs.

C.I.3.7.2.1 ***Seismic Analysis Methods***

Identify and describe the applicable seismic analysis methods (e.g., response spectrum analysis, modal time history analysis, direct integration time history analysis, frequency domain time history analysis, equivalent static load analysis) for all Seismic Category I SSCs. Discuss how the foundation torsion, rocking, and translation are considered in the dynamic system analysis method. Indicate the analysis method to be used for seismic Category I and non-Seismic Category I (Seismic Category II and non-seismic) SSCs. Describe the types of soil-structure system models that are to be analyzed and by which analysis methods. Indicate the manner in which the seismic dynamic analysis considers the maximum relative displacement among supports.

Indicate other significant effects accounted for in the seismic dynamic analysis, such as hydrodynamic effects and nonlinear response. If tests or empirical methods are used in lieu of analysis for any Seismic Category I SSCs, provide the testing procedure, load levels, and acceptance bases. If these tests or empirical methods have not been completed at the time the COL application is filed, describe the implementation program, including milestones. Provide specific information regarding consideration of inelastic/nonlinear behavior of SSCs when a nonlinear analysis is performed.

C.I.3.7.2.2 ***Natural Frequencies and Responses***

When modal time history analyses and/or response spectrum analyses are performed, provide the modal properties (natural frequencies, participation factors, mode shapes, modal masses, and percentage of cumulative mass). For all seismic system analyses performed (modal time history analyses and response spectrum analyses), provide seismic responses (maximum absolute nodal accelerations, maximum displacement relative to the top of foundation mat, maximum member forces and moments) for major Seismic Category I structures. Also, provide the in-structure response spectra at major Seismic Category I equipment elevations and points of support, generated from the system dynamic response analyses.

C.I.3.7.2.3 ***Procedures Used for Analytical Modeling***

Provide a description of the types of model (finite element model, lumped-mass stick model, hybrid model, etc.) used for Seismic Category I structures. Provide criteria and procedures used for modeling in the seismic system analyses. Indicate how foundation torsion, rocking, and translation are modeled for the seismic system analyses. Include criteria and bases used to determine whether a component or structure should be analyzed as part of a system analysis or independently as a subsystem.

C.I.3.7.2.4 ***Soil/Structure Interaction (SSI)***

As applicable, provide definition and location of the control motion and modeling methods of SSI analysis used in the seismic system analysis, as well as their bases. Include information on (1) extent of embedment, (2) depth of soil over bedrock, (3) layering of soil strata, and (4) strain-dependent shear modulus (reduction curves and hysteretic damping ratio relations) appropriate for each layer of the site soil column. If applicable, specify the procedures by which strain-dependent soil properties (e.g., hysteretic damping, shear modulus, and pore pressure) and layering, were incorporated into the site response analyses used to generate free field ground motions, as well as how these soil properties are used when considering the variation of soil properties are incorporated into the SSI analysis. Show how the upper and lower bound iterated soil properties used in the SSI analyses are consistent with those generated from the free-field analyses. (If necessary, reference material provided in Section C.I.3.7.1.3.) Specify the type of soil foundation model (lumped soil spring model, finite element model, etc.). If the finite element model is used, specify the criteria for determining location of the bottom and side boundaries of the analysis model as applicable. Specify procedures used to account for effects of adjacent structures (through soil structure-to-structure interaction), if any, on structural response in the SSI analysis.

If it is necessary to apply a forcing function at boundaries of the soil foundation model to simulate earthquake motion for performing a dynamic analysis for soil-structure system, discuss the theories and procedures used to generate the forcing function system such that response motion of the soil media in the free field at the site is identical to the design ground motion, and such that these boundary effects do not influence the SSI analyses.

Describe the procedures by which strain-dependent soil properties, embedded effects, layering, and variation of soil properties are incorporated into the analysis. If lumped spring-dashpot methods are used, provide theories and methods for calculating the soil springs, and discuss the suitability of such methods for the particular site conditions and the parameters used in the SSI analysis. Also, show how frequency-dependent soil properties of the lumped spring-dashpot models for different modes of response are properly accounted for.

Provide discussion of any other methods used for SSI analysis or the basis for not using SSI analysis.

C.I.3.7.2.5 *Development of Floor Response Spectra*

Describe the procedures, basis, and justification for developing floor response spectra considering the three components of earthquake motion, two horizontal and one vertical, as specified in Regulatory Guide 1.122, "Development of Floor Design Response Spectra Seismic Design of Floor-Supported Equipment or Components." If a single artificial time history analysis method is used to develop floor response spectra, demonstrate that (1) provisions of Regulatory Guide 1.122, including peak broadening requirements, apply, (2) response spectra of the artificial time history to be employed in the free field envelope the free-field design response spectra for all damping values actually used in the response spectra, and (3) the PSD generated from the time history envelops the target power spectral density. If multiple time histories are applied to generate floor response spectra, provide the basis for the methods used to account for uncertainties in parameters. If a modal response spectrum analysis method is used to develop floor response spectra, provide the basis for its conservatism and equivalence to a time history method.

C.I.3.7.2.6 *Three Components of Earthquake Motion*

Indicate the extent to which procedures for considering the three components of earthquake motion in determining seismic response of SSCs are in conformance with Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Revision 2.

C.I.3.7.2.7 *Combination of Modal Responses*

When a modal time history analysis method and/or a response spectrum analysis method is used to calculate seismic response of SSCs, provide a description of the procedure for combining modal responses (i.e., shears, moments, stresses, deflections, and accelerations), including that for modes with closely-spaced frequencies. Also, indicate the extent to which recommendations of Regulatory Guide 1.92, Revision 2, including those applicable for adequate consideration of high-frequency modes, are followed to combine modal responses.

C.I.3.7.2.8 ***Interaction of Non-Seismic Category I Structures with Seismic Category I Structures***

Provide a description of the location of all plant structures (Seismic Category I, Seismic Category II, and non-seismic structures), including the distance between structures and the height of each structure. Provide the design criteria used to account for seismic motion of non-seismic Category I (Seismic Category II and non-seismic) structures, or portions thereof, in seismic design of Seismic Category I structures or parts thereof. Describe the seismic design of non-seismic Category I structures whose continued function is not required, but whose failure could adversely impact the safety function of SSCs or result in incapacitating injury to control room occupants. Describe design criteria that will be applied to ensure protection of Seismic Category I structures from structural failure of non-Category I structures as a result of seismic effects.

C.I.3.7.2.9 ***Effects of Parameter Variations on Floor Response Spectra***

Describe the procedures that will be used to consider effects of expected variations of structural properties, damping values, soil properties, and uncertainties attributable to modeling of soil structure systems on floor response spectra and time histories.

C.I.3.7.2.10 ***Use of Constant Vertical Static Factors***

Where applicable, identify and justify application of equivalent static factors as vertical response loads for the seismic design of Seismic Category I SSCs in lieu of using the response loads generated from a vertical seismic-system dynamic analysis method.

C.I.3.7.2.11 ***Method Used to Account for Torsional Effects***

Describe the method used to consider torsional effects in the seismic analysis of Seismic Category I structures, including evaluation and justification of static factors or any other approximate methods used (in lieu of a combined vertical, horizontal, and torsional system dynamic analysis) to account for torsional accelerations in seismic design of Seismic Category I structures. Also, describe the method used to consider the torsional effects attributable to accidental eccentricities for each Seismic Category I structure.

C.I.3.7.2.12 ***Comparison of Responses***

Where both response spectrum analysis and time history analysis methods are applied, provide the responses obtained from both methods at selected points in major Seismic Category I structures, together with a comparative discussion of the responses.

C.I.3.7.2.13 ***Methods for Seismic Analysis of Dams***

Provide a comprehensive description of analytical methods and procedures that will be used for seismic system analysis of Seismic Category I dams, including assumptions made, boundary conditions used, and procedures by which strain-dependent soil properties are incorporated into the analysis.

C.I.3.7.2.14 ***Determination of Dynamic Stability of Seismic Category I Structures***

Provide a description of the dynamic methods and procedures used to determine dynamic stability (overturning, sliding, and floatation) of Seismic Category I structures.

C.I.3.7.2.15 ***Analysis Procedure for Damping***

Describe the procedure used to account for damping in various elements of a soil-structure system model.

C.I.3.7.3 **Seismic Subsystem Analysis**

This section of DG-1145 covers civil structure-related subsystems such as platforms, trusses, buried piping, conduit, tunnels, dams, dikes, above-ground tanks, etc. The seismic analysis of mechanical subsystems (such as piping, mechanical components, NSSS systems, etc.) is covered in Section C.I.3.9.2 of this guide.

C.I.3.7.3.1 **Seismic Analysis Methods**

Describe analysis methods to be used for seismic analysis of Seismic Category I subsystems. Provide information as requested in Section C.I.3.7.2.1, but as applied to Seismic Category I subsystems. Provide the basis for using the equivalent static load method of analysis, if used, and the procedures for determining equivalent static loads.

C.I.3.7.3.2 ***Procedures Used for Analytical Modeling***

Provide criteria and procedures used for modeling seismic subsystems. Confirm use of criteria and bases described in Section C.I.3.7.2.3 to determine whether a component or structure should be independently analyzed as a subsystem.

C.I.3.7.3.3 ***Analysis Procedure for Damping***

Provide information as requested in Section C.I.3.7.2.15, but as applied to Seismic Category I subsystems.

C.I.3.7.3.4 ***Three Components of Earthquake Motion***

Provide information as requested in Section C.I.3.7.2.6, but as applied to Seismic Category I subsystems.

C.I.3.7.3.5 ***Combination of Modal Responses***

Provide information as requested in Section C.I.3.7.2.7, but as applied to Seismic Category I subsystems.

C.I.3.7.3.6 ***Use of Constant Vertical Static Factors***

Provide information as requested in Section C.I.3.7.2.10, but as applied to Seismic Category I subsystems.

C.I.3.7.3.7 *Buried Seismic Category I Piping, Conduits, and Tunnels*

Describe seismic criteria and methods for considering effects of earthquakes on buried piping, conduits, tunnels, and auxiliary systems. These criteria include compliance characteristics of soil media; dynamic pressures; seismic wave passage; and settlement attributable to earthquake and differential movements at support points, penetrations, and entry points into other structures provided with anchors.

C.I.3.7.3.8 *Methods for Seismic Analysis of Category 1 Concrete Dams*

Describe the analytical methods and procedures that will be used for seismic analysis of Seismic Category I concrete dams, including assumptions made, models developed, boundary conditions used, analysis methods used, hydrodynamic effects considered, and procedures by which strain-dependent material properties of foundations are incorporated into the analysis.

C.I.3.7.3.9 *Methods for Seismic Analysis of Above-Ground Tanks*

Provide seismic criteria and analysis methods that consider hydrodynamic forces, tank flexibility, soil-structure interaction, and other pertinent parameters for seismic analysis of Seismic Category I above-ground tanks.

C.I.3.7.4 Seismic Instrumentation

Discuss the proposed instrumentation system for measuring effects of an earthquake.

C.I.3.7.4.1 *Comparison with Regulatory Guide 1.12*

Discuss the proposed seismic instrumentation program and compare it with the seismic instrumentation guidelines of Regulatory Guide 1.12, "Instrumentation for Earthquakes," Revision 2. Provide the bases for elements of the proposed seismic instrumentation program that differ from those of the guidelines in Regulatory Guide 1.12, Revision 2.

C.I.3.7.4.2 *Location and Description of Instrumentation*

Describe locations of seismic instrumentation such as triaxial peak accelerographs, triaxial time history accelerographs, and triaxial response spectrum recorders that will be installed in selected Seismic Category I structures and components. Specify the bases for selection of the seismic instrumentation and installation locations, and discuss the extent to which the instrumentation will be employed to verify seismic analyses following an earthquake.

C.I.3.7.4.3 *Control Room Operator Notification*

Describe the procedures that will be followed to inform the control room operator of the peak acceleration level, cumulative absolute velocity, and input response spectra values shortly after occurrence of an earthquake. Include the bases for establishing predetermined values for activating the readout of the seismic instrumentation to the control room operator.

C.I.3.7.4.4 *Comparison with Regulatory Guide 1.166*

Discuss the response procedure immediately after an earthquake and compare it with Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions." Provide the bases for elements of the response procedure that differ from those of the guidelines in Regulatory Guide 1.166.

C.I.3.7.4.5 *Instrument Surveillance*

Discuss requirements for instrument surveillance testing and calibration pertaining to instrument operability and reliability.

C.I.3.7.4.6 *Program Implementation*

Describe the implementation program for the seismic monitoring program, including milestones.

C.I.3.8 *Design of Category I Structures*

C.I.3.8.1 Concrete Containment

Provide the following information on concrete containments and on concrete portions of steel/concrete containments:

(1) physical description
(2) applicable design codes, standards, and specifications
(3) loading criteria, including loads and load combinations
(4) design and analysis procedures
(5) structural acceptance criteria
(6) materials, quality control programs, and special construction techniques
(7) testing and inservice inspection programs, including milestones

C.I.3.8.1.1 Description of the Containment

Define the primary structural aspects and elements relied upon to perform the containment function by providing a physical description of the concrete containment or concrete portions of steel/concrete containment, including plan and section views. Provide the geometry of the concrete containment or concrete portions of steel/concrete containments, including plan views at various elevations and sections in at least two orthogonal directions. Describe the arrangement of the containment and the relationship and interaction of the containment structure with its surrounding structures and with its interior compartments. Explain the effect these structures have upon the design boundary conditions and expected structural behavior of the containment when subjected to design loads. Provide general descriptive information for the following:

(1) base foundation including reinforcement, the anchorage and stiffening system, and methods by which the interior structures are anchored

(2) containment structure wall, including the main reinforcement and prestressing tendons, and its anchorage and stiffening system; the major penetrations and the reinforcement surrounding them; and major structural attachments to the wall which penetrate the containment structure or any attachment to the containment structure wall to support external structures

(3) for the containment structure, the main reinforcement and prestressing tendons; its anchorage and stiffening system; and any major attachments made from the inside

(4) applicable structural features, such as containment refueling seals and drains, seismic gaps between adjacent structural elements, rock anchors, sub-foundation draining system and containment settlement monitoring system

In Section C.I.3.8.2, discuss steel components of concrete containments that resist pressure and are not backed by structural concrete.

C.I.3.8.1.2 ***Applicable Codes, Standards, and Specifications***

Provide design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards used in the design, fabrication, construction, testing, and inservice inspection of the containment. Identify the specific edition, date, or addenda of each document.

C.I.3.8.1.3 **Loads and Load Combinations**

Discuss loads and load combinations utilized in the design of the containment structure, with emphasis on the extent of compliance with Article CC-3000 of the ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containment" and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Those normally applicable to concrete containment include the following loads:

(1) loads encountered during pre-operational testing

(2) loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads attributable to operating temperature, hydrostatic loads, and hydrodynamic loads

(3) loads sustained in the event of severe environmental conditions, including those induced by the design wind and the OBE

(4) loads sustained during extreme environmental conditions, including those induced by the design-basis tornado and the SSE

(5) loads sustained during abnormal plant conditions, including the design-basis loss-of- coolant accident (LOCA)

(6) loads imposed by other postulated accidents such as high-energy pipe ruptures, with associated elevated temperature effects and pressure and localized loads such as jet impingement and associated missile impact

(7) external pressure loads generated by events inside or outside the containment

(8) loads encountered and sustained after abnormal plant conditions, such as flooding of the containment subsequent to a LOCA

(9) loads generated as a result of an inadvertent full actuation of a post accident inerting hydrogen control system, (assuming carbon dioxide) but not including seismic or design-basis accident loadings [see 10 CFR 50.34(f)(3)(v)(B)(1)].

(10) pressure and dead loads alone during an accident that releases hydrogen generated from 100% fuel clad metal-water reaction and accompanied by either hydrogen burning or added pressure from post-accident inerting [see 10 CFR 50.34(f)(3)(v)(A)(1)].

Discuss various combinations of the above loads that are normally postulated, such as normal operating loads with severe environmental and abnormal loads, and post-LOCA flooding loads with severe environmental loads.

Discuss any other site related or plant related loads and load combinations applicable to Containment. Examples of such loads include those induced by floods, potential aircraft crashes, explosive hazards in proximity to the site, and missiles generated from activities of nearby military installations or turbine failures.

C.I.3.8.1.4 ***Design and Analysis Procedures***

Describe the design and analysis method used for the containment, including key assumptions and the basis for selection of structural models and boundary conditions, with emphasis on the extent of compliance with Article CC-3000 of the ASME Code, Section III, Division 2, and/or specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Discuss loads such as axissymmetric, nonaxisymmetric, localized, or transient. Provide analysis and design of concrete characteristics such as creep and shrinkage. Reference all computer programs utilized to permit identification with available published programs. Describe proprietary computer programs in sufficient detail to establish their applicability and the method for validating the programs. Discuss effects of seismic tangential (membrane) shears. Provide analysis results of the effects of expected variation in assumptions and material properties. Describe the method of analyzing large thickened penetration regions and their effect on the containment behavior. Provide the analysis and design methods for the containment wall and its anchorage system.

C.I.3.8.1.5 ***Structural Acceptance Criteria***

Specify the acceptance criteria relating to stresses, strains, gross deformations, and other parameters that quantitatively identify margins of safety, with emphasis on the extent of compliance with Article CC-3000 of the ASME Code, Section III, Division 2 and/or to the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Provide information to address the containment as an entire structure, and also the margins of safety related to the major important local areas of the containment, including openings, anchorage zones, and other areas important to the safety function. Address the various loading combinations in terms of allowable limits for at least the following major parameters:

(1) compressive stresses in concrete, including membrane, membrane plus bending, and localized stresses

(2) shear stresses in concrete

(3) tensile stresses in reinforcement

(4) tensile stresses in pre-stressing tendons

(5) tensile or compressive stress/strain limits in the liner plate, including membrane and membrane plus bending

(6) force/displacement limits in the containment structure anchors, including those induced by strains in the adjacent concrete

C.I.3.8.1.6 *Materials, Quality Control, and Special Construction Techniques*

Identify materials used in the construction of the containment, with emphasis on the extent of compliance with Article CC-2000 of the ASME Code, Section III, Division 2, and/or to the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Provide a summary of the engineering properties of the materials of construction, such as:

(1) concrete ingredients
(2) reinforcing bars and splices
(3) pre-stressing system
(4) liner plate
(5) liner plate anchors and associated hardware
(6) structural steel used for embedment, such as beam seats and crane brackets
(7) corrosion-retarding compounds

Describe the quality control program for containment fabrication and construction, with emphasis on the extent of compliance with Articles CC-4000 and CC-5000 of the ASME Code, Section III, Division 2, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Describe the extent to which the quality control program covers the examination of materials, including tests to determine the physical properties of material and the combination of materials used for construction. Describe the extent to which the quality control program covers the examination of placement of material, erection tolerances, reinforcement, and pre-stressing system.

Identify and describe special, new, or unique construction techniques and the effects that those techniques may have on the structural integrity of the completed containment.

Identify and describe the detailed program for the use of grouted tendons for the containment structure, and indicate the extent to which the recommendations of Regulatory Guide 1.107, “Qualifications for Cement Grouting for Pre-stressing Tendons in Containment Structures,” are followed.

C.I.3.8.1.7 *Testing and Inservice Inspection Requirements*

Describe the testing and inservice inspection program, including milestones, for the containment, with emphasis on the extent of compliance with Articles CC-6000 and CC-9000 of the ASME Code, Section III, Division 2, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards, and the extent to which the testing and inservice inspection program follow recommendations of Regulatory Guide 1.18, “Structural Acceptance Test for Concrete Primary Reactor Containment;" Regulatory Guide 1.35, “Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment Structures”; and Regulatory Guide 1.90, “Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons.” Discuss the initial structural integrity testing, as well as those tests related to the inservice inspection programs and requirements. Provide information on the technical specification pertaining to the incorporation of inservice inspection programs. Define the objectives of the tests, as well as the acceptance criteria for the results. Discuss the extent of additional testing and inservice inspection, including milestones, if new or previously untried design approaches are used.

C.I.3.8.2 Steel Containment

Provide information similar to that requested in Section C.I.3.8.1, but for steel containment and Class MC (see ASME Code, Section III, Subsection NE) vessels, parts, or appurtenances of steel or concrete containment. In particular, provide the information described below.

C.I.3.8.2.1 *Description of the Containment*

Provide a physical description of the steel containment and other Class MC components, and supplement with plan and section views sufficient to define the primary structural aspects and elements relied upon to perform the containment or other Class MC component function.

Provide the geometry of the containment or component, including plan views at various elevations and sections in at least two orthogonal directions. Describe the arrangement of the containment structure, particularly the relationship and interaction of the containment structure with its surrounding structures and with its interior compartments and floors, to establish the effect that these structures could have upon the design boundary conditions and expected behavior of the containment structure when subjected to the design loads. Provide the following general descriptive information related to cylindrical containment structures:

(1) the foundation of the steel containment:

- (a) If the bottom of the steel containment is continuous, describe the method by which this containment structure and its supports are anchored to the concrete foundation. Describe the foundation, in Section C.I.3.8.5.
- (b) If the bottom of the steel containment is not continuous, and where a concrete base slab covered with a liner plate is used for a foundation, describe the method of anchorage of the steel containment structure walls in the concrete base slab, particularly the connection between the floor liner plate and the steel containment structure. Describe the concrete foundation in Section C.I.3.8.1.

(2) any major structural attachments, such as beam seats, pipe restraints, crane brackets, and shell stiffeners in the hoop and vertical directions

(3) the dome of the steel containment structure, including any reinforcement at the dome/wall junction, penetrations or attachments on the inside, such as supports for containment spray piping, and any stiffening of the dome

(4) major penetrations of steel or concrete containment, or portions thereof (in particular, portions of the penetrations that are intended to resist pressure, but are not backed by concrete, such as fuel transfer tubes, electrical penetrations, and access openings such as personnel locks)

(5) applicable structural features, such as containment refueling seals and drains, seismic gaps between adjacent structural elements, rock anchors, the sub-foundation draining system, and the containment settlement monitoring system

Provide similar information for containment structures that are not cylindrical.

C.I.3.8.2.2 ***Applicable Codes, Standards, and Specifications***

Provide information similar to that requested for concrete containment in Section C.I.3.8.1.2, but as applicable to steel containment or other Class MC components.

C.I.3.8.2.3 ***Loads and Load Combinations***

Specify the loads used in the design of the steel containment or other Class MC components, with emphasis on the extent of compliance with Article NE-3000 of the ASME Code, Section III, Division 1, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards, and the extent to which the loads and load combinations follow the recommendations of Regulatory Guide 1.57, "Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components," are followed. Include the following items:

(1) loads encountered during pre-operational testing

(2) loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads attributable to operating temperature, hydrostatic loads, and hydrodynamic loads

(3) loads sustained in the event of severe environmental conditions, including those induced by the design wind and the OBE

(4) loads sustained in the event of extreme environmental conditions, including those that would be induced by the design-basis tornado and the SSE

(5) loads sustained in the event of abnormal plant conditions, including LOCA

(6) loads induced by other postulated accidents such as high-energy pipe ruptures with associated elevated temperature effects, pressures, and possible localized impact loads such as jet impingement and associated missile impact

(7) external pressure loads generated by events inside or outside the containment

(8) loads encountered and sustained after abnormal plant conditions, including flooding of the containment

(9) loads generated as a result of an inadvertent full actuation of a post accident inerting hydrogen control system, (assuming carbon dioxide) but not including seismic or design-basis accident loadings [see 10 CFR 50.34(f)(3)(v)(B)(1)]

(10) pressure and dead loads alone during an accident that releases hydrogen generated from 100% fuel clad metal-water reaction and accompanied by either hydrogen burning or added pressure from post-accident inerting [see 10 CFR 50.34(f)(3)(v)(A)(1)]

Discuss various combinations of the above loads that are normally postulated, such as normal operating loads with extreme environmental loads and abnormal loads.

As explained in Section C.I.3.8.1.3, discuss any other site-related or plant-related design loads that may be applicable.

C.I.3.8.2.4 ***Design and Analysis Procedures***

Describe the design and analysis method used, including key assumptions and the basis for selection of structural models and boundary conditions for the steel containment, with emphasis on the extent of compliance with Subsection NE of the ASME Code, Section III, Division 1, as augmented by applicable provisions of the Regulatory Guide 1.57, and/or to the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. In particular, discuss (1) treatment of local buckling effects, (2) the expected behavior under loads, including non-axisymmetric and localized loads, and (3) the computer programs utilized. Reference these computer programs to permit identification with available published programs. Describe proprietary computer programs in sufficient detail to establish their applicability and the method for validating the programs.

C.I.3.8.2.5 ***Structural Acceptance Criteria***

Specify the acceptance criteria related to allowable stresses, strains and gross deformation and other response characteristics that quantitatively identify the structural behavior of the containment, with emphasis on the extent of compliance with Subsection NE of the ASME Code, Section III, Division 1, and/or to the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards, and the extent to which the structural acceptance criteria follow the recommendations of Regulatory Guide 1.57. Specify and address the various loading combinations in terms of allowable limits for at least the following major parameters:

(1) primary stresses, including general membrane, local membrane, and bending plus local membrane stresses

(2) primary and secondary stresses

(3) peak stresses

(4) buckling criteria

C.I.3.8.2.6 ***Materials, Quality Control, and Special Construction Techniques***

Identify and specify the materials to be used in the construction of the steel containment with emphasis on the extent of compliance with Article NE-2000 of Subsection NE of the ASME Code, Section III, Division 1, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Identify major materials such as:

(1) steel plates used as containment structure components

(2) structural steel shapes used for stiffeners, beam seats, and crane brackets. Describe the method for corrosion protection

Describe the quality control program for the fabrication and construction of the containment with emphasis on the extent of compliance with Article NE-5000 of the ASME Code, Section III, Division 1, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards, especially for the following:

(1) nondestructive examination of the materials, including tests to determine their physical properties
(2) welding procedures
(3) erection tolerances

Identify and describe any special construction techniques and potential effects of such techniques on the structural integrity of the completed containment.

C.I.3.8.2.7 ***Testing and Inservice Inspection Requirements***

Describe the containment testing and inservice inspection programs, including milestones, with emphasis on the extent of compliance with Article NE-6000 of Subsection NE of the ASME Code, Section HI, Division 1, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards. Discuss the proposed initial structural testing, including the objectives of the test, and specify the acceptance criteria for the results. Discuss the extent of additional testing and inservice inspection, including milestones, if new or previously untried design approaches are used. Provide the criteria for testing the structural integrity for components of the containment such as personnel and equipment locks. Submit test program criteria for any other components that are relied upon for containment integrity. Provide programs for inservice inspection in areas subject to corrosion.

C.I.3.8.3 **Concrete and Steel Internal Structures of Steel or Concrete Containment**

Provide information similar to that requested in Section C.I.3.8.1, but for internal structures of the containment. The containment internal structures are those concrete and steel structures that are inside (not part of) the containment pressure boundary and support the reactor coolant system components and related piping systems and equipment. Provide the information described in the following subsections.

C.I.3.8.3.1 ***Description of the Internal Structures***

Define the primary structural aspects and elements relied upon to perform the safety-related functions by describing and including a physical description of the internal structures, including plan and section views.

Provide general arrangement diagrams and principal features of major internal structures. Describe the major structures, especially the following:

(1) for PWR containment:

  (a) reactor support system
  (b) steam generator support system
  (c) reactor coolant pump support system
  (d) primary shield wall and reactor cavity
  (e) secondary shield walls
  (f) other major internal structures, such as supports, the refueling cavity walls, in-containment refueling water storage tank, the operating floor, intermediate floors, and various platforms

(2) for BWR containment:

   (a) drywell structure and appurtenances such as the drywell head and major penetrations

   (b) weir wall

   (c) refueling pool and operating floor

   (d) reactor and recirculating pump and motor support system

   (e) reactor pedestal

   (f) reactor shield wall

   (g) other major interior structures, as appropriate, including the various platforms inside and outside the drywell

C.I.3.8.3.2 ***Applicable Codes, Standards, and Specifications***

Provide information similar to that requested for concrete containment in Section C.I.3.8.1.2, and Regulatory Guide 1.142, but as applicable to the internal structures of the containment structures as listed in Section C.I.3.8.3.1.

C.I.3.8.3.3 ***Loads and Load Combinations***

Discuss and specify the loads used in the design of the containment internal structures listed in Section C.I.3.8.3.1. As a minimum, include the following items:

(1) loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads attributable to operating temperature, hydrostatic loads, and hydrodynamic loads

(2) loads sustained in the event of severe environmental conditions, including those induced by the OBE

(3) loads sustained in the event of extreme environmental conditions, including those that would be induced by the SSE

(4) loads sustained in the event of abnormal plant conditions, including LOCA

(5) loads by other postulated accidents, such as high-energy pipe ruptures with associated elevated temperature effects, pressures, and possible other localized impacts

Discuss the various combinations of the above loads that are normally postulated, such as normal operating loads, normal operating loads with severe environmental loads, and normal operating loads with extreme environmental loads and abnormal loads.

Provide specific information, emphasizing the following considerations:

(1) the extent to which the criteria comply with ACI-349, "Proposed ACI Standard: Code Requirements for Nuclear Safety Related Concrete Structures," for concrete, and with the AISC N690, "Specification for Design, Fabrication and Erection of Structural Steel for Buildings,"[1] for steel, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards

(2) for concrete pressure-resisting portions of the structure, the extent to which the criteria comply with Article CC-3000 of the ASME Code, Section III, Division 2, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards

(3) for steel pressure-resisting portions of the structures described in item 2 above, the extent to which the applicant's criteria comply with Article NE-3000 of Subsection NE of the ASME Code, Section III, Division 1; the recommendations of Regulatory Guide 1.57 and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards

(4) for steel linear supports, the extent to which the applicant's criteria comply with Subsection NF of the ASME Code, Section III, Division 1, augmented with Regulatory Guide 1.57 and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards

C.I.3.8.3.4 ***Design and Analysis Procedures***

Describe the design and analysis method and assumptions and identify the boundary conditions of those internal structures listed in Section C.I.3.8.3.1. Provide the expected behavior under load and the mechanisms for load transfer to these structures and then to the containment base. Reference the computer programs utilized to permit identification with available published programs. Describe proprietary computer programs in sufficient detail to establish their applicability and the method for validating the programs.

Specify the extent to which the design and analysis procedures comply with ACI-349 and with the AISC Specifications for concrete and steel structures, respectively, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards.

Describe the design and analysis method used with the assumptions regarding boundary conditions, for reactor coolant system linear supports. Specify and identify the type of analysis (elastic or plastic), and the methods of load transfer, particularly seismic and accident loads. Specify the extent of compliance with design and analysis procedures delineated in Subsection NF of the ASME Code, Section III, Division 1, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards.

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[1]The structures listed are those of the BWR Mark III containment. For other BWR containment concepts, the applicable major interior structures should be described accordingly.

Describe the design and analysis method utilized for reactor primary shield walls, including the method for transfer of the individual loads and load combinations to the walls and their foundations. Describe the normal operating thermal gradient, if any, and seismic loads and accident loads, as they may act on the entire cavity or portions thereof.

Describe the design and analysis method utilized, including assumptions for secondary shield walls and operating and intermediate floors on structural framing and behavior under loads. Describe the method and assumptions, with particular emphasis on modeling techniques, boundary conditions, and force-time functions where elastoplastic behavior is assumed and the ductility of the walls is relied upon to absorb the energy associated with jet and missile loads. Describe the methods of ensuring elastic behavior for the differential pressure, particularly in determining an equivalent static load for the impulsive pressure load.

For concrete pressure-resisting portions of the containment, discuss the extent to which the criteria comply with Article CC-3000 of the ASME Code, Section III, Division 2. For steel pressure-resisting portions of containment, discuss the extent to which the criteria comply with Article NE-3000 of Subsection NE of the ASME Code, Section III, Division 1, as well as the extent to which the recommendations of Regulatory Guide 1.57 are followed.

C.I.3.8.3.5 ***Structural Acceptance Criteria***

Provide information similar to that requested for concrete containment in Section C.I.3.8.1.5, but as applicable to the various containment internal structures listed in Section C.I.3.8.3.1.

C.I.3.8.3.6 ***Materials, Quality Control, and Special Construction Techniques***

Identify and describe the materials, quality control programs, and any special construction techniques.

Describe the major materials of construction, such as the concrete ingredients, reinforcing bars and splices, and the structural steel and various supports and anchors.

Describe the quality control program proposed for the fabrication and construction of the containment interior structures, including nondestructive examination of the materials to determine physical properties, placement of concrete, and erection tolerances.

Identify and describe special, new, or unique construction techniques to determine their effects on the structural integrity of the completed interior structure.

Provide the following information:

(1) the extent to which the material and quality control requirements comply with ACI-349 for concrete, and with the AISC specifications for steel, as applicable

(2) for steel linear supports of the reactor coolant system, the extent to which the material and quality control requirements comply with Subsection NF of the ASME Code, Section III, Division 1

(3) for quality control in general, the extent of compliance with ANSI N45.2.5, and recommendations of Regulatory Guide 1.55, “Concrete Placement in Category I Structures”

(4) for welding of reinforcing bars, the extent to which the design complies with the ASME Code, Section III, Division 2 (identify and justify any exceptions)

C.I.3.8.3.7 ***Testing and Inservice Inspection Requirements***

Describe the testing and inservice inspection programs, including milestones, for the internal structures. Specify test requirements for internal structures related directly and critically to the functioning of the containment. Describe the inservice inspection requirements. As stated in Section C.I.3.8.3.6, identify the extent of compliance with the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards.

C.I.3.8.4 ***Other Seismic Category I Structures***

Provide information for all Seismic Category I structures not covered by Sections C.I.3.8.1, C.I.3.8.2, C.I.3.8.3, or C.I.3.8.5. Provide information similar to that requested for Section C.I.3.8.1.

C.I.3.8.4.1 ***Description of the Structures***

Provide descriptive information, including plan and section views of each structure, to define the primary structural aspects and elements relied upon for the structure to perform its safety-related function. Describe the relationship between adjacent structures, including any separation or structural ties. Describe the plant's Seismic Category I structures, especially the following:

(1) containment enclosure buildings

(2) auxiliary buildings

(3) fuel storage buildings

(4) control buildings

(5) diesel generator buildings

(6) other Seismic Category I structures, such as pipe and electrical conduit tunnels, waste storage facilities, stacks, intake structures, pumping stations, water wells, cooling towers, and concrete dams, embankments, and tunnels. Describe structures that are safety related but, because of other design provisions, are not classified as Seismic Category I

C.I.3.8.4.2 ***Applicable Codes, Standards, and Specifications***

Provide information similar to that requested for concrete Containment in Section C.I.3.8.1.2, but as applicable to all other Seismic Category I structures.

C.I.3.8.4.3 ***Loads and Load Combinations***

Specify and identify the loads used in the design of all other Seismic Category I structures including the following:

(1) loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads attributable to operating temperature, and hydrostatic loads such as those in spent fuel pools

(2) loads sustained in the event of severe environmental conditions, including those induced by the OBE and the design wind specified for the plant site

(3) loads sustained in the event of extreme environmental conditions, including those induced by the SSE and the design-basis tornado specified for the plant site

(4) loads sustained during abnormal plant conditions, such as rupture of high-energy pipe with associated elevated temperatures and pressures within or across compartments and possibly jet impingement and impact forces

Discuss the various combinations of the above loads that are normally postulated, such as normal operating loads, normal operating loads with severe environmental loads, normal operating loads with extreme environmental loads, normal operating loads with abnormal loads, normal operating loads with severe environmental loads and abnormal loads, and normal operating loads with extreme environmental loads and abnormal loads.

The loads and load combinations described above are generally applicable to most structures. Discuss other site-related design loads, such as those induced by floods, potential aircraft crashes, explosive hazards in proximity to the site, and projectiles and missiles generated from activities of nearby military installations.

C.I.3.8.4.4 ***Design and Analysis Procedures***

Describe the design and analysis method, with assumptions regarding boundary conditions and emphasis on the extent of compliance with ACI-349 and the AISC specifications for concrete and steel structures, respectively. Describe the expected behavior under load and the mechanisms of load transfer to the foundations. Reference computer programs to permit identification with available published programs. Describe proprietary computer programs to the maximum extent practical to establish the applicability of the program and the method used to validate the program.

C.I.3.8.4.5 ***Structural Acceptance Criteria***

Specify the design criteria related to stresses, strains, gross deformations, factors of safety, and other parameters that quantitatively identify the margins of safety. Emphasize the extent of compliance with ACI-349 for concrete, and the ANSI/AISC N690-1984 specifications for steel, and/or the specific edition, date, or addenda of design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards.

C.I.3.8.4.6 ***Materials, Quality Control, and Special Construction Techniques***

Address the materials and quality control programs, and identify any new or special construction techniques, as outlined in Section C.I.3.8.3.6.

C.I.3.8.4.7 ***Testing and Inservice Inspection Requirements***

Specify any testing and inservice inspection requirements.

C.I.3.8.5 **<u>Foundations</u>**

Provide the information similar to that requested for concrete containment in Section C.I.3.8.1, but as applicable to the foundations of all Seismic Category I structures. As appropriate, concrete foundations of steel or concrete containment should be discussed in this section as well as in Section C.I.3.8.1.

Address the information for foundations for all Seismic Category I structures constructed of materials other than soil for the purpose of transferring loads and forces to the basic supporting media.

C.I.3.8.5.1 ***Description of the Foundations***

Provide descriptive information, including plan and section views of each foundation, to define the primary structural aspects and elements relied upon to perform the foundation function. Describe the relationship between adjacent foundations, including any separation and the reasons for such separation. In particular, discuss the type of foundation and its structural characteristics. Provide the general arrangement of each foundation, with emphasis on the methods of transferring horizontal shears, such as those that are seismically induced, to the foundation media. If shear keys are utilized for such purposes, include the general arrangement of the keys. If waterproofing membranes are used, discuss their effect on the capability of the foundation to transfer shears.

Provide information to adequately describe other types of foundation structures, such as pile foundations, caisson foundations, retaining walls, abutments, and rock and soil anchorage systems.

C.I.3.8.5.2 ***Applicable Codes, Standards, and Specifications***

Provide information similar to that requested in Section C.I.3.8.1.2, but as applicable to the foundations of all Seismic Category I structures.

C.I.3.8.5.3 ***Loads and Load Combinations***

Provide information similar to that requested in Section C.I.3.8.4.3, but as applicable to the foundations of all Seismic Category I structures.

C.I.3.8.5.4 ***Design and Analysis Procedures***

Provide information similar to that requested in Section C.I.3.8.4.4, but as applicable to the foundations of all Seismic Category I structures.

Discuss the assumptions regarding boundary conditions as well as the methods by which lateral loads and forces and overturning moments are transmitted from the structure to the foundation media. Describe the methods by which the effects of settlement are taken into consideration.

C.I.3.8.5.5 ***Structural Acceptance Criteria***

Provide information similar to that requested in Section C.I.3.8.4.5, but as applicable to the foundations of all Seismic Category I structures.

Describe, and indicate the design limits imposed on, the various parameters that define the structural stability of each structure and its foundations, including differential settlements and factors of safety against overturning and sliding.

C.I.3.8.5.6 ***Materials, Quality Control, and Special Construction Techniques***

Provide information similar to that requested in Section C.I.3.8.4.6 for the foundations of all Seismic Category I structures.

C.I.3.8.5.7 ***Testing and Inservice Inspection Requirements***

Discuss information similar to that requested in Section C.I.3.8.4.7 for the foundations of all Seismic Category I structures.

If programs for continued surveillance and monitoring of foundations are required, provide a discussion to define the various aspects of the program, including milestones.

C.I.3.9 Mechanical Systems[2] and Components

C.I.3.9.1 <u>Special Topics for Mechanical Components</u>

Provide information concerning the design transients and resulting loads and load combinations with appropriate specified design and service limits for Seismic Category I components and supports, including both those designated as ASME Code Class 1, 2, 3, or core support (CS), and those that are not covered by the ASME Code.

C.I.3.9.1.1 ***Design Transients***

Provide a complete list of transients used in the design and fatigue analysis of all ASME Code Class 1 and CS components, component supports, and reactor internals. Include the number of events for each transient, as well as the number of load and stress cycles per event and for events in combination. Provide the number of transients assumed for the design life of the plant, and describe the environmental conditions to which equipment important to safety will be exposed over the life of the plant (e.g., coolant water chemistry). Classify all transients (or combinations of transients) with respect to the plant and system operating condition categories identified as "normal," "upset," "emergency," "faulted," or "testing." Vibratory analysis for flow-induced vibration, acoustic resonance and startup testing should be in compliance with Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals During Pre-operational and Initial Startup Testing."

C.I.3.9.1.2 ***Computer Programs Used in Analyses***

Provide a list of computer programs used in dynamic and static analyses to determine the structural and functional integrity of Seismic Category I Code and non-Code items, including the following information:

(1) author, source, dated version, and facility

(2) description and the extent and limitations of the code's applications

(3) demonstration that the computer code's solutions to a series of test problems and the source of the test problems

C.I.3.9.1.3 ***Experimental Stress Analysis***

If experimental stress analysis methods are used in lieu of analytical methods for Seismic Category I ASME Code and non-Code items, provide sufficient information to show the validity of the design.

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[2]Fuel system design information is addressed in Section 4.2.

C.I.3.9.1.4 ***Considerations for the Evaluation of the Faulted Condition***

Describe the analytical methods (e.g., elastic or elastic-plastic) used to evaluate stresses for Seismic Category I ASME Code and non-Code items, including a discussion of their compatibility with the type of dynamic system analysis used. Show that the stress-strain relationship and ultimate strength value used in the analysis for each component is valid. If the use of elastic, elastic-plastic, or limit item analysis concurrently with elastic or elastic-plastic system analysis is invoked, show that the calculated component or component support deformations and displacements do not violate the corresponding limits and assumptions on which the method used for the system analysis is based. When elastic-plastic stress or deformation design limits are specified for ASME Code and non-Code components, provide the methods of analysis used to calculate the stresses and/or deformations resulting from the faulted condition loadings. Describe the procedure for developing the loading function for each component.

C.I.3.9.2 **Dynamic Testing and Analysis of Systems, Components, and Equipment**

Provide the criteria, testing procedures, and dynamic analyses employed to ensure the structural and functional integrity of piping systems, mechanical equipment, reactor internals, and their supports (including supports for conduit and cable trays, and ventilation ducts) under vibratory loadings, including those attributable to flow-induced vibration, acoustic resonance, postulated pipe breaks, and seismic events.

C.I.3.9.2.1 ***Piping Vibration, Thermal Expansion, and Dynamic Effects***

Provide information concerning the piping vibration, thermal expansion, and dynamic effects testing that will be conducted during startup functional testing on ASME Code Class 1, 2, and 3 systems; other high-energy piping systems inside Seismic Category I structures; high-energy portions of systems for which failure could reduce the functioning of any Seismic Category I plant feature to an unacceptable level; and Seismic Category I portions of moderate-energy piping systems located outside containment. Show that these tests will demonstrate that the piping systems, restraints, components, and supports have been designed to (1) withstand the flow-induced dynamic loadings under operational transient and steady-state conditions anticipated during service, and (2) not restrain normal thermal motion.

Include the following information concerning the piping vibration, thermal expansion, and dynamic effects testing:

(1) List the systems that will be monitored.

(2) List the different flow modes of operation and transients such as pump trips, valve closures, etc., to which the components will be subjected during the test.

(3) List the selected locations in the piping system at which visual inspections and measurements will be performed during the tests. For each of these selected locations, provide the deflection (peak-to-peak) or other appropriate criteria to be used to show that the stress and fatigue limits are with the design levels. Provide the rationale and bases for the acceptance criteria and selection of locations to monitor pipe motions.

(4) List the snubbers on systems that experience sufficient thermal movement to measure snubber travel from cold to hot position.

(5) Describe the thermal motion monitoring program to ensure that adequate clearances are provided to allow unrestrained normal thermal movement of systems, components, and supports.

(6) Describe the corrective actions that will be taken if vibration is noted beyond acceptable levels, piping system restraints are determined to be inadequate or are damaged, or no snubber piston travel is measured.

(7) If the piping vibration, thermal expansion, and dynamic effects testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.9.2.2 *Seismic Analysis and Qualification of Seismic Category I Mechanical Equipment*

Describe the seismic system analysis and qualification of Category I systems, components, equipment, and their supports (including supports for conduit and cable trays and ventilation ducts) performed to ensure functional integrity and operability during and after a postulated seismic occurrence.

C.I.3.9.2.2.1 Seismic Qualification Testing

For the methods and criteria for seismic qualification testing of Seismic Category I mechanical equipment, refer to Section C.I.3.10.

C.I.3.9.2.2.2 Seismic System Analysis Methods

Describe the seismic analysis methods (e.g., response spectra, time history, equivalent static load). Include the following information in the description:

(1) manner in which the dynamic system analysis is performed

(2) method chosen for selection of significant modes and an adequate number of masses or degrees of freedom

(3) manner in which the seismic dynamic analysis considers maximum relative displacements between supports

(4) other significant effects that are accounted for in the seismic dynamic analysis, such as piping interactions, externally applied structural restraints, hydrodynamic effects (both mass and stiffness effects), and nonlinear response.

If a static load method is used in lieu of a dynamic analysis, provide justification that the system can be realistically represented by a simple model, and that the method produces conservative results.

C.I.3.9.2.2.3 Determination of Number of Earthquake Cycles

Describe the number of earthquake cycles assumed during one seismic event, the maximum number of cycles for which systems and components are designed, and the criteria used to establish these parameters.

C.I.3.9.2.2.4 Basis for Selection of Frequencies

Provide the criteria or procedures used to separate fundamental frequencies of components and equipment from the forcing frequencies of the support structure.

C.I.3.9.2.2.5 <u>Three Components of Earthquake Motion</u>

Describe how the three components of earthquake motion are considered in determining the seismic response of systems and components.

C.I.3.9.2.2.6 <u>Combination of Modal Responses</u>

When a response spectra method is used, describe how modal responses (e.g., shears, moments, stresses, deflections, and accelerations) were combined, including those for modes with closely spaced frequencies.

C.I.3.9.2.2.7 <u>Analytical Procedures for Piping</u>

Describe the analytical methods (e.g., response spectra, time history, equivalent static load) used for the seismic analysis of piping systems, including the methods used to consider differential piping support movements at different support points located within a structure and between structures.

C.I.3.9.2.2.8 <u>Multiple-Supported Equipment Components with Distinct Inputs</u>

Describe the analytical methods used for the seismic analysis of equipment and components supported at different elevations within a building and between buildings.

C.I.3.9.2.2.9 <u>Use of Constant Vertical Static Factors</u>

Justify, where applicable, the use of constant static forces instead of vertical seismic system dynamic analysis to compute the vertical response loads for the design of affected systems, components, equipment, and their supports.

C.I.3.9.2.2.10 <u>Torsional Effects of Eccentric Masses</u>

Describe the methods used to consider the torsional effects of eccentric masses (e.g., valve operators) in seismic system analyses.

C.I.3.9.2.2.11 <u>Buried Seismic Category I Piping Conduits, and Tunnels</u>

Describe the seismic criteria and methods used to analyze buried piping, conduits and tunnels, including the procedures used to consider the inertia effects of soil media, and the differential displacements at structural penetrations.

C.I.3.9.2.2.12 <u>Interaction of Other Piping with Seismic Category I Piping</u>

Describe the seismic analysis methods used to account for the seismic motion of non-Category I piping systems in the seismic design of Category I piping.

C.I.3.9.2.2.13 <u>Analysis Procedure for Damping</u>

Describe the criteria used to account for damping in systems, components, equipment, and their supports.

C.I.3.9.2.2.14 **Test and Analysis Results**

Provide the results of tests and analyses to demonstrate adequate seismic qualification. If the seismic qualification testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.9.2.3 *Dynamic Response Analysis of Reactor Internals Under Operational Flow Transients and Steady-State Conditions*

For a prototype (first of a design) reactor, describe the dynamic system analysis and response of the structural components within the reactor vessel caused by operational flow transients and steady-state conditions. Demonstrate the acceptability of the reactor internals design for normal operating conditions, and provide the predicted input forcing functions and the vibratory response of the reactor internals.

Provide analytical methods and procedures to predict vibrations of BWR reactor pressure vessel internals (including the steam dryer) and other main steam system components. The dynamic responses to operational transients and hydrodynamic and acoustic loadings should be determined at locations where sensors would be mounted on the reactor internals (including steam dryers and main steam system components). Discuss specific locations for calculated responses, considerations used in defining the mathematical model, interpretations of analytical results, acceptance criteria, and methods of verifying predictions by means of tests.

For a non-prototype reactor, provide references to the reactor that is prototypical of the reactor being reviewed, along with a brief summary of test and analysis results.

C.I.3.9.2.4 *Pre-Operational Flow-Induced Vibration Testing of Reactor Internals*

Describe the pre-operational and startup test program for flow-induced vibration testing of reactor internals, demonstrating that flow-induced vibrations experienced during normal operation will not cause structural failure or degradation.

For a prototype reactor, describe flow modes, vibration monitoring sensor types and locations, procedures and methods to be used to process and interpret the measured data, planned visual inspections, planned comparisons of test results with analytical predictions, and possible supplementary tests (e.g., component vibration tests, flow tests, scaled model tests).

For a non-prototype reactor, provide references to the reactor that is prototypical of the reactor being reviewed, along with a brief summary of test and analysis results.

Identify and justify any deviation from the guidance provided in Regulatory Guide 1.20.

Provide a detailed analysis of potential adverse flow effects (e.g., flow induced vibrations and acoustic resonances) that can severely impact BWR reactor pressure vessel internals (including the steam dryer) and other main steam system components that are either different from the designated prototype design or not covered in the prototype test program. The analysis should be supplemented by acoustic and computational fluid dynamic analyses and scale model testing. Describe the utilization of instruments on vulnerable components (including pressure, strain and acceleration sensors on the steam dryer), in addition to satisfying the provisions discussed in Chapter 3.9.5 to obtain direct loading data to ensure structural adequacy of the components against the potential adverse flow effects. For a prototype reactor, if the flow-induced vibration testing of reactor internals has not been completed at the time the COL application is filed, provide documentation describing the implementation program, including milestones and completion dates.

C.I.3.9.2.5 ***Dynamic System Analysis of the Reactor Internals Under Faulted Condition***

Discuss the dynamic system analysis methods used to confirm the adequacy of the structural design of the reactor internals and the unbroken loop of the reactor piping system, as it relates to withstanding dynamic effects with no loss of function under the simultaneous occurrence of a LOCA or steam line break and SSE.

Include the following information concerning the dynamic system analysis:

(1) Provide typical diagrams of the dynamic system mathematical modeling of piping, pipe supports, and reactor internals, along with fuel element assemblies and control rod assemblies and drives, used in the analysis, including a discussion of the bases for any structural partitioning and directional decoupling of components.

(2) Describe the methods used to obtain the forcing functions and a description of the forcing functions used for the dynamic analysis of the LOCA or steam line break and SSE event (including system pressure differentials, direction, rise time, magnitude, duration, initial conditions, spatial distribution, and loading combinations).

(3) Describe the methods used to compute the total dynamic structural responses, including the buckling response, of those structures in compression.

(4) Discuss the results of the dynamic analysis.

C.I.3.9.2.6 ***Correlations of Reactor Internals Vibration Tests with the Analytical Results***

Describe the method used to correlate the results of the reactor internals pre-operational vibration test with the analytical results derived from dynamic analyses of reactor internals under operational flow transients and steady-state conditions. Include the method used to verify the mathematical model used in the faulted condition (LOCA, steam line break, and SSE) by comparing certain dynamic characteristics such as natural frequencies.

C.I.3.9.3 **ASME Code Class 1, 2, and 3 Components and Component Supports, and Core Support Structures**

Discuss information related to the structural integrity of pressure-retaining components, component supports, and core support structures designed and constructed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, as well as with General Design Criteria 1, 2, 4, 14, and 15. Also incorporate design information related to component design for steam generators (as called for in Section C.I.5.4.2), if applicable, including field run piping and internal parts of components.

C.I.3.9.3.1 ***Loading Combinations, System Operating Transients, and Stress Limits***

Provide the design and service load combinations (e.g., design and service loads, including system operating transients, in combination with loads resulting from postulated seismic and other transient initiating events) specified for components constructed in accordance with the ASME Code and designated as Code Class 1, 2, or 3. This should include Class 1, 2, and 3 component support structures and core support structures, to determine that appropriate design and service limits have been designated for all loading combinations. Describe how actual design and service stress limits and deformation criteria comply with applicable limits specified in the Code. Provide information on service stress limits that allow inelastic deformation of Code Class 1, 2, and 3 components; component supports; and core support structures, and provide justification for proposed design procedures. Include information on field run piping and internal parts of components (e.g., valve discs and seats and pump shafting) that are subjected to dynamic loading during operation of the component.

Include the following information for ASME Code Class 1 components, core support structures, and ASME Code Class 1 component supports:

(1) summary description of mathematical or test models used

(2) methods of calculations or tests, including simplifying assumptions, identification of method of system and component analysis used, and demonstration of their compatibility (see Section C.I.3.9.1.4) in the case of components and supports that are designed to faulted limits

(3) summary of the maximum total stress, deformation, and cumulative usage factor values for each of the component operating conditions for all ASME Code Class I components. Identify those values that differ from the allowable limits by less than 10%, and provide the contribution of each of the loading categories, (e.g., seismic, dead weight, pressure, and thermal) to the total stress for each maximum stress value identified in this range

Include the following information for all other classes of components and their supports:

(1) summary description of any test models used (see Section C.I.3.9.1.3 of this guide)

(2) summary description of mathematical or test models used to evaluate faulted conditions, as appropriate, for components and supports (see Sections C.I.3.9.1.2 and C.I.3.9.1.4 of this guide)

(3) for all ASME Code Class 2 and 3 components required to shut down the reactor or mitigate consequences of a postulated piping failure without offsite power, a summary of the maximum total stress and deformation values for each of the component operating conditions (identify those values that differ from the allowable limits by less than 10%)

Include a listing of transients appropriate to ASME Code Class 1, 2, and 3 components, core support structures, and component supports categorized on the basis of plant operating condition. In addition, for ASME Code Class 1 components, core support structures, and component supports, include the number of cycles to be used in the fatigue analysis appropriate to each transient (see Section C.I.3.9.1.1).

C.I.3.9.3.2 ***Design and Installation of Pressure-Relief Devices***

Describe the design and installation criteria applicable to the mounting of pressure-relief devices (i.e., safety and relief valves) for over pressure protection of ASME Class 1, 2, and 3 components, including information to permit evaluation of applicable load combinations and stress criteria. Provide information to allow the design review to consider plans for accommodating the rapidly applied reaction force that occurs when a safety or relief valve opens, and the transient fluid-induced loads applied to piping downstream from a safety or relief valve in a closed discharge piping system (including dynamic structural response attributable to a BWR safety relief valve discharge into the suppression pool). Describe the design of safety and relief valve systems with respect to load combinations postulated for the valves, upstream piping or header, downstream or vent piping, system supports, and BWR suppression pool discharge devices such as ramsheads and quenchers, if applicable.

For load combinations, identify the most severe combination of applicable loads attributable to internal fluid weight, momentum, and pressure; dead weight of valves and piping; thermal load under heat up; steady-state and transient valve operation; reaction forces when valves are discharging (i.e., thrust, bending, torsion); seismic forces (i.e., SSE); and dynamic forces attributable to BWR safety relief valve discharge in the suppression pool, if applicable. Include as valve discharge loads the reaction loads attributable to discharge of loop seal water slugs and sub-cooled or saturated liquid under transient or accident conditions.

Discuss the method of analysis and magnitude of any dynamic load factors used. Discuss and include in the analysis a description of the structural response of the piping and support system, with particular attention to the dynamic or time history analyses employed in evaluating the appropriate support and restraint stiffness effects under dynamic loadings when valves are discharging. Present results of the analysis.

If use of hydraulic snubbers is proposed, describe snubber performance characteristics to ensure that their effects have been considered in analyses under steady-state valve operation and repetitive load applications caused by cyclic valve opening and closing during the course of a pressure transient.

C.I.3.9.3.3 ***Pump and Valve Operability Assurance***

Identify all active ASME Class 1, 2, and 3 pumps and valves. Present criteria to be employed in a test program, or a program consisting of tests and analysis, to ensure operability of pumps that are required to function and valves that are required to open or close to perform a safety function during or following the specified plant event. Discuss features of the program, including conditions of test, scale effects (if appropriate), loadings for specified plant event, transient loads (including seismic component, dynamic coupling to other systems, stress limits, deformation limits), and other information pertinent to assurance of operability. Include design stress limits established in Section C.I.3.9.3.1.

Include program results, summarizing stress and deformation levels and environmental qualification, as well as maximum test envelope conditions for which each component qualifies, including end connection loads and operability results.

C.I.3.9.3.4 ***Component Supports***

Provide load combinations, system operating transients, stress limits, and deformation limits for component supports, as discussed in Section C.I.3.9.3.1.

Provide information to enable evaluation of supports for ASME Code Class 1, 2, and 3 components, including assessment of design and structural integrity of plate and shell, linear, and component standard types of supports for active components. Analyze and/or test the component supports as discussed in Section C.I.3.9.3.3, and include their effects on operability in the discussion provided in that section. Present the criteria used for the analysis or test program, as well as the results of the analysis and/or test programs as discussed in Sections C.I.3.9.3.1 and C.I.3.9.3.3.

C.I.3.9.4 **Control Rod Drive Systems**

Provide information on the control rod drive systems (CRDSs). For electromagnetic systems, include the control rod drive mechanism (CRDM) up to the coupling interface with reactivity control elements. For hydraulic systems, include the CRDM, hydraulic control unit, condensate supply system, and scram discharge volume, up to the coupling interface with reactivity control elements. For both types of systems, treat the CRDM housing as part of the reactor coolant pressure boundary (RCPB). Information on CRDS materials should be included in Section C.I.4.5.1.

If other types of CRDSs are proposed, or if new features that are not specifically mentioned here are incorporated in current types of CRDSs, provide information regarding the new systems or new features.

C.I.3.9.4.1 *Descriptive Information of CRDS*

Provide an evaluation of the system's adequacy to properly perform its design function, including design criteria, testing programs, drawings, and a summary of the method of operation of the control rod drives.

C.I.3.9.4.2 *Applicable CRDS Design Specifications*

Indicate the design codes, standards, specifications, and standard practices, as well as NRC general design criteria, regulatory guides, and positions, that are applied in the design, fabrication, construction, and operation of the CRDS. List the various criteria along with the names of the apparatuses to which they apply:

(1) List the pressurized parts of the system in Section C.I.3.2.2:

  (a) For those portions that are part of the RCPB, indicate the extent of compliance with the Class 1 requirements in Section III of the ASME Code.

  (b) For those portions that are not part of the RCPB, indicate the extent of compliance with other specified parts of Section III or other sections of the ASME Code.

(2) Provide an evaluation of the non-pressurized portions of the CRDS, demonstrating the acceptability of design margins for allowable values of stress, deformation, and fatigue. If an experimental testing program is used in lieu of analysis, discuss how the program adequately covers stress, deformation, and fatigue in the CRDS. If this experimental testing program has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.9.4.3 *Design Loads, Stress Limits, and Allowable Deformations*

Present information that pertains to the applicable design loads and their appropriate combinations, the corresponding design stress limits, and the corresponding allowable deformations. The deformations of interest are those where a failure of movement could be postulated to occur and such movement would be necessary for a safety-related function:

(1) If experimental testing is used in lieu of establishing a set of stress and deformation allowable, describe the testing program, including the load combinations, design stress limits, and allowable deformation criteria. If the experimental testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

(2) For components that are not designed to the ASME Code, provide the design limits and safety margins.

(3) For components that are designed to the ASME Code, provide information similar to that requested in Section C.I.3.9.3.

(4) Compare the actual design with the design criteria and limits to demonstrate that the criteria and limits have not been exceeded.

C.I.3.9.4.4 *CRDS Operability Assurance Program*

Provide plans for conducting an operability assurance program or references to previous test programs or standard industry procedures for similar apparatuses. Show how the operability assurance program includes a life cycle test program that fulfills the following criteria:

(1) Demonstrate the ability of the control rod drive components to function during and after normal operation, anticipated operational occurrences, seismic events, and postulated accident conditions over the full range of temperatures, pressures, loadings, and misalignment expected in service.

(2) Include functional tests to determine insertion and withdrawal times, latching operation, scram operation and time, system valve operation and scram accumulator leakage for hydraulic CRDSs, ability to overcome a stuck rod condition, and wear.

Describe the implementation program for the operability assurance program, including milestones.

C.I.3.9.5 <u>Reactor Pressure Vessel Internals</u>

Discuss the specific design codes, load combinations, allowable stress and deformation limits, and other criteria used in designing the reactor internals, for both ASME-Code-designed core support structures and internals designed to other standards. Ensure the structural and functional integrity of the reactor internals including the steam dryer.

C.I.3.9.5.1 *Design Arrangements*

Present the physical or design arrangements of all reactor internals structures, systems, components, and assemblies, including the manner of positioning and securing such items within the reactor pressure vessel, the manner of providing for axial and lateral retention and support of the internals components and assemblies, and the manner of accommodating dimensional changes attributable to thermal and other effects. Describe the functional requirements for each component. Verify that any significant changes in design from that used in previously licensed plants of similar design do not affect the acoustic and flow-induced vibration test results requested in Section C.I.3.9.2.4.

C.I.3.9.5.2 *Loading Conditions*

Specify the plant and system operating conditions and design basis events that provide the basis for the design of the reactor internals to sustain normal operation, vibratory flow-induced vibration and acoustic loading, anticipated operational occurrences, postulated accidents, and seismic events in accordance with the information requested in Section C.I.3.9.1.1.

Identify the design codes, code cases and acceptance criteria applicable to the design, analysis, fabrication, and nondestructive examination of the internals components. Identify internal components that are designated as core support structures and internal structures, and discuss the implications of this designation on applicable design criteria. Indicate the extent to which the design and construction of the core support structures are in accordance with Subsection NG of the ASME Code. Also indicate the extent to which the design of other reactor internals will be consistent with Article NG-3000 of the ASME Code.

C.I.3.9.5.3 ***Design Bases***

List all combinations of design and service loadings that are accounted for in the design of the reactor internals (e.g., acoustic and flow-induced vibration, operating differential pressure and thermal loads, thermal stratification, seismic loads, flow-induced vibration loads, acoustic loads, transient pressure loads associated with postulated LOCAs, and asymmetric blowdown pressurization and loading resulting from pipe ruptures at postulated locations that are not excluded based on leak-before-break analyses). Describe the definition of these loads and the method of load combinations for normal, upset, emergency, and faulted service conditions. For each specific load combination, provide the allowable design or service limits to be applied to the reactor internals, including steam dryers. Provide the deflection, cycling, and fatigue limits, considering the effects of component service environments. Verify that the allowable deflections will not interfere with the functioning of all related components (e.g., control rod guide tubes and standby cooling systems). Provide a summary of the maximum calculated total stress, deformation, and cumulative usage factor for each designated design or service limit. Details of the dynamic analyses should be presented in Section C.I.3.9.2.

C.1.3.9.5.4 ***BWR Reactor Pressure Vessel Internals Including Steam Dryer***

Present a detailed analysis of potential adverse flow effects (flow-induced vibrations and acoustic resonances) that can severely impact reactor pressure vessel internal components (including the steam dryer) and other main steam system components, as applicable. The analysis should be supplemented by acoustic and computational fluid dynamic analyses and scale model testing. Describe the utilization of instrumentation on vulnerable components (including pressure, strain, and acceleration sensors on the steam dryer), in addition to satisfying the provisions discussed in Section 3.9.2.4 to obtain direct loading data and to ensure structure adequacy of those components against the potential adverse flow effects. For a prototype reactor, if the flow-induced vibration testing of reactor internals has not been completed at the time the COL application is filed, describe the implementation program, including milestones and completion dates.

C.I.3.9.6 **Functional Design, Qualification, and Inservice Testing Programs for Pumps, Valves, and Dynamic Restraints**

Describe the functional design and qualification provisions and inservice testing (IST) programs for certain safety-related pumps, valves, and dynamic restraints (snubbers) (i.e., those safety-related pumps, valves and snubbers that are typically designated as Class 1, 2, or 3 under Section III of the ASME Code, plus those pumps, valves and snubbers that are not categorized as Class 1, 2, or 3 but are considered to be safety-related) to ensure that they will be in a state of operational readiness to perform their safety functions throughout the life of the plant.

C.I.3.9.6.1 ***Functional Design and Qualification of Pumps, Valves, and Dynamic Restraints***

(1) Describe the provisions in the design of safety-related pumps, valves, and piping that allow testing of pumps and valves at the maximum flow rates specified in the plant accident analyses.

(2) Describe the provisions in the functional design and qualification of each safety-related pump and valve that demonstrate the capacity of the pumps and valves to perform their intended functions for a full range of system differential pressures and flows, ambient temperatures, and available voltage (as applicable) from normal operating to design-basis conditions.

(3) Verify that the qualification program for safety-related valves that are part of the RCPB includes testing and analyses that demonstrate that these valves will not experience any leakage, or increase in leakage, from their loading.

(4) Describe the provisions in the functional design and qualification of dynamic restraints in safety-related systems and access for performing IST program activities that 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 for initial fuel load.

(5) Particular attention should be given to flow-induced loading in functional design and qualification to incorporate degraded flow conditions such as those that might be encountered by the presence of debris, impurities, and contaminants in the fluid system (e.g., containment sump pump recirculating water with debris).

C.I.3.9.6.2 ***Inservice Testing Program for Pumps***

(1) Provide a list of pumps that are to be included in the IST program, including their code class.

(2) Describe the IST program (including test parameters and acceptance criteria) for pump speed, fluid pressure, flow rate, and vibration at normal, IST, and design-basis operating conditions.

(3) Describe the proposed methods for establishing and measuring the reference values and IST values for the pump parameters listed above, including instrumentation accuracy and range.

(4) Describe the proposed pump test plan and schedule, (including test duration), and include this information in the technical specifications.

(5) Describe the implementation program, including milestones, for the pump IST programs that 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 for initial fuel load.

C.I.3.9.6.3 ***Inservice Testing Program for Valves***

(1) Provide a list of valves that are to be included in the IST program, including their type, valve identification number, code class, and valve category.

(2) Describe the IST program (including test requirements, procedures, and acceptance criteria) for valve pre-service tests, valve replacement, valve repair and maintenance, and indication of valve position.

(3) Present the proposed methods for measuring the reference values and IST values for power-operated valves, including motor-operated valves, air-operated valves, hydraulic-operated valves, and solenoid-operated valves.

(4) Describe the valve test procedures and schedules (including justifications for cold shutdown and refueling outage test schedules), and include this information in the technical specifications.

(5) Describe the implementation program, including milestones, for the valve IST programs that 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 for initial fuel load. Include specific milestones associated with the implementation of MOV programs.

C.I.3.9.6.3.1 Inservice Testing Program for Motor-Operated Valves (MOVs)

(1) Describe the IST program that will periodically verify the design-basis capability of safety-related MOVs.

(a) Show how periodic testing (or analysis combined with test results where testing is not conducted at design-basis conditions) will objectively demonstrate continued MOV capability to open and/or close under design-basis conditions.

(b) Justify any IST intervals that exceed either 5 years or 3 refueling outages, whichever is longer.

(2) Show how successful completion of the pre-service and inservice testing of MOVs will demonstrate that the following criteria are met:

(a) Valve fully opens and/or closes as required by its safety function.

(b) Adequate margin exists and includes consideration of diagnostic equipment inaccuracies, degraded voltage, control switch repeatability, load sensitive MOV behavior, and margin for degradation.

(c) Maximum torque and/or thrust (as applicable) achieved by the MOV (allowing sufficient margin for diagnostic equipment inaccuracies and control switch repeatability) does not exceed the allowable structural and undervoltage motor capability limits for the individual parts of the MOV.

C.I.3.9.6.3.2 Inservice Testing Program for Power-Operated Valves (POVs) Other than MOVs

(1) Describe how the POVs will be qualified to perform their design-basis functions either prior to installation or as part of pre-operational testing.

(2) Describe the POV IST program and show how the program incorporates the lessons learned from MOV analysis and tests performed in response to GL 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance."

(3) Explain how solenoid-operated valves are verified to meet their Class 1E electrical requirements by performing their safety functions for the appropriate electrical power supply amperage and voltage.

C.I.3.9.6.3.3 Inservice Testing Program for Check Valves

(1) Describe the pre-service and inservice tests to be conducted on each check valve:

(a) Describe the diagnostic equipment or nonintrusive techniques that will be used to monitor internal component condition and measure such parameters as fluid flow, disk position, disk movement, disk impact forces, leak tightness, leak rates, degradation, and disk testing. Describe the diagnostic equipment and its operating principals, and justify the technique. Discuss how the operation and accuracy of the diagnostic equipment and techniques will be verified during pre-service testing.

(b) Verify that testing will be performed (to the extent practical) under temperature and flow conditions that will exist during normal operation as well as cold shutdown, and in other modes if such conditions are significant.

(c) Verify that the testing results will identify the flow required to open the valve to the full-open position.

(d) Verify that testing will include the effects of rapid pump starts and stops and any other reverse flow conditions that may be required by expected system operating conditions.

(2) Explain the nonintrusive (diagnostic) techniques to be used to periodically assess degradation and performance characteristics of check valves.

(3) Verify that the acceptance criteria for successful completion of the pre-service and inservice testing will include the following assessments:

(a) Demonstrate that the valve disk fully opens or fully closes as expected during all test modes that simulated expected system operating conditions based on the direction of the differential pressure across the valve.

(b) Determine valve disk positions without disassembly.

(c) Verify free disk movement to and from the seat.

(d) Demonstrate that the valve disk is stable in the open position under normal and other required system operating fluid flow conditions.

(e) For passive plant designs, verify that the valve disk moves freely off the seat under normal and other minimum expected differential pressure conditions.

(4) Confirm that piping design features will accommodate all applicable check valve testing requirements.

(5) Show how the valve IST program meets the requirements of Appendix II to the ASME OM Code.

C.I.3.9.6.3.4 Pressure Isolation Valve (PIV) Leak Testing

Provide a list of PIVs, including the classification, allowable leak rate, and test interval for each valve.

C.I.3.9.6.3.5 Containment Isolation Valve (CIV) Leak Testing

Provide a list of CIVs, including the allowable leak rate for each valve or valve combination.

C.I.3.9.6.3.6 Inservice Testing Program for Safety and Relief Valves

(1) Provide a list of safety and relief valves, including the set pressure and allowable tolerances for each valve.

(2) Provide the overall combined accuracy of the test equipment (including gauges, transducers, load cells, and calibration standards) used to determine valve set-pressures.

C.I.3.9.6.3.7 Inservice Testing Program for Manually Operated Valves

Provide a list of manually operated valves, including their safety-related function.

C.I.3.9.6.3.8 Inservice Testing Program for Explosively Activated Valves

Provide a list of explosively actuated valves, including a test plan and corrective actions.

C.I.3.9.6.4 ***Inservice Testing Program for Dynamic Restraints***

(1) Provide a table listing all safety-related components that use snubbers in their support systems:

   (a) Identify the systems and components that use snubbers.

   (b) Indicate the number of snubbers used in each system and on the components in that system.

   (c) Identify the type(s) of snubber (hydraulic or mechanical) and the corresponding supplier.

   (d) Specify whether the snubber was constructed to any industry (e.g., ASME) codes.

   (e) State whether the snubber is used as a shock, vibration, or dual-purpose snubber.

   (f) If a snubber is identified as either a dual-purpose or vibration arrester type, indicate whether the snubber and/or component were evaluated for fatigue strength.

(2) Describe the IST program (including test frequency and duration and examination methods) related to visual inspections (e.g., checking for degradation, cracked fluid reservoirs, missing parts, and leakage) and functional testing of dynamic restraints. Describe and state the basis for dynamic restraint testing.

(3) Describe the steps to be taken to ensure that all snubbers are properly installed prior to pre-operational piping and plant start-up tests.

(4) Confirm the accessibility provisions for maintenance, inservice inspection and testing, and possible repair or replacement of snubbers.

(5) Describe the implementation program, including milestones, for the snubber IST programs that 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 for initial fuel load.

C.I.3.9.6.5 ***Relief Requests and Alternative Authorizations to ASME OM Code***

Provide information regarding components for which the applicant is requesting relief from (or proposing an alternative to) the ASME OM Code requirements:

(1) Identify the component by name, number, functions, ASME Section III Code class, valve category (as defined in ISTC-1033 of the ASME OM Code), and pump group (as defined in ISTB-2000 of the ASME OM Code).

(2) Identify the ASME OM Code requirement(s) from which the applicant is requesting relief or an alternative.

(3) For a relief request pursuant to 10 CFR 50.55a(f)(6)(i) or (g)(6)(i), specify the basis under which relief is requested and explain why complying with the ASME OM Code is impractical or should otherwise not be required.

(4) For an alternative request pursuant to 10 CFR 50.55a(a)(3), provide details regarding the proposed alternative(s) demonstrating that (i) the proposed IST will provide an acceptable level of quality and safety, or (ii) compliance with the specified requirement would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

(5) Describe the implementation program, including milestones, for the proposed IST program.

C.I.3.9.7 [Reserved]

C.I.3.9.8 [Reserved]

C.I.3.10 *Seismic and Dynamic Qualification of Mechanical and Electrical Equipment*

Identify all instrumentation, electrical equipment, and mechanical components (other than pipes), including their supports, that should be designed to withstand the effects of earthquakes and the full range of normal and accident loadings. Include (1) equipment associated with systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment reactor heat removal; (2) equipment essential to preventing significant release of radioactive material to the environment, and (3) instrumentation needed to assess plant and environs conditions during and after an accident as described in Regulatory Guide 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants." Include equipment (1) that performs the above functions automatically, (2) that operators use to perform the above functions manually, and (3) for which failure can prevent satisfactory accomplishment of one or more of the above safety functions. Such equipment includes that in the reactor protection system, engineered safety features Class 1E equipment, the emergency power system, and all auxiliary safety-related systems and supports. Examples of mechanical equipment include pumps, valves, fans, valve operations, snubbers, battery and instrument racks, control consoles, cabinets, and panels; examples of electrical equipment include valve operator motors, solenoid valves, relays, pressure switches, level transmitters, electrical penetrations, and pump and fan motors.

C.I.3.10.1 Seismic Qualification Criteria

Provide the criteria used for seismic qualification, including the decision criteria for selecting a particular test or method of analysis, the considerations defining the seismic and other relevant dynamic load input motion, and the process to demonstrate the adequacy of the seismic qualification program. Indicate the extent to which the seismic qualification criteria use the guidance in Regulatory Guide 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants."

C.I.3.10.2 Methods and Procedures for Qualifying Mechanical and Electrical Equipment and Instrumentation

Describe the methods and procedures, including test and/or analysis results, used to ensure the structural integrity and functionality of mechanical and electrical equipment for operation in the event of a SSE. If the postulation of an OBE is required, address five occurrences of the OBE followed by a full set event or a number of fractional peak cycles equivalent to the maximum peak cycle for five OBE events followed by one full SSE, in combination with other relevant design-basis load.

C.I.3.10.3 Methods and Procedures of Analysis or Testing of Supports of Mechanical and Electrical Equipment and Instrumentation

Describe the methods and procedures, including results, used to analyze or test the supports for mechanical and electrical equipment, as well as the verification procedures used to account for possible amplification of vibratory motion (amplitude and frequency content) under seismic and dynamic conditions. Include supports for such items as battery racks and instrument racks, pumps, valves, valve operators, fans, control consoles, cabinets, panels, and cable trays.

C.I.3.10.4 <u>Test and Analyses Results and Experience Database</u>

Provide the results of tests and analyses that demonstrate adequate seismic qualification. If the seismic and dynamic qualification testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones and completion dates. If qualification by experience is proposed, submit for staff review and approval the methods and procedures, including details of the experience data base to ensure structural integrity and the functionality of those in-scope mechanical and electrical equipment as described in section C.I.3.10.2.

C.I.3.11 *Environmental Qualification of Mechanical and Electrical Equipment*

Identify the mechanical and electrical equipment (including instrumentation and control and certain accident monitoring equipment specified in Regulatory Guide 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants") that is within the scope of 10 CFR 50.49, "Environmental qualification of electric equipment important to safety for nuclear power plants," to perform its safety functions under all normal environmental conditions, anticipated operational occurrences, and accident and post-accident environmental conditions. Include the mechanical and electrical equipment associated with systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, containment and reactor heat removal. Also include equipment for which postulated failure might affect the safety function of safety-related equipment or mislead an operator, as well as equipment that is otherwise essential to prevent significant releases of radioactive material to the environment.

C.I.3.11.1 <u>Equipment Location and Environmental Conditions</u>

Specify the location of each piece of equipment, both inside and outside containment. For equipment inside containment, specify whether the location is inside or outside of the missile shield (for PWRs), or inside or outside of the drywell (for BWRs).

Specify both the normal and accident environmental conditions for each item of equipment, including temperature, pressure, humidity, radiation, chemicals, submergence, and vibration (non-seismic) at the location where the equipment must perform. For the normal environment, provide specific values, including those attributable to loss of environmental control systems. For the accident environment, identify the cause of the postulated environment (e.g., LOCA, steam line break, or other), specify the environmental conditions as a function of time, and identify the length of time that each item of equipment is required to operate in the accident environment.

C.I.3.11.2 <u>Qualification Tests and Analyses</u>

Demonstrate that (1) the equipment is capable of maintaining functional operability under all service conditions postulated to occur during the equipment's installed life for the time it is required to operate, and (2) failure of the equipment after performance of its safety function will not be detrimental to plant safety or mislead an operator. Consider all environmental conditions that may result from any normal mode of plant operation, anticipated operational occurrences, design-basis events, post-design-basis events, and containment tests. Provide a description of the qualification tests and analyses performed on each item of equipment to ensure that it will perform under the specified normal and accident environmental conditions.

Document how the design will meet the requirements of 10 CFR 50.49; 10 CFR 50.67, General Design Criteria 1, 2, 4, and 23 of Appendix A to 10 CFR Part 50; and Criteria III, XI, and XVII of Appendix B to 10 CFR Part 50. Indicate the extent to which the guidance contained in applicable regulatory guides (some of which are listed below) will be utilized, or document and justify the use of alternative approaches:

- Regulatory Guide 1.30 (Safety Guide 30), "Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment"
- Regulatory Guide 1.40, "Qualification Tests of Continuous-Duty Motors Installed Inside the Containment of Water-Cooled Nuclear Power Plants"
- Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants"
- Regulatory Guide 1.73, "Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants"
- Regulatory Guide 1.89, "Environmental Qualification of Certain Electrical Equipment Important to Safety for Nuclear Power Plants"
- Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident"
- Regulatory Guide 1.131, "Qualification Tests of Electric Cables, Field Splices, and Connections for Light-Water-Cooled Nuclear Power Plants"
- Regulatory Guide 1.151, "Instrument Sensing Lines"
- Regulatory Guide 1.156, "Environmental Qualification of Connection Assemblies for Nuclear Power Plants"
- Regulatory Guide 1.158, "Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants"
- Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems"
- Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design-Basis Accidents at Nuclear Power Reactors"

C.I.3.11.3 Qualification Test Results

Provide documentation of the qualification test results and qualification status for each type of equipment. If the qualification testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.11.4 Loss of Ventilation

Provide the bases that ensure that loss of environmental control systems (e.g., heat tracing, ventilation, heating, air conditioning) will not adversely affect the operability of each item of equipment, including electric control and instrumentation equipment and instrument sensing lines that rely on heat tracing for freeze protection. Describe the analyses performed to identify the "worst case" environment (e.g., temperature, humidity), including identification and determination of the limiting condition with regard to temperature that would require reactor shutdown. Describe any testing (factory or onsite) performed to confirm satisfactory operability of control and electrical equipment under extreme environmental conditions. Provide documentation of the successful completion of qualification tests and

qualification status for each type of equipment. If the qualification testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.11.5 Estimated Chemical and Radiation Environment

Identify the chemical environment for both normal operation and the design-basis accident. For engineered safety features inside containment (e.g., containment spray, emergency core cooling system initiation, or recirculating phase), identify the chemical composition and resulting pH of the liquids in the reactor core and the containment sump.

Identify the radiation dose and dose rate used to determine the radiation environment and indicate the extent to which estimates of radiation exposures are based on a radiation source term that is consistent with NRC staff-approved source terms and methodology. For exposure of organic components on emergency safety feature (ESF) systems, tabulate beta and gamma exposures separately for each item of equipment and list the average energy of each type of radiation. For ESF systems outside containment, indicate whether the radiation estimates account for factors affecting the source term such as containment leak rate, meteorological dispersion (if appropriate), and operation of other ESF systems. List all assumptions used in the calculation.

Provide documentation of successful completion of qualification tests and qualification status for each type of equipment. If the qualification testing has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.11.6 Qualification of Mechanical Equipment

Define the process established to determine the suitability of environmentally sensitive mechanical equipment (e.g., seals, gaskets, lubricants, fluids for hydraulic systems, and diaphragms) needed for safety-related functions and to verify that the design of such materials, parts, and equipment is adequate:

(1) Identify safety-related mechanical equipment located in harsh environmental areas.

(2) Identify nonmetallic sub-components of such equipment.

(3) Identify the environmental conditions and process fluid parameters for which this equipment must be qualified.

(4) Identify the nonmetallic material capabilities.

(5) Evaluate the environmental effects on the nonmetallic components of the equipment.

Provide documentation of successful completion of qualification tests and/or analysis and qualification status for each type of equipment. If the qualification testing or analysis has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.3.12 *Piping Design Review*

C.1.3.12.1 <u>Introduction</u>

This section covers the design of the piping system and piping support which comprises seismic Category I, Category II, and non-safety systems. This section discusses the adequacy of the structural integrity as well as the functional capability of the safety related piping system, piping components, and their associated supports. Piping systems are to be designed to perform their safety related functions under all postulated combinations of normal operating conditions, system operating transients, postulated pipe breaks, and seismic events. This includes pressure-retaining piping components and their supports, buried piping, instrumentation lines, and the interaction of nonseismic Category I piping and associated supports with seismic Category I piping and associated supports. This section covers the design transients and resulting loads and load combinations with appropriate specified design and service limits for seismic Category I piping and piping support, including both those designated as ASME Code Class 1, 2, 3, and those not covered by the ASME Code.

C.1.3.12.2 <u>Codes and Standards</u>

Provide a table showing compliance with the NRC's regulations at 10 CFR 50.55a, "Codes and Standards." This table should identify the piping system, including associated supports. In the event that conformance to the regulations of 10 CFR 50.55a would result in hardships or unusual difficulties without a compensating increase in the level of safety and quality, provide a complete description of the circumstances resulting in such cases and the basis for proposed alternative requirements. Describe how an equivalent and acceptable level of safety and quality will be provided by the proposed alternative requirements.

Discuss information related to design and analyses of the piping system, including piping components and associated supports in accordance with Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereinafter referred as the Code). Provide requirements and procedures used in preparation of design specification of the piping system, including loading combinations, design data and other design inputs. Provide design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards used in the design, or that will be used in the fabrication, construction, testing, and in service inspection of the piping system. Identify the specific edition, date, or addenda of each document.

The ASME Code cases that may be used for the design of the ASME Code Class l, 2,and 3 piping system are those recommended in Regulatory Guide 1.84. If Code Cases other than those listed in Regulatory Guide 1.84 are used, show that their use will result in as acceptable a level of quality and safety for the component as would be achieved by following the Code Cases endorsed in Regulatory Guide 1.84. The design reports for ASME Code Class 1, 2, and 3 piping system and piping support should be available for NRC audit.

C.1.3.12.3 <u>Piping Analysis Methods</u>

Identify and describe the design consistent with seismic subsystem analysis related to seismic analysis methods (e.g., response spectrum analysis, modal time history analysis, direct integration time history analysis, frequency domain time history analysis, equivalent static load analysis) used for Seismic Category I and non-seismic Category I (Seismic Category II and non-seismic) piping system and piping support.

Indicate the manner in which consideration is given in the seismic dynamic analysis to maximum relative displacement among supports. Indicate other significant effects accounted for in the dynamic seismic analysis, such as hydrodynamic effects and nonlinear response.

Describe the procedure used for analytical modeling, number of earthquake cycles, selection of frequencies, damping criteria (consistent with RG 1.61), combination of modal responses, equivalent static factors, the analysis for small bore piping, and interaction of Category I systems with other systems. Since there are numerous technical issues related to piping design and piping support other than seismic and those criteria discussed in the Standard Review Plan (SRP), discuss also any acceptable methods that are common industry practices and/or practical engineering considerations proven through extensive experience.

C.1.3.12.3.1 ***Experimental Stress Analyses***

If experimental stress analysis methods are used in lieu of analytical methods for seismic category I ASME Code and non-Code piping system design, provide sufficient information to show the validity of the design. It is recommended, prior to use of the experimental stress analysis method, that details of the method as well as the scope and extent of its application be submitted for approval. The experimental stress analysis method should comply with Appendix II to ASME Code, Section III, Division 1.

C.1.3.12.3.2 ***Modal Response Spectrum Method***

Modal response spectrum and time history methods form the basis for the analyses of all major Seismic Category I piping systems and components. Describe the procedures for considering the three components of earthquake motion in determining seismic response of piping system and piping support and provide a description of the procedure for combining modal responses (i.e., shears, moments, stresses, deflections, and accelerations), including that for modes with closely-spaced frequencies. Also, indicate the extent to which recommendations of Regulatory Guide 1.92, Revision 2, including those applicable for adequate consideration of high-frequency modes, are followed to combine modal responses.

If any alternative seismic analyses method is used, provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.3.3 ***Response Spectra Method (or Independent Support Motion Method)***

As an alternative to the enveloped response spectra method, independent support motion seismic analyses may be used where there is more than one supporting structure for the piping system. This means that all supports are located on the same floor or portions of the floor of a structure. A support group is defined by supports that have the same time history input. The responses from motions of supports in two or more different groups are combined by the square root sum of the squares method. For this procedure, the criteria for damping values should be consistent with RG 1.61.

C.1.3.12.3.4 *Time History Method*

A time history analyses may be performed using either the modal superposition method or the direct integration method. Describe the seismic analysis method used and include in the description:

(1) manner in which the dynamic system analysis is performed

(2) method chosen for selection of significant modes and an adequate number of masses or degrees of freedom

(3) manner in which consideration is given in the seismic dynamic analysis to maximum relative displacements between supports

(4) other significant effects that are accounted for in the dynamic seismic analysis, such as piping interactions, externally applied structural restraints, hydrodynamic effects (both mass and stiffness effects), types of loading and condition, damping criteria, and nonlinear response

If a static load method is used instead of a dynamic analysis, provide justification that the system can be realistically represented by a simple model and the method produces conservative results.

C.1.3.12.3.5 *Inelastic Analyses Method*

Provide a detailed description of the methodology, the specific system, and the acceptance criteria if inelastic analyses method is to be used for piping design analyses. The acceptance criteria to be used should be consistent with guidelines of SRP Section 3.9.1. Prior to using the inelastic method for analyses, it should be submitted for review and approval.

C.1.3.12.3.6 *Small Bore Piping Method*

The response spectrum method is an acceptable seismic analysis methodology for the analysis of both small and large bore piping. Describe in detail the method used for seismic analyses, including analyses procedure and criteria for small and large bore piping. If an equivalent static load method is proposed, it should be consistent with the recommendations of SRP Section 3.9.2.II.2.a(2)(c). Provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.3.7 *Nonseismic/Seismic Interaction (II/I)*

Provide a description of the location of all piping systems (seismic Category I, seismic Category II, and non-seismic structures), including the distance between various piping systems. Provide the design criteria used to account for seismic motion of non-seismic Category I (Seismic Category II and non-seismic) piping or portions thereof, in the seismic design of Seismic Category I structures or portions thereof. Describe the seismic design of non-seismic Category I piping systems whose continued function is not required, but whose failure could adversely impact the safety function of structures, systems and components. Describe design criteria that will be applied to ensure functionality of Seismic Category I systems despite impacts from failure of non-Category I piping due to seismic effects.

C.1.3.12.3.8 *Seismic Category I Buried Piping*

Describe seismic criteria and methods for considering the effects of earthquakes on buried piping, conduits, tunnels, and auxiliary systems. These criteria should include compliance characteristics of soil media; dynamic pressures; seismic wave passage; and settlement due to earthquake and differential movements at support points, penetrations, and entry points into other structures provided with anchors.

C.1.3.12.4 <u>Piping Modeling Technique</u>

Provide criteria and procedures used for modeling that are applicable to seismic Category I ASME Code and non-Code piping systems. Include criteria and bases used to determine whether the piping system and piping support is being analyzed as part of a system analysis or independently as a subsystem. Provide a description of the types of model (finite element model, lumped-mass stick model, hybrid model, etc.) used for Seismic Category I piping system. Describe and provide verification of all computer programs used for analyses of Seismic Category I piping designated as Code Class 1, 2, and 3 and non-Code items with methods recommended in SRP Section 3.9.1. Describe the computer codes used for the design of the piping systems and supports. Verify that these computer codes are in accordance with those used in the NRC benchmark problems appropriate for these piping analyses methods. References to the NRC benchmark problems are provided in the SRP.

C.1.3.12.4.1 *Computer Codes*

Provide a list of computer programs used in dynamic and static analyses to determine the structural and functional integrity of Seismic Category I Code and non-Code piping system, consistent with C.I.3.9.1.2 of this guide.

C.1.3.12.4.2 *Dynamic Piping Model*

Provide a description of the types of model (finite element, hybrid model, etc.) used for Seismic Category I piping and piping support. Provide criteria and procedures used for modeling in the seismic system analyses. Indicate how the dynamic piping model for the seismic system analyses accounts for the effects of torsion (including eccentric masses), bending, shear, and axial deformations, and effects due to the changes in stiffness values of curved members. Include criteria and bases used to determine whether a piping system is to be analyzed as part of a larger structural system analysis or independently as a subsystem.

C.1.3.12.4.3 *Piping Benchmark Program*

Provide a list of computer programs used in dynamic and static analyses to determine the structural and functional integrity of the Seismic Category I piping system design and the non-Code piping system design.

Verify that the computer programs used for the analysis are in accordance with the appropriate NRC benchmark problems for the analyses methods used for design. References to the NRC benchmark problems are provided in the SRP.

Provide the mathematical models for a series of selected piping systems and the associated analyses using the computer programs identified above. Compare the results of the analyses of each model to modal frequencies, maximum pipe moments, maximum support loads, maximum equipment nozzle loads, and maximum deflections. For values obtained using the computer program, provide justification for any deviations from values obtained using the approved dynamic analyses method.

C.1.3.12.4.4 *Decoupling Criteria*

Provide the criteria used to decouple smaller piping systems from larger piping systems. When piping is supported by larger piping, either use a coupled dynamic model of the supported piping and supporting piping, or use the amplified response spectra at the connection point to the supporting piping, with a decoupled model of the supported piping.

C.1.3.12.5 <u>Piping Stress Analysis Criteria</u>

C.1.3.12.5.1 *Seismic Input Envelope vs. Site-Specific Spectra*

Provide design ground motion response spectra for the SSE. If the ground response spectra are different from the generic ground response spectra, such as the response criteria provided in Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," provide the procedure and basis to calculate response spectra for each damping ratio to be used.

Describe the procedures, basis, and justification for developing floor response spectra as specified in Regulatory Guide 1.122, "Development of Floor Design Response Spectra." If a single artificial time history analysis method is used to develop floor response spectra, demonstrate that (1) provisions of Regulatory Guide 1.122, including peak broadening requirements, apply, and (2) the response spectra of the artificial time history to be employed in the free field envelops the free-field design response spectra for all damping values actually used in the response spectra. If multiple time histories are applied to generate floor response spectra, provide the basis for the methods used to account for uncertainties in parameters.

C.1.3.12.5.2 *Design Transients*

Provide a complete list of transients used in the design and fatigue analysis of all ASME Code Class 1 piping system and support component consistent with C.I.3.9.1.1 of this guide.

C.1.3.12.5.3 *Loadings and Load Combination*

Provide the design and service loading combinations for piping system and pipe support, consistent with C.I.3.9.3.1 of this guide.

C.1.3.12.5.4 *Damping Values*

Provide the specific percentage of critical damping values used for seismic Category I piping system and piping support (e.g., damping values for the type of construction or fabrication). Also, compare the damping values assigned to piping system and piping support with the acceptable damping values provided in Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants." Provide the basis for any proposed damping values that differ from those recommended in Regulatory Guide 1.61 and the rationale for the proposed variation.

C.1.3.12.5.5 *Combination of Modal Responses*

When the response spectrum analysis method is used to evaluate seismic response of piping system and piping support, provide a description of the procedure for combining modal responses (i.e., shears, moments, stresses, deflections, and accelerations), including that for modes with closely-spaced frequencies. Also, indicate the extent to which recommendations of Regulatory Guide 1.92, Revision 2, including those applicable for adequate consideration of high-frequency modes, are followed to combine modal responses.

C.1.3.12.5.6 *High-Frequency Modes*

Describe the method used to account for selection of high frequency modes in seismic response spectrum analysis of the piping system and piping support. The method proposed should be consistent with recommendation described in Appendix A of SRP Section 3.7.2. If any other method is proposed in lieu of these methods, provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.5.7 *Fatigue Evaluation for ASME Code Class 1 Piping*

Describe the method used to account for effects of the environment on the fatigue design of the piping system.

C.1.3.12.5.8 *Fatigue Evaluation of ASME Code Class 2 and 3 Piping*

Describe the method used to account for effects of the environment on the fatigue design of the class 2 and 3 piping system and associated support.

C.1.3.12.5.9 *Thermal Oscillations in Piping Connected to the Reactor Coolant System*

Describe the piping stress analyses methodology developed for the design of the piping system connected to the Reactor Coolant System (RCS) for identification and evaluation of piping systems susceptible to thermal stresses from unanalyzed temperature oscillation. Describe a program to ensure continued integrity of the piping system consistent with NRC Bulletin Letter (BL) 88-08. If an alternative method is proposed in lieu of these methods to ensure the integrity of the piping system, provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.5.10 *Thermal Stratification*

Evaluate and describe the method for the piping design to compensate for the effects identified in BL 79-13 and BL 88-11 of thermal stratification and cycling. Describe a program that will ensure continued integrity of the piping system to compensate for thermal stratification as per BL 79-13 and/or BL 88-11. If any other method is proposed in lieu of these methods, provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.5.11 *Safety Relief Valve Design, Installation, and Testing*

Describe the design and installation criteria applicable to the piping system and piping support when connected to pressure-relief devices (i.e., safety and relief valves) for overpressure protection of ASME Class 1, 2, and 3 components meeting the criteria specified in C.I.3.9.3.2 of this guide.

C.1.3.12.5.12 **Functional Capability**

Identify and describe the design of all ASME Code class 1, 2, and 3 piping systems whose functionality is essential for safe shutdown for all Service Level D loading conditions. The design should be consistent with recommendations in NUREG-1367, "Functional Capability of Piping Systems," and GDC 2.

C.1.3.12.5.13 ***Combination of Inertial and Seismic Anchor Motion Effects***

If piping is supported at multiple locations within a single structure or is attached to two separate structures, describe the methods and analyses of the piping system relative to building movements at supports and anchors (seismic anchor motion), as well as, with respect to the effects of seismic inertial loads. Evaluate the effects of relative displacements at support points by imposing the maximum support displacements in the most unfavorable combination consistent with SRP Section 3.9.2.

C.1.3.12.5.14 ***Operating Basis Earthquake as a Design Load***

Appendix S to 10 CFR Part 50, "Earthquake Engineering Criteria for Nuclear Power Plants," allows the use of single-earthquake design by providing an option to use an OBE value of one-third the maximum vibratory ground acceleration of the SSE, and to eliminate the requirement to perform explicit response analyses for the OBE.

For applications that use this option, provide an evaluation to determine the effects of displacement-limited seismic anchor motions (SAM) on ASME Code components and supports to ensure their functionality during and following an SSE. For piping systems, the effects of SAM due to an SSE should be combined with the effects of other normal operational loadings that might occur concurrently. The condition for such criteria was stated in NUREG-1503, " Final SER Related to Certification of the Advanced BWR Design."

C.1.3.12.5.15 ***Welded Attachments***

Describe and explain the design of support members, connections, or attachments welded to piping. These should be designed such that their failure under unanticipated loads does not cause failure in the pipe pressure boundary. Any Code Cases used as the basis for design of welded attachments should be consistent with Regulatory Guide 1.84.

C.1.3.12.5.16 ***Modal Damping for Composite Structures***

Describe the procedure used to determine the composite modal damping value for the piping system. Composite modal damping for coupled building and piping systems may be used for piping systems that are coupled to concrete building structures.

Composite modal damping may also be used for piping systems that are coupled to flexible equipment or flexible valves. The composite modal damping approach should be consistent with the acceptance criteria given in Section 3.7.2 of the SRP.

C.1.3.12.5.17 ***Minimum Temperature for Thermal Analyses***

Provide the thermal expansion analyses criteria for the piping design to evaluate the stresses and loadings above the stress-free reference temperature.

C.1.3.12.5.18 ***Inter-System Loss-of-Coolant Accident***

Describe and evaluate the various design features of the low-pressure piping systems that interface with the Reactor Coolant Pressure Boundary (RCPB). The design of the low-pressure piping systems should be such that it can withstand full RCS pressure without compromising its functionality.

C.1.3.12.5.19 ***Effects of environment on Fatigue Design***

Describe the method and procedures used to account for the effects of the environment on the fatigue design of piping system and associated support connected to RCPB components. The method proposed should be consistent with recommendation of the draft Regulatory Guide DG-1143.

C.1.3.12.6 **<u>Piping Support Design Criteria</u>**

Describe the method used in the design of ASME Code Class 1, 2, and 3 pipe supports.

C.1.3.12.6.1 ***Applicable Codes***

Provide design codes, standards, specifications, regulations, general design criteria, regulatory guides, and other industry standards that are used in the design or that will be used in the fabrication, construction, testing, and inservice inspection of the piping support. Identify the specific edition, date, or addenda of each document. The design of piping supports should be in accordance with ASME Code, Section III, Class 1, 2, and 3, Subsection NF and Appendix F.

C.1.3.12.6.2 ***Jurisdictional Boundaries***

Describe the jurisdictional boundaries between pipe supports and interface attachment points. The jurisdictional boundaries should be in accordance with Subsection NF of Section III of the ASME Code.

C.1.3.12.6.3 ***Loads and Load Combinations***

Provide loads, loading combinations (including system operating transients), and stress criteria for piping supports, including margins of safety. The stress limits for pipe supports design should meet the criteria of ASME Code Section III Subsection NF.

C.1.3.12.6.4 ***Pipe Support Baseplate and Anchor Bolt Design***

Describe the design of pipe support baseplate and anchor bolt. The design of the pipe support baseplate and anchor bolt should be consistent with NRC BL 79-02, Revision 2. If any other design is used, provide the basis for its conservatism and equivalence in safety to the applicable regulatory position.

C.1.3.12.6.5 ***Use of Energy Absorbers and Limit Stops***

Provide the design and analyses of the special engineered supports (rigid gapped supports) used in the piping system. The recommended analyses consist of an iterative response spectra analysis of the piping and support system. The iterations establish calculated piping displacements that are compatible with the stiffness and gap of the rigid gapped supports.

C.1.3.12.6.6 ***Use of Snubbers***

If use of hydraulic snubbers is proposed for piping support, the design and analyses should be consistent with C.I.3.9.3.2 of this guide.

C.1.3.12.6.7 ***Pipe Support Stiffnesses***

Discuss and describe pipe support stiffness values and support deflection limits used in the piping analyses and support designs.

C.1.3.12.6.8 ***Seismic Self-Weight Excitation***

Describe the design and analyses with consideration of the service loading combination resulting from postulated events and the designation of appropriate service limits for pipe support seismic loads.

C.1.3.12.6.9 ***Design of Supplementary Steel***

Describe the design and analysis of structural steel used as pipe supports. The design of pipe support from structural steel should be in accordance with Subsection NF of Section III of the ASME Code.

C.1.3.12.6.10 ***Consideration of Friction Forces***

For sliding type of supports, describe and analyze the friction loads induced by the pipe on the support.

C.1.3.12.6.11 ***Pipe Support Gaps and Clearances***

Provide information on pipe support gaps and clearances to be used between the pipe and the frame type of support.

C.1.3.12.6.12 ***Instrumentation Line Support Criteria***

Provide the design criteria for instrumentation line supports. The design loads and load combination for safety related instrumentation supports are similar to those for pipe supports. The design for instrumentation line support should be in accordance with criteria described in ASME Code Section III Subsection NF.

C.1.3.12.6.13 ***Pipe Deflection Limits***

Provide and describe the pipe deflection limits for standard component pipe supports. The standard component pipe support movement should remain within manufacturer's recommended design limits. This criterion applies to limit stops, snubbers, rods, hangers, and sway struts.

C.I.3.13 *Threaded Fasteners (ASME Code Class 1, 2, and 3)*

Provide the criteria used to select materials to fabricate threaded fasteners (e.g., threaded bolts, studs, etc) in ASME Code Class 1, 2, or 3 systems. Also provide criteria to fabricate, design, test, and inspect the threaded fasteners in these systems, both prior to initial service and during service.

C.I.3.13.1 Design Considerations

C.I.3.13.1.1 *Materials Selection*

Provide information pertaining to the selection of materials and material testing of threaded fasteners. Indicate the level of conformance with applicable codes or standards. For threaded fasteners made from ferritic steels (i.e., low alloy steel or carbon grades), discuss the material testing used to establish the fracture toughness of the materials.

C.I.3.13.1.2 *Special Materials Fabrication Processes and Special Controls*

Provide information pertaining to the fabrication of threaded fasteners. Identify particular fabrication practices or special processes used to mitigate the occurrence of stress corrosion cracking or other forms of material degradation in the fasteners during service. Discuss any environmental considerations that were accounted for in selecting materials used to fabricate threaded fasteners. Discuss the use of lubricants and/or surface treatments in mechanical connections that are secured by threaded fasteners.

C.I.3.13.1.3 *Fracture Toughness Requirements for Threaded Fasteners Made of Ferritic Materials*

For threaded fasteners in ASME Code Class 1 systems that are fabricated from ferritic steels, discuss the fracture toughness tests performed on the threaded fasteners and demonstrate compliance with applicable acceptance criteria set forth in Appendix G to 10 CFR Part 50.

C.I.3.13.1.4 *[Reserved]*

C.I.3.13.1.5 *Certified Material Test Reports*

Summarize the material fabrication results and material property test results in the certified material test reports (CMTRs), pursuant to Section III of the ASME Boiler and Pressure Vessel Code, Division 1.

C.I.3.13.2 Inservice Inspection Requirements

Demonstrate compliance with the inservice inspection requirements of 10 CFR 50.55a and Section XI of the ASME Boiler and Pressure Vessel Code, Division 1.

If the pre-service inspections, fracture toughness testing, or CMTRs have not been completed at the time the COL application is filed, describe the implementation program, including milestones.