**NRC RAI 3.12-1**

*DCD Tier 2, Table 1.9-22, identifies that the 2004 edition of the ASME Code, Section III, is applicable to the ESBWR piping design. Explain how the requirements of 10 CFR 50.55a(b) will be satisfied.*

**GE Revised Response**

DCD Tier 2, Table 1.9-22 will be revised to identify the 2001 edition of the ASME Code, including Addenda through 2003, as being applicable to the ESBWR design for Subsections NB, NC, ND, NF and NG. This change makes the DCD basis consistent with 10 CFR 50.55a(b) and the basis for Regulatory Guide 1.84, Revision 33, and Regulatory Guide 1.147, Revision 14, which discuss the applicability of specific ASME Codes cases.

~~Changes will not be made to DCD Tier 2 Tables 3.8-6 and 3.8-9, nor Table 1.9-22 for ASME BPVC Section III NCA, CC and NE code subsections. Refer to RAI 3.8-5 resolution that provides required ASME BPVC code reconciliation to the current ASME BPVC Section III 2004 NCA, CC and NE code subsections. Per RAI 3.8-45, Table 3.8-6, reference 14, ASME 2004 CC code has been deleted since CC is not applicable to Seismic Category I internal structures.~~

**DCD/LTR Impact**

DCD Tier #2 Table 1.9-22 will be revised as noted in the attached markup.

## Table 1.9-22

## Industrial Codes and Standards[2] Applicable to ESBWR

| Code or Standard Number | Year | Title |
|---|---|---|
| NQA-1-1983 | 1983 | Quality Assurance Program Requirements for Nuclear Facilities(Note: more recent versions exist) |
| NQA-1a-1983 | 1983 | Addenda to ANSI/ASME NQA-1-1983 Edition, Quality Assurance Requirements for Nuclear Facility Applications<br>(Note: more recent versions exist) |
| NQA-2-1983 | 1983 | Quality Assurance Requirements for Nuclear Facility Applications (Note: more recent versions exist) |
| PTC 6-1996 | 1996 | Steam Turbines |
| PTC 6A-2000 | 2000 | Appendix A to PT6, the Test Code for Steam Turbines |
| PTC 8.2-1990 | 1990 | Centrifugal Pumps |
| PTC 17-1973 | 1973 (R 2003) | Reciprocating Internal-Combustion Engines |
| PTC 23-2003 | 2003 | Atmospheric Water Cooling Equipment |
| PTC 25-2001 | 2001 | Pressure Relief Devices |
| PTC 26-1962 | 1962 | Speed Governing Systems for Internal Combustion Engine Generator Units |
| RA-S-2002 | 2002 | Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications |
| TDP-1-1998 | 1998 | Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation (Fossil) |
| TDP-2-1985 | 1985 | Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation (Nuclear) |
| BPVC Sec I | 2001 including Addenda through 2003 | Boiler & Pressure Vessel Code (BPVC) Section I, Rules for Construction of Power Boilers |
| BPVC Sec II | 2001 including Addenda through 2003 | BPVC Section II, Materials<br>Part A Ferrous Material Specifications<br>Part B Non-Ferrous Material Specifications<br>Part C Specifications for Welding Rods, Electrodes, and Filler Metals<br>Part D Properties |
| BPVC Sec III | 2004 | BPVC Section III, Rules for Construction of Nuclear Facility Components<br><br>Division 1: NCA, NE<br>Division 2: CC, NCA<br>Code for Concrete Containments |
| BPVC Sec III | 2001 including Addenda through 2003 | BPVC Section III, Rules for Construction of Nuclear Facility Components<br><br>Division 1: NB, NC, ND, NF, NG<br>Note: All limitations and modifications specified in 10 CFR 50.55a(b)(1) are required to be met |

**NRC RAI 3.12-2**

(a) *DCD Tier 2, Table 5.2-1, Sections 3.7 and 3.9 include the following ASME Code Cases which have been annulled by the ASME as noted in the current Regulatory Guides (RGs) 1.84 and 1.147: N-247, N-411-1, N-420, N-463-1, N-476, N-479-1 and N-608. Discuss what alternatives are being considered to address the issues contained in these Code Cases.*

(b) *The staff approved, in RG 1.84, Code Cases N-71-18, N-122-2, and N-416-3 that are the revised versions of these Code Cases referenced in the DCD. Describe the changes in these revised Code Cases that may impact the design criteria presented in the DCD and how they were addressed.*

(c) *The staff's acceptance status of several Code Cases in DCD Tier 2, Table 5.2-1, have been changed. (i) The DCD indicates that Code Cases N-318-5 and N-416-2 were conditionally accepted, but they are now unconditionally endorsed by the staff. Note that Code Case N-416-3, not its previous revision, has been currently endorsed by the staff. (ii) The DCD also indicates that Code Case N-491-2 was not listed in RG 1.147, but it is now endorsed by the staff. Since the acceptance status of these Code Cases given in the DCD has been changed, address the changes in the applicability of these Code Cases in the DCD for ESBWR piping design.*

**GE Revised Response**

(a) Evaluation of the applicable code cases cited in RAI 3.12-2(a) are provided below.

(a1) N-247 "Certified Design Report Summary for Component Standard Support": The design report will be furnished according to ASME Code NCA-3551.1. This code case will be deleted. DCD Tier #2 Table 5.2-1 will be revised as noted in the attached markup.

(a2) N-411-1: "Alternative Damping Values for Response Spectra Analysis of Class 1, 2, and 3 Piping": This code case will be deleted. DCD Tier #2 section 3.7.1.2, 3.7.3.5 and Table 3.7-1 footnote will be revised as noted in the attached markup. Please refer to the response for NRC RAI 3.12-19.

(a3) N-420 "Linear Energy Absorbing Support for Subsection NF, Class 1, 2 and 3 Construction Section III, Division1": ESBWR does not use "Linear Energy Absorbing Support". This code case will be deleted. DCD Tier #2 section 3.7.1.2 and 3.9.3.7.1(6) will be revised as noted in the attached markup.

(a4) N463-1 "Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514-2": This code case is not applicable to ESBWR design at this time. In the future when ESBWR is in operation, the flaw evaluation should be calculated in accordance with Section XI of ASME Code. This code case will be deleted. DCD Tier #2 Table 5.2-1 will be revised as noted in the attached markup.

(a5) N-476: "Class 1, 2, 3 and MC Linear Component Supports – Design Criteria for Single Angle Members": This code case will be deleted. DCD Tier #2 section 3.9.3.7.1 footnote, section 3.9.3.7.2. footnote and 3.9.3.8 footnote will be revised as noted in the attached markup.

(a6) N-479-1 "Boiling Water Reactor (BWR) Main Steam Hydrostatic Test":
This code case is the inquiry: "For the main steam system in a BWR in which the boundary valve between the Class 2 portion and the Class 1 portion is not capable of isolating the Class 1 portion from Class 2 portion during hydrostatic test of the Class 2 portion, what rule may be used as an alternative to the requirements of Section XI, Division 1, IWC-5222 ?"
The hydrostatic test for Class 1 is defined in NB-6000. The minimum hydrostatic pressure is 1.25 of the design pressure specified in NB6221. Similar requirement is defined in NC-6000 for Class 2 piping. The minimum hydrostatic pressure is 1.25 of the design pressure. There are two main steam isolation valves isolate the Class 1 and Class 2 piping. Since this code case is deleted from the RG, The ESBWR hydrostatic test will comply to the ASME Code requirements.
This code case will be deleted. DCD Tier #2 Table 5.2-1 will be revised as noted in the attached markup.

(a7) N-608- Applicable Code Edition and Addenda, NCA-1140(a)(2), Section III, Division 1: The applicable Code edition is clearly specified *DCD Tier 2, Table 1.9-22.* This code case will be deleted. DCD Tier #2 Table 5.2-1 will be revised as noted in the attached markup.

(b) Evaluation of the changes in these revised Code Cases that may impact the design criteria presented in the DCD and how they were addressed are provided below:

(b1) Code Case N-71-18 is for "Additional Material for Subsection NF, Class 1, 2, 3 and MC Supports Fabricated by Welding Section III, Division I". This code case will be deleted from Table 5.2-1.~~Since there is no additional material used in the ESBWR design, this Code Case does not impact the design criteria presented in the DCD.~~

(b2) Code Case N-122-2 provides the Procedure for the Design of Rectangular Cross Section Attachment on Class 1 Piping. The revised Code Case reduced the stress indices of $C_T$, $C_L$ and $C_N$ by 50% as compared to the previous version. The design results using the previous Code Case are conservative for lug attachment analysis. Therefore, this Code Case does not impact the design criteria presented in the DCD. DCD Tier #2 Table 5.2-1 will be updated to show Code Case N-122-2 as the applicable revision. At the end of DCD Tier #2, subsection 3.9.3.4, the following statement will be added:
" If Code Case N-122-2 is used for analysis of a class 1 pipe, the analysis complying with this Case will be included in the Design Report for the piping system." as noted in the attached markup.

(b3) Code Case N-416-3 provides Alternative Test Requirement for Weld Repair. This code case only pertains to testing after a weld repair, and it does not impact the design criteria presented in the DCD. DCD Tier #2 Table 5.2-1 will be revised as noted in the attached markup to show Code Case N-416-3 as the applicable revision.

(c) DCD Tier 2, Table 5.2-1 will be changed to allow unconditional use of Code Cases N-318-5 and N-416-3 in DCD Revision 2.

**DCD/LTR Impact**

DCD Tier #2 Table 5.2-1, section 3.7.1.2, 3.7.3.5, Table 3.7-1 footnote, 3.9.3.7.1(6), 3.9.3.7.1 footnote, section 3.9.3.7.2. footnote, 3.9.3.8 footnote, 3.9.3.4 will be revised as noted in the attached markup.

## Table 5.2-1
## Reactor Coolant Pressure Boundary Components (Applicable Code Cases)

| Number | Title | Applicable Equipment | Remarks |
|---|---|---|---|
| N-60-5 | Material for Core Support Structures, Section III, Division 1 | Core Support | Accepted per RG 1.84 |
| ~~N-71-17~~ | ~~Additional Materials for Subsection NF, Classes 1, 2, 3 and MC Component Supports Fabricated by Welding, Section III, Division I.~~ | ~~Component Support~~ | ~~Conditionally Accepted per RG 1.84~~ |
| N-122-2 | Stress Indices for Structure Attachments, Class 1, Section III, Division 1. | Piping | Accepted per RG 1.84 |
| | (Deleted) | | |
| N-249-14 | Additional Material for Subsection NF, Classes 1, 2, 3 and MC Component Supports Fabricated Without Welding, Section III, Division 1. | Component Support | Conditionally Accepted per RG 1.84 |
| N-318-5 | Procedure for Evaluation of the Design of Rectangular Cross-Section Attachments on Class 2 or 3 Piping, Section III, Division 1. | Piping | Accepted per RG 1.84 |
| N-319-3 | Alternate Procedure for Evaluation of Stress in Butt Weld Elbows in Class 1 Piping, Section III, Division 1. | Piping | Accepted per RG 1.84 |
| N-391-2 | Procedure for Evaluation of the Design of Hollow Circular Cross-Section Welded Attachments on Class 1 Piping. Section III, Division 1. | Piping | Accepted per RG 1.84 |

NRC RAI 3.12-3 (OPEN ITEM)

*The current staff position for the ISM method of analysis is presented in Volume 4, Section 2 of NUREG-1061, "Report of the USNRC Piping Review Committee." Some differences were noted between the ISM method of response combinations presented in the DCD Tier 2, Section 3.7.3.9, and the method given in NUREG-1061 (e.g., the SRSS method in the DCD and absolute sum method in NUREG-1061 for combining group responses for a given direction). Indicate whether all of the provisions contained in NUREG-1061 for the ISM method of analysis will be followed or provide the technical justification for any alternatives.*

GE Response

NUREG-1503 paragraph 3.9.2.2, page 3-62 provides the guidelines for ISM analysis method.

As an alternative to the enveloped response spectrum method, GE chose to use the multiple-support excitation analysis method. When this method is used, the staff's position is that the response resulting from motions of supports between two or more different support groups may be combined by the SRSS method if a support group is defined by supports that have the same time history input. This usually means all supports located on the same floor or portion of a floor in a structure.

DCD Revision 2 will be revised to incorporate this guideline.

**NRC RAI 3.12-4**

*In a time history analysis, the numerical integration time step, Δt, must be sufficiently small to accurately define the dynamic excitation and to ensure stability and convergence of the solution up to the highest frequency of significance. DCD Tier 2, Section 3.7.2.1.1, indicates that for the most commonly used numerical integration methods, the maximum time step is limited to one-tenth of the shortest period of significance. An acceptable approach for selecting the time step, Δt, is that the Δt used shall be small enough such that the use of ½ of Δt does not change the response by more than 10%. Indicate whether this is part of the analysis requirements or provide a technical justification for not considering this criterion along with the other criterion described above for seismic and hydrodynamic loading analyses.*

**GE Revised Response** (NO CHANGE TO RAI REQUIRED)

The convergence criterion of using ½ Δt to result in no more than a 10% change in response is part of the requirement for time history analysis. DCD Tier 2, Section 3.7.2.1.1 will be updated accordingly.

Hydrodynamic loads are addressed in the RBV dynamic loadings per DCD Tier #2 section 3.7 1st paragraph.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.2.1.1 will be revised as noted in the attached markup.

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = \{P\} \quad (3.7\text{-}1)$$

where,

| | | |
|---|---|---|
| $[M]$ | = | mass matrix |
| $[C]$ | = | damping matrix |
| $[K]$ | = | stiffness matrix |
| $\{u\}$ | = | column vector of time-dependent relative displacements |
| $\{\dot{u}\}$ | = | column vector of time-dependent relative velocities |
| $\{\ddot{u}\}$ | = | column vector of time-dependent relative accelerations |
| $\{P\}$ | = | column vector of time-dependent applied forces |
| | = | $-[M]\{\ddot{x}_g\}$ for support excitation in which $\{\ddot{x}_g\}$ is column vector of time-dependent support accelerations |

The above equation can be solved by modal superposition or direct integration in the time domain, or by the complex frequency response method in the frequency domain. For the time domain solution, the numerical integration time step is sufficiently small to accurately define the dynamic excitation and to render stability and convergency of the solution up to the highest frequency (or shortest period) of significance. ~~An alternative~~ The approach for selecting the time step, Δt, is that the Δt used shall be small enough such that the use of ½ of Δt does not change the response by more than 10%. For most of commonly used numerical integration methods (such as Newmark β-method and Wilson θ-method), the maximum time step is limited to one-tenth of the shortest period of significance. For the frequency domain solution, the dynamic excitation time history is digitized with time steps no larger than the inverse of two times the highest frequency of significance and the frequency interval is selected to accurately define the transfer functions at structural frequencies within the range of significance.

The modal superposition method is used when the equation of motion (Equation 3.7-1) can be decoupled using the transformation,

$$\{u\} = [\phi]\{q\} \quad (3.7\text{-}2)$$

where,

| | | |
|---|---|---|
| $[\phi]$ | = | mode shape matrix; often mass normalized, i.e., $[\phi]^T[M][\phi] = [1]$ |
| $\{q\}$ | = | column vector of normal or generalized coordinates |

Substituting Equation 3.7-2 into Equation 3.7-1 and multiplying each term by the transposition of the mode shape matrix results in the uncoupled equation of motion due to the orthogonality of

**NRC RAI 3.12-6**

*When developing seismic floor response spectra for use in a response spectrum analysis for piping and equipment analysis, the peaks of the spectra obtained from a time history analysis are generally broadened by plus and minus 15% to account for modeling uncertainties. When performing a time history analysis of piping and equipment for seismic and hydrodynamic loads, describe how the uncertainties in the material properties of the structure/soil and in the modeling techniques used in the analysis to develop the loading are accounted for in the time history analysis. Indicate whether the digitized time history is adjusted to account for the material/modeling uncertainties. Describe all of the dynamic loads for which the time history will be adjusted to account for modeling uncertainties and provide the basis for the amount of the adjustment. Also, indicate how the hydrodynamic building spectra are broadened to account for the modeling uncertainties.*

**GE Response**

When the calculated floor acceleration time history is used in the time history analysis of piping and equipment, the uncertainties in the time history are accounted for by expanding and shrinking the time history within $1/(1\pm0.15)$ so as to change the frequency content of the time history within ±15%. Alternatively, a synthetic time history that is compatible with the broadened floor response spectra may be used. The methods of peak broadening are applicable to seismic and other building dynamic loads.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.2.9 will be revised as noted in the attached markup.

**Step 3** — Higher modes can be assumed to respond in phase with the ZPA and, thus, with each other; hence, these modes are combined algebraically, which is equivalent to pseudo-static response to the inertial forces from these higher modes excited at the ZPA. The pseudo-static inertial forces associated with the summation of all higher modes for each DOFi are given by:

$$P_i = ZPA \times M_i \times e_i \qquad (3.7\text{-}13)$$

where $P_i$ is the force or moment to be applied at DOFi, and $M_i$ is the mass or mass moment of inertia associated with DOFi. The system is then statically analyzed for this set of pseudo-static inertial forces applied to all of the degrees of freedom to determine the maximum responses associated with high-frequency modes not included in Step 1.

**Step 4** — The total combined response to high-frequency modes (Step 3) is combined by the SRSS method with the total combined response from lower-frequency modes (Step 1) to determine the overall peak responses.

This procedure requires the computation of individual modal responses only for lower-frequency modes (below the ZPA). Thus, the more difficult higher-frequency modes need not be determined. The procedure ensures inclusion of all modes of the structural model and proper representation of DOF masses.

In lieu of the above procedure, an alternative method is as follows. Modal responses are computed for enough modes to ensure that the inclusion of additional modes does not increase the total response by more than 10%. Modes that have natural frequencies less than that at which the spectral acceleration approximately returns to the ZPA are combined in accordance with Regulatory Guide 1.92. Higher-mode responses are combined algebraically (i.e., retain sign) with each other. The absolute value of the combined higher modes is then added directly to the total response from the combined lower modes.

The methods of combining modal responses described above meet the requirements in Regulatory Guide 1.92~~ Revision 1 and Appendix A to SRP 3.7.2. These methods remain acceptable by Draft Regulatory Guide DG-1127 for proposed revision 2 of Regulatory Guide 1.92~~.

### *3.7.2.8 Interaction of Non-Category I Structures with Seismic Category I Structures*

### *3.7.2.9 Effects of Parameter Variations on Floor Response Spectra [RAI 3.12-6, 3.12-10]*

Floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak broadened to account for uncertainties in the structural frequencies owing to uncertainties in the material properties of the structure and soil and to approximations in the modeling techniques used in the analysis. If no parametric variation studies are performed, the spectral peaks associated with each of the structural frequencies are broadened by ±15%. If a detailed parametric variation study is made, the minimum peak broadening ratio is ±10%. ~~In lieu of peak broadening, the peak shifting~~

Deleted in DCD Rev 2

method of Appendix N of ASME Section III, as permitted by Regulatory Guide 1.84, can be used.

When calculated floor acceleration time history is used in the time history analysis for piping and equipment, the uncertainties in the time history are accounted for by expanding and shrinking the time history within 1/(1±0.15) so as to change the frequency content of the time history within ±15%. Alternatively, a synthetic time history that is compatible with the broadened floor spectra may be used.

The methods of peak broadening described above are applicable to seismic and other building dynamic loads.

## 3.7.3 Seismic Subsystem Analysis [RAI 3.12-10]

This section applies to Seismic Category I (C-I) and Seismic Category II (C-II) subsystems (equipment and piping) that are qualified to satisfy the performance requirements according to their C-I or C-II designation. Input motions for the qualification are usually in the form of floor response spectra and displacements obtained from the primary system dynamic analysis. Input motions in terms of acceleration time histories are used when needed. Dynamic qualification can be performed by analysis, testing, or a combination of both, or by the use of experience data. This section addresses the aspects related to analysis only. For ASME components, the guidelines in Appendix N and ASME Section III are applicable.

### *3.7.3.1 Seismic Analysis Methods [RAI 3.12-20]*

The methods of analysis described in Subsection 3.7.2.1 are equally applicable to equipment and piping systems. Among the various dynamic analysis methods, the response spectrum method is used most often. For multi-supported systems analyzed by the response spectrum method, the input motions can be either the envelope spectrum with Uniform Support Motion (USM) of all support points or the Independent Support Motion (ISM) at each support. Additional considerations associated with the ISM response spectrum method of analysis are given in Subsection 3.7.3.9. For equipment analysis, refer to the requirements of Step 1 of section 3.7.2.7 for ZPA cut-off frequency determination.

### *3.7.3.2 Determination of Number of Earthquake Cycles*

### *3.7.3.3 Procedures Used for Analytical Modeling*

#### 3.7.3.3.1 Piping Systems [RAIs 3.12-12, 3.12-32, 3.12-33]

Mathematical models for Seismic Category 1 piping systems are constructed to reflect the dynamic characteristics of the system. The continuous system is modeled as an assemblage of pipe elements (straight sections, elbows, and bends) supported by hangers and anchors, and restrained by pipe guides, struts and snubbers. Pipe and hydrodynamic fluid masses are lumped at the nodes and connected by zero-mass elastic elements, which reflect the physical properties of the corresponding piping segment. The mass node points are selected to coincide with the locations of large masses, such as valves, pumps, and motors, and with locations of significant geometry change. All concentrated weights

(3) The non-Category I structures, systems or components are analyzed and designed to prevent their failure under SSE conditions in a manner such that the margin of safety of these structures, systems or components is equivalent to that of Seismic Category I structures, systems or components. SSCs in this category are classified as C-II.

### *3.7.2.9 Effects of Parameter Variations on Floor Response Spectra*

Floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak broadened by ±15% to account for uncertainties in the structural frequencies owing to uncertainties in the material properties of the structure and soil and to approximations in the modeling techniques used in the analysis. When the calculated floor acceleration time history is used in the time history analysis for piping and equipment, the uncertainties in the time history are accounted for by expanding and shrinking the time history within 1/(1±0.15) so as to change the frequency content of the time history within ±15%. Alternatively, a synthetic time history that is compatible with the broadened floor response spectra may be used.

The methods of peak broadening described above are applicable to seismic and other building dynamic loads.

### *3.7.2.10 Use of Equivalent Vertical Static Factors*

Equivalent vertical static factors are used when the requirements for the static coefficient method in Subsection 3.7.2.1.3 are satisfied. All Seismic Category I structures are dynamically analyzed in the vertical direction. No constant static factors are utilized.

### *3.7.2.11 Methods Used to Account for Torsional Effects*

One method of treating the torsional effects in the dynamic analysis is to carry out a dynamic analysis that incorporates the torsional degrees of freedom. For structures having negligible coupling of lateral and torsional motions, a two-dimensional model without the torsional degrees of freedom can be used for the dynamic analysis and the torsional effects are accounted for in the following manner. The locations of the center of mass are calculated for each floor. The center of rigidity and torsional stiffness are determined for each story. Torsional effects are introduced in each story by applying a torsional moment about its center of rigidity. The torsional moment is calculated as the sum of the products of the inertial force applied at the center of mass of each floor above, and a moment arm equal to the distance from the center of mass of the floor to the center of rigidity of the story, plus 5% of the maximum building dimension at the level under consideration. To be conservative, the absolute values of the moments are used in the sum. The torsional moment and story shear are distributed to the resisting structural elements in proportion to each individual stiffness.

The seismic analysis for primary building structure is performed using a three-dimensional model including the torsional degrees of freedom.

### *3.7.2.12 Comparison of Responses*

Since only the time history method is used for the dynamic analysis of Seismic Category I structures, a comparison of responses with the response spectrum method is not necessary.

**NRC RAI 3.12-10**

*DCD Tier 2, Section 3.7.3, refers to the guidelines in Appendix N of the ASME Code, as being applicable to design/analysis of ESBWR subsystems. The NRC staff has not explicitly endorsed Appendix N in its entirety. Identify all Appendix N guidance used in the ESBWR piping design/analysis that differs from the guidance provided in the current SRPs and RGs. If any differences exist and are used in the ESBWR piping design/analysis, then provide technical justification for using the Appendix N guidance.*

**GE Revised Response**

For ESBWR analyses, the NRC SRPs and RGs are the first priority to use. Reference to Appendix N will be deleted from DCD Tier 2, Section 3.7.3 and Section 3.7.2.9.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.3 and 3.7.2.9 will be revised as noted in the attached markup.

NRC RAI 3.12-11 (OPEN ITEM)

*DCD Tier 2, Appendix 3D, provides a description of the major computer programs used in the analysis and design of safety related components, equipment, and structures. According to this appendix, the quality of these programs and computer results is controlled. The programs are verified for their application by appropriate methods, such as hand calculations, or comparison with results from similar programs, experimental tests, or published literature, including analytical results or numerical results to the benchmark problems. To facilitate the staff review of the computer programs used in the ESBWR design, provide the following additional information:*

*(a) Identify which computer programs will be used during the design certification phase and which programs may be used in the future during the COL application phase.*

*(b) Identify which programs have already been reviewed by the NRC on prior plant license applications. Include the program name, version, and prior plant license application. As stated in SRP 3.9.1, this will eliminate the need for the licensee to resubmit, in a subsequent license application, the computer solutions to the test problems used for verification.*

*(c) Confirm that the following information is available for staff review for each program: the author, source, dated version, and facility; a description, and the extent and limitation of the program application; and the computer solutions to the test problems described above.*

GE Response

(a) The programs used in the certification phase are:

PISYS07 It is a computer code for analyzing piping systems subjected to both static and dynamic piping loads.

ANSI713 The program is for calculating stresses and cumulative usage factors for Class 1, 2 and 3 piping components in accordance with articles NB, NC and ND-3650 of ASME Code Section III. ANSI7 is also used to combine loads and calculate combined service levels A, B, C and D load on piping supports and pipe-mounted equipment.

All of the programs in Appendix 3D.4 may also be used in the future during the COL application phase.

(b) PISYS05 has been benchmarked against NRC piping models. The results are documented in GE report NEDO 24210, dated August 1979 (Reference 3D 1 of

Appendix 3D), for mode shapes and uniform support motion response spectrum analysis (USMA) options. The independent support motion response spectrum analysis (ISMA) option has been validated against NUREG/CR 1677.

The PISYS05 computer program has been reviewed by NRC, and the results are benchmarked with NUREG/CR-6049. PISYS07 USMA and ISMA analyses are the same as PISYS05. It has been benchmarked with NUREG/CR-6049.

(c) The computer programs listed in Appendix 3D are available for staff review. These programs are Level 2 programs. The author, source, dated version, and facility; a description, and the extent and limitation of the program application; and the computer solutions to the test problems are contained in the design record file of each program.

DCD change

The PISYS program has been benchmarked against NRC piping models. The results are documented in Reference 3D-1 for mode shapes and USMA options. The ISMA option has been validated against NUREG/CR-1677 (Reference 3D-2).

Subsequently, the PISYS07 program, which is used for ESBWR piping analysis, has been benchmarked against NUREG/CR-6049. ~~If applicable, COL applicants are also required to benchmark piping computer codes against NUREG/CR-6049[DK163].~~

### 3D.4.2 Component Analysis - ANSI7

ANSI7 is a computer code for calculating stresses and cumulative usage factors for Class 1, 2 and 3 piping components in accordance with articles NB, NC and ND-3650 of ASME Code Section III. ANSI7 is also used to combine loads and calculate combined service levels A, B, C and D loads on piping supports and pipe-mounted equipment.

### 3D.4.3 Area Reinforcement - NOZAR

The Nozzle Area Reinforcement (NOZAR) computer program performs an analysis of the required reinforcement area for openings. The calculations performed by NOZAR are in accordance with the rules of ASME Code Section III.

### 3D.4.4 Dynamic Forcing Functions

#### *3D.4.4.1 Relief Valve Discharge Pipe Forces Computer Program - RVFOR*

The relief valve discharge pipe connects the pressure-relief valve to the suppression pool. When the valve is opened, the transient fluid flow causes time-dependent forces to develop on the pipe wall. This computer program computes the transient fluid mechanics and the resultant pipe forces using the method of characteristics.

#### *3D.4.4.2 Turbine Stop Valve Closure - TSFOR*

The TSFOR program computes the time-history forcing function in the main steam piping due to turbine stop valve closure. The program utilizes the method of characteristics to compute fluid momentum and pressure loads at each change in pipe section or direction.

#### *3D.4.4.3 Hydraulic Transients-RELAP5/Mod 3.3*

The RELAP5 computer code is a light water reactor transient analysis code developed for the U.S. Nuclear Regulatory Commission for use in rulemaking, licensing audit calculations, evaluation of operator guidelines, and as a basis for nuclear plant analyses. Specific applications of this capability have included simulations of transients such as loss of feed-water, loss of offsite power, station blackout, and turbine trip. RELAP5 is a highly generic code that, in addition to calculating the behavior of a reactor coolant system during a transient, can be used for simulating a wide variety of hydraulic and thermal transients in both nuclear and non-nuclear systems involving mixtures of steam, water, non-condensables, and solutes.

The RELAP5 hydrodynamic model is a one-dimensional, transient, two-fluid model for flow of a two-phase steam-water mixture that can contain non-condensable components in the steam phase and/or a soluble component in the water phase.

The two-fluid equations of motion (mass, momentum, and energy conservation for each phase) that are used as the basis for the RELAP5 hydrodynamic model are formulated in terms of volume and time-averaged parameters of the flow. Phenomena that depend upon transverse

**NRC RAI 3.12-12**

*DCD Tier 2, Section 3.7.3.3.2, provides criteria to model lumped-masses for equipment in a dynamic analysis. Clarify whether these criteria are also applied to the development of piping system mathematical models. If not, provide the criteria used for piping system mathematical models.*

**GE Response** (NO CHANGE TO RAI REQUIRED)

The lumped-masses for equipment are modeled and included in the mathematical model when the effect on the piping cannot be uncoupled from the piping. For this case, the equivalent equipment properties with the associated lump masses are included in piping models.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.3.3.1 will be revised as noted in the attached markup.

support points or the Independent Support Motion (ISM) at each support. Additional considerations associated with the ISM response spectrum method of analysis are given in Subsection 3.7.3.9. For piping analysis, the ZPA cutoff frequency for modal response analysis of subsystems for seismic and other building dynamic loads is 100 Hz. For equipment analysis, refer to the requirements of Step 1 of Section 3.7.2.7 for ZPA cutoff frequency determination.

### *3.7.3.2 Determination of Number of Earthquake Cycles*

The SSE is the only design earthquake considered for the ESBWR Standard Plant. To account for the cyclic effects of the more frequent occurrences of lesser earthquakes and their aftershocks, the fatigue evaluation for ASME Code Class 1, 2, and 3 components and core support structures takes into consideration two SSE events with 10 peak stress cycles per event for a total of 20 full cycles of the peak SSE stress. This is equivalent to the cyclic load basis of one SSE and five OBE events as currently recommended in the SRP 3.7.3. Alternatively, a number of fractional vibratory cycles equivalent to 20 full SSE vibratory cycles may be used (with an amplitude not less than one-third of the maximum SSE amplitude) when derived in accordance with Appendix D of IEEE-344.

For equipment seismic qualification performed in accordance with IEEE-344 as endorsed by Regulatory Guide 1.100, the equivalent seismic cyclic loads are five 0.5 SSE events followed by one full SSE event. Alternatively, a number of fractional peak cycles equivalent to the maximum peak cycles for five 0.5 SSE events may be used in accordance with Appendix D of IEEE-344 when followed by one full SSE.

### *3.7.3.3 Procedures Used for Analytical Modeling*

The mathematical modeling of equipment and piping is generally developed according to the finite element technique following the basic modeling procedures described in Section 3.7.2.3 for primary systems.

#### 3.7.3.3.1 Piping Systems

Mathematical models for Seismic Category 1 piping systems are constructed to reflect the dynamic characteristics of the system. The continuous system is modeled as an assemblage of pipe elements (straight sections, elbows, and bends) supported by hangers and anchors, and restrained by pipe guides, struts and snubbers. Pipe and hydrodynamic fluid masses are lumped at the nodes and connected by zero-mass elastic elements, which reflect the physical properties of the corresponding piping segment. The mass node points are selected to coincide with the locations of large masses, such as valves, pumps, and motors, and with locations of significant geometry change. All concentrated weights on the piping systems, such as the valves, pumps, and motors, are modeled as lumped mass rigid systems if their fundamental frequencies are greater than the cutoff frequency in Subsection 3.7.2.1.1. ~~Additional criteria regarding lump masses for components are specified in subsection 3.7.3.3.2.~~ On straight runs, mass points are located at spacing no greater than the span which would have a fundamental frequency equal to the cutoff frequency stipulated in Subsection 3.7.2.1.1, when calculated as a simply supported beam with uniformly distributed mass. The torsional effects of valve operators and other equipment with offset center of gravity with respect to the piping center line are included in the analytical model. Furthermore, all pipe guides and snubbers are modeled so as to produce

**NRC RAI 3.12-13**

*DCD Tier 2, Section 3.7.3.3.3, states that if special engineered pipe supports are used, the modeling and analytical methodology shall be in accordance with methodology accepted by the regulatory agency at the time of certification or at the time of application, per discretion of the applicant. Clarify whether the statement means that the modeling and analytical methodology will be determined at the COL application stage and will be submitted for review and approval by the staff. If this is the case, the DCD should be revised accordingly. Otherwise, additional clarification of this statement is needed.*

**GE Revised Response**

~~The use of special engineered pipe supports is not expected, and the need to use it during the detailed design phase is not foreseen. If its use should be essential at any point during the development of detailed engineering, the modeling and analytical methodology will be based on applicable design codes and allowables approved by the NRC. .~~Since the specific modeling and analytical methodology for individual special engineered pipe supports can not be defined at this time, special supports will not be allowed. If it is found that there is a need for special pipe supports in the future, a separate licensing submittal will be provided to the NRC staff for review of the methodology.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.3.3.3 will be revised as noted in the attached markup.

Moving the natural frequencies of the equipment into the higher amplification region of the excitation thereby conservatively increases the equipment response level.

Similarly, in the case of live loads (mobile) and variable support stiffness, the location of the load and the magnitude of the support stiffness are chosen to lower the system natural frequencies. Similar to the above discussion, this ensures conservative dynamic responses because the lowered equipment frequencies tend to be shifted to the higher amplification range of the input motion spectra. If not, the model is adjusted to give more conservative responses.

#### 3.7.3.3.3 Modeling of Special Engineered Pipe Supports

~~Modifications to the normal linear elastic piping analysis methodology used with conventional~~ Special engineered pipe supports ~~are~~ shall not be used. ~~required to calculate the loads acting on the supports and on the piping components when the special engineered supports, described in Subsection 3.9.3.7.1 (6), are used. These modifications are needed to account for greater damping of the energy absorbers and the non-linear behavior of the limit stops. The use of special engineered pipe supports is not expected, and the need to use it during the detailed design phase is not foreseen. If its use should be essential at any point during the development of detailed engineering, the modeling and analytical methodology will be based on applicable design codes and allowables approved by the NRC. In addition, the information required by Regulatory Guide 1.84 shall be provided to the regulatory agency.~~

### *3.7.3.4 Basis for Selection of Frequencies*

Where practical, in order to avoid adverse resonance effects, equipment and components are designed/selected such that their fundamental frequencies are less than half or more than twice the dominant frequencies of the support structure. Moreover, in any case, the equipment is analyzed and/or tested to demonstrate that it is adequately designed for the applicable loads considering both its fundamental frequency and the forcing frequency of the applicable support structure.

### *3.7.3.5 Analysis Procedure for Damping*

Damping values for equipment and piping are shown in Table 3.7-1 and are consistent with Regulatory Guide 1.61. For ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems, alternative damping values specified in Figure 3.7-37 may be used. For systems made of subsystems with different damping properties, the analysis procedures described in Subsection 3.7.2.13 are applicable.

### *3.7.3.6 Three Components of Earthquake Motion*

The applicable methods of spatial combination of responses due to each of the three input motion components are described in Subsection 3.7.2.6.

### *3.7.3.7 Combination of Modal Responses*

The applicable methods of modal response combination are described in Subsection 3.7.2.7.

(OPEN ITEM)

NRC RAI 3.12-14

*DCD Tier 2, Section 3D.4.1 of Appendix 3D, indicates that the PISYS program has been benchmarked against NRC piping models. The results are documented in GE report NEDO-24210, dated August 1979 (Reference 3D-1 of Appendix 3D), for mode shapes and uniform support motion response spectrum analysis (USMA) options. The independent support motion response spectrum analysis (ISMA) option has been validated against NUREG/CR-1677. With regard to the benchmarking of the PISYS program, provide the following information:*

(a) *The version of the PISYS program used for the ESBWR analysis should be benchmarked against NUREG/CR-6049, "Piping Benchmark Problems for the GE ABWR." The piping benchmark problems in NUREG/CR-6049 are more recent and more representative of the current piping systems in the ESBWR. If NUREG/CR□6049 will not be used to benchmark the piping computer code used by COL applicants, then provide an explanation.*

(b) *Indicate where the requirement for the COL applicant to benchmark the use of any piping analysis program(s) in accordance with the current DCD validation methods is located.*

GE Response

(a) Appendix 3D paragraph 3D.4.1 last paragraph will add the following in DCD Revision 2:

"Subsequently, the PISYS07 program, which is used for ESBWR piping analysis, has been benchmarked against NUREG/CR-6049. ~~If applicable, COL applicants are also required to benchmark piping computer codes against NUREG/CR-6049.~~

(b) Appendix 3D paragraph 3D.4.1 last paragraph will be modified in DCD Revision 2 as shown in the (a) response.

The PISYS program has been benchmarked against NRC piping models. The results are documented in Reference 3D-1 for mode shapes and USMA options. The ISMA option has been validated against NUREG/CR-1677 (Reference 3D-2).

Subsequently, the PISYS07 program, which is used for ESBWR piping analysis, has been benchmarked against NUREG/CR-6049. ~~If applicable, COL applicants are also required to benchmark piping computer codes against NUREG/CR-6049~~[DK163].

### 3D.4.2 Component Analysis - ANSI7

ANSI7 is a computer code for calculating stresses and cumulative usage factors for Class 1, 2 and 3 piping components in accordance with articles NB, NC and ND-3650 of ASME Code Section III. ANSI7 is also used to combine loads and calculate combined service levels A, B, C and D loads on piping supports and pipe-mounted equipment.

### ~~3D.4.3 Area Reinforcement - NOZAR~~

~~The Nozzle Area Reinforcement (NOZAR) computer program performs an analysis of the required reinforcement area for openings. The calculations performed by NOZAR are in accordance with the rules of ASME Code Section III~~.

### 3D.4.4 Dynamic Forcing Functions

#### *3D.4.4.1 Relief Valve Discharge Pipe Forces Computer Program - RVFOR*

The relief valve discharge pipe connects the pressure-relief valve to the suppression pool. When the valve is opened, the transient fluid flow causes time-dependent forces to develop on the pipe wall. This computer program computes the transient fluid mechanics and the resultant pipe forces using the method of characteristics.

#### *3D.4.4.2 Turbine Stop Valve Closure - TSFOR*

The TSFOR program computes the time-history forcing function in the main steam piping due to turbine stop valve closure. The program utilizes the method of characteristics to compute fluid momentum and pressure loads at each change in pipe section or direction.

#### *3D.4.4.3 Hydraulic Transients-RELAP5/Mod 3.3*

The RELAP5 computer code is a light water reactor transient analysis code developed for the U.S. Nuclear Regulatory Commission for use in rulemaking, licensing audit calculations, evaluation of operator guidelines, and as a basis for nuclear plant analyses. Specific applications of this capability have included simulations of transients such as loss of feed-water, loss of offsite power, station blackout, and turbine trip. RELAP5 is a highly generic code that, in addition to calculating the behavior of a reactor coolant system during a transient, can be used for simulating a wide variety of hydraulic and thermal transients in both nuclear and non-nuclear systems involving mixtures of steam, water, non-condensables, and solutes.

The RELAP5 hydrodynamic model is a one-dimensional, transient, two-fluid model for flow of a two-phase steam-water mixture that can contain non-condensable components in the steam phase and/or a soluble component in the water phase.

The two-fluid equations of motion (mass, momentum, and energy conservation for each phase) that are used as the basis for the RELAP5 hydrodynamic model are formulated in terms of volume and time-averaged parameters of the flow. Phenomena that depend upon transverse

(OPEN ITEM)

NRC RAI 3.12-15

*DCD Tier 2, Section 3.7.3.17, indicates that where small, Seismic Category II piping is directly attached to Seismic Category I piping, it can be decoupled from Seismic Category I piping. However, the DCD did not describe how the small branch piping will be analyzed in the piping design for both inertial and Seismic Anchor Motion (SAM) responses (e.g., small bore handbook or like other (larger) piping, equivalent static method or dynamic analysis). Describe the seismic analysis methods and procedures, including the input floor response spectrum and input SAM displacements, that apply to the small branch piping design. The description should also describe how any amplification effects and SAM effects, from the main run pipe at the attachment to the small branch pipe, are considered.*

GE Response

The non-safety related piping and components whose structural failure due to an SSE could hinder the operation of the safety-related piping components, shall be designed to withstand the SSE without loss of piping integrity. The load combination and acceptance criteria are as follows.

The load combination and criteria are as follows.

| Seismic Category | Description | Load Combination | Acceptance Criteria |
|---|---|---|---|
| II | Sustained Loads | PD + WT | EQ 8 $\leq$ 1.5 $S_h$ |
| | Occasional Loads | PD + WT + RV2I | EQ 9 $\leq$ 1.8 $S_h$ or 1.5 Sy |
| | Thermal Range | TE | EQ 13 $\leq$ $S_A$+ f($S_h$ - $S_L$) |
| | Structural Integrity | PD + WT + SSEI<br>PD + WT + $[(CHUGI)^2 + (RV2I)^2]^{1/2}$<br>PD + WT + $[(CONDI)^2 + (RV2I)^2]^{1/2}$<br>PT + WT + API | ND 3600 EQ 9 < 3Sh and no greater than 2.0 Sy and Meet NUREG 1367 |

For dynamic and SAM analyses,

1. Decouple criteria is 25 to 1 in the ratio of "moment of inertia" of run pipe to branch pipe.
2. Linear spectrum with accelerations from the seismic and dynamic analyses used in the large bore piping analysis (run pipe) are applied to this interface point for the small branch piping design, as well as the seismic and dynamic displacements at the connection point.
3. Formal analysis methods and procedures similar to the main pipe should be used, or more conservative handbook analysis may also be used.

**NRC RAI 3.12-16**

*DCD Tier 2, Section 3.9.3.3, indicates that the main steam ASME Class 1 piping thermal loads are less than 2.4 Sy per equation 12 of NB-3600. Describe how the stress of 2.4 Sy satisfies the ASME Code Equation 12 allowable limit of 3 Sm.*

**GE Revised Response** (NO CHANGE TO RAI REQUIRED)

$S_y$ is a typo and will be changed to $S_m$ in DCD Tier #2 section 3.9.3.3 and 3.9.3.4 under the "ASME Class 1,2 and 3 Piping".

The last sentence of the first paragraph of 3.9.3.3 will be changed in DCD Tier #2, in addition to a sentence added to 3.9.3.4 under "ASME Class 1, 2 and 3 Piping".

DCD Tier #2 Table 3.9-9 acceptance criteria for service level A & B was revised.

**DCD/LTR Impact**

DCD Tier #2 section 3.9.3.3, 3.9.3.4 and Table 3.9-9 will be revised as noted in the attached markup.

**ASME Class 2 and 3 Vessels**

The Class 2 and 3 vessels (all vessels not previously discussed) are constructed in accordance with the Code. The stress analysis of these vessels is performed using elastic methods.

**ASME Class 1, 2 and 3 Valves**

The Class 1, 2, and 3 valves (all valves not previously discussed) are constructed in accordance with the Code.

All valves and their extended structures are designed to withstand the accelerations due to seismic and other RBV loads. The attached piping is supported so that these accelerations are not exceeded. The stress analysis of these valves is performed using elastic methods. Refer to Subsection 3.9.3.5 for additional information on valve operability.

**ASME Class 1, 2 and 3 Piping**

The Class 1, 2 and 3 piping (all piping not previously discussed) is constructed in accordance with the Code. For Class 1 piping, stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the Code. For Class 2 and 3 piping, stresses are calculated on an elastic basis and evaluated in accordance with NC/ND-3600 of the Code. In the event that a NB-3600 analysis is performed for Class 2 or 3 pipe, all the analysis requirements for Class 1 pipe as specified in this document and the ASME code will be performed. Table 3.9-9 shows the specific load combinations and acceptance criteria for Class 1 piping systems. For the Class 1 piping that experiences the most significant stresses during operating conditions, the thermal loads per Equation 12 of NB-3600 are less than 2.4 $S_{m}$, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600. The piping considered in this category is the RWCU/SDC, feedwater, main steam, and isolation condenser steam piping within the containment. These were evaluated to be limiting based on differential thermal expansion, pipe size, transient thermal conditions and high energy line conditions. If Code Case N-122-2 is used for analysis of a class 1 pipe, the analysis complying with this Case will be included in the Design Report for the piping system. For submerged piping and associated supports, the applicable direct external loads (e.g. hydrodynamic etc.) applied to the submerged components shall be included in the analysis.

### *3.9.3.5 Valve Operability Assurance*

Active mechanical (with or without electrical operation) equipment designed to perform a mechanical motion for its safety-related function is Seismic Category I. Equipment with faulted condition functional requirements includes active pumps and valves in fluid systems such as the RHR System, ECCS, and MS system.

This subsection discusses operability assurance of active Code valves, including the actuator that is a part of the valve (Subsection 3.9.2.2).

Safety-related valves are qualified by testing and analysis and by satisfying the stress and deformation criteria at the critical locations within the valves. Operability is assured by meeting the requirements of the programs defined in Subsection 3.9.2.2, Section 3.10, Section 3.11 and the following subsections.

## Table 3.9-9

## Load Combinations and Acceptance Criteria for Class 1 Piping Systems

| Condition | Load Combination for all terms[(1) (2)] | Acceptance Criteria |
|---|---|---|
| Design | PD + WT | Eq 9 $\leq$ 1.5 $S_m$ NB-3652 |
| Service Level A & B | PP, TE, ΔT1, ΔT2 , TA-TB, $RV_1$, $RV_2I$, $RV_2D$, TSV, SSEI, SSED | ~~Fatigue NB-3653:~~<br>Eq 12 & 13 $\leq$ 2.4 $S_m$<br>Fatigue - NB-3653:<br>U < 0.10~~1.0~~ |
| Service Level B | PP + WT + (TSV)<br>PP + WT + $(RV_1)$<br>PP + WT + $(RV_2I)$ | Eq 9 $\leq$ 1.8 $S_m$, but not greater than 1.5 $S_y$<br>Pressure not to exceed 1.1$P_a$ (NB-3654) |
| Service Level C | PP + WT + $[(CHUGI)^2 + (RV_1)^2]^{1/2}$<br>PP + WT + $[(CHUGI)^2 + (RV_2I)^2]^{1/2}$ | Eq 9 $\leq$2.25 $S_m$, but not greater than 1.8 $S_y$<br>Pressure not to exceed 1.5 $P_a$ (NB-3654) |
| Service Level D | PP + WT + $[(SSEI)^2 + (TSV)^2]^{1/2}$<br>PP + WT + $[(SSEI)^2 + (CHUGI)^2 + (RV_1)^2]^{1/2}$<br>PP + WT + $[(SSEI)^2 + (CHUGI)^2 + (RV_2I)^2]^{1/2}$<br>PP + WT + $[(SSEI)^2 + (CONDI)^2 + (RV_1)^2]^{1/2}$<br>PP + WT + $[(SSEI)^2 + (CONDI)^2 + (RV_2I)^2]^{1/2}$<br>PP + WT + $[(SSEI)^2 + (API)^2]^{1/2}$ | Eq 9 $\leq$ 3.0 $S_m$ but not greater than 2.0 $S_y$<br>Pressure not to exceed 2.0 $P_a$ (NB-3654) |

(1) $RV_1$ and TSV loads are used for MS Lines only

(2) $RV_2$ represents $RV_2$ ALL (all valves), $RV_2SV$ (single Valve) and $RV_2$ AD (Automatic Depressurization operation)

Where: API = Annulus Pressurization Loads (Inertia Effect)

CHUGI = Chugging Load (Inertia Effect)

ONDI = Condensation Oscillation (Inertia Effect)

PD = Design Pressure

PP = Peak Pressure or the Operating Pressure Associated with that transient

$RV_1$ = SRV Opening Loads (Acoustic Wave)

NRC RAI 3.12-17 (OPEN ITEM)

*Note 3 to DCD Tier 2, Table 3.9-2 indicates that the method used in the combination of dynamic responses of piping loadings is in accordance with NUREG-0484, Revision 1. Table 3.9-9 specifies a number of load combinations that specify an SRSS load combination. Describe how the NUREG-0484 criteria were satisfied for the Service Level D load combinations.*

GE Response

The technical approach is a linear elastic analysis for Level D. According to that established criteria in Section 5 of NUREG-0484, SRSS combination specified in Table 3.9-9 is suitable for earthquake combinations with LOCA.

NRC RAI 3.12-18

*Note 12 to DCD Tier 2, Table 3.9-2 provides a modification to the ASME Class 2 and 3 criteria to address SSE seismic anchor motion stresses. However note 12 did not include any additions/changes to the Class 1 piping requirements of ASME Code Section III, Subsection NB-3600, for equations 10, 11 and 12 (similar to the additions/changes made for Class 2 and 3 piping). Clarify whether there are any additions or changes for the Class 1 piping requirements and what earthquake level (for inertia and SAM) will be used to satisfy the ASME Code equations.*

GE Original Response

Table 3.9-2 specifies SSE load. This includes the inertia and the anchor motion effect. This is the same designation as other dynamic loads. The SAM is included in Equation 10, 12, 13 and 14 evaluations. The piping design specification for Service Level A&B is shown below as an example.

**Table 2. Main Steam Piping System**

| Condition | Load Combination for All Terms(1)(2)(3) | Acceptance Criteria(7) |
|---|---|---|
| Service Levels A & B | PP, TE, ΔT1(4), ΔT2(5), TA-TB(6), $RV_1$, $RV_2I$, $RV_2D$, TSV, SSEI, SSED | Eq 12 & 13 $\leq 2.4\ S_m$<br>Fatigue - NB-3653<br>U < 0.1 |

GE Revised Response

Note 12 of DCD Tier #2 Table 3.9-2 will be modified to include the same criteria that was specified in ABWR DCD.

**DCD/LTR Impact**

**DCD Tier #2 Table 3.9-2 will be revised as noted in the attached markup.**

(9) The piping systems that are qualified to the leak-before-break criteria of Subsection 3.6.3 are excluded from the pipe break events to be postulated for design against LOCA dynamic effects, viz., SBL, IBL and LBL.

(10) This applies only to the main steamlines and components mounted on it. The low probability that the TSV closure and SRV loads can exist at the same time results in this combination being considered under service level D.

(11) Applies only to fatigue evaluation of ASME Code Class 1 components and core support structures. See Dynamic Loading Event No. 13, Table 3.9-1, and Note 5 of Table 3.9-1 for number of cycles.

(12) For ASME Code Class 1, 2 and 3 piping the following changes and additions to ASME Code Section III Subsection NB-3600, NC-3600 and ND-3600 are necessary and shall be evaluated to meet the following stress limits:

(a) ASME Code Class 1 Piping:

$$S_{SAM} = C_2 \frac{D_0 M_c}{2I} \le 6.0\ S_m \qquad \text{Eq. (12a)}$$

Where: $S_{SAM}$ is the nominal value of seismic anchor motion stress

$M_c$ is the combined moment range equal to the greater of (1) the resultant range of thermal and thermal anchor movements plus one-half the range of the SSE anchor motion, or (2) the resultant range of moment due to the full range of the SSE anchor motions alone.

$C_2$, $D_0$ and I are defined in ASME Code Subsection NB-3600.

SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsection NB-3600 Equations (10) and (11).

(b) For ASME Code Class 2 and 3 piping: ~~the following changes and additions to ASME Code Section III Subsection NC-3600 and ND-3600 are necessary and shall be evaluated to meet the following stress limits:~~

$$S_{SAM} = i \frac{M_c}{Z} \le 3.0\ S_h \quad (\le 2.0 S_y)$$ Eq. (10~~2~~b~~a~~)

Where: $S_{SAM}$ and $M_c$ are as defined in (a) above, and ~~is the nominal value of seismic anchor motion stress~~

~~$M_c$ is the combined moment range equal to the greater of (1) the resultant range of thermal and thermal anchor movements plus one-half the range of the SSE anchor motion, or (2) the resultant range of moment due to the full range of the SSE anchor motions alone.~~

i and Z are defined in ASME Code Subsections NC/ND-3600

SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsections NC/ND-3600 Equation (9), Service Levels A and B and Equations (10) and (11).

(13) ASME Code Class 1, 2 and 3 Piping systems, which are essential for safe shutdown under the postulated events are designed to meet the requirements of NUREG-1367. Piping system dynamic moments can be calculated using an elastic response spectrum or time history analysis.

(9) The piping systems that are qualified to the leak-before-break criteria of Subsection 3.6.3 are excluded from the pipe break events to be postulated for design against LOCA dynamic effects, viz., SBL, IBL and LBL.

(10) This applies only to the main steamlines and components mounted on it. The low probability that the TSV closure and SRV loads can exist at the same time results in this combination being considered under service level D.

(11) Applies only to fatigue evaluation of ASME Code Class 1 components and core support structures. See Dynamic Loading Event No. 13, Table 3.9-1, and Note 5 of Table 3.9-1 for number of cycles.

(12) For ASME Code Class 1, 2 and 3 piping the following changes and additions to ASME Code Section III Subsection NB-3600, NC-3600 and ND-3600 are necessary and shall be evaluated to meet the following stress limits:

(a) ASME Code Class 1 Piping:

$$S_{SAM} = C_2 \frac{D_0}{2I} Mc \leq 6.0\ S_m \qquad \text{Eq. (12a)}$$

Where: $S_{SAM}$ is the nominal value of seismic anchor motion stress

$M_c$ is the combined moment range equal to the greater of (1) the resultant range of thermal and thermal anchor movements plus one-half the range of the SSE anchor motion, or (2) the resultant range of moment due to the full range of the SSE anchor motions alone.

$C_2$, $D_o$ and I are defined in ASME Code Subsection NB-3600.

SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsection NB-3600 Equations (10) and (11).

(b) For ASME Code Class 2 and 3 piping:

$$S_{SAM} = i \frac{M_c}{Z} \leq 3.0\ S_h \quad (\leq 2.0 S_y) \qquad \text{Eq. (10b)}$$

Where: $S_{SAM}$ and $M_c$ are as defined in (a) above, and

i and Z are defined in ASME Code Subsections NC/ND-3600

SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsections NC/ND-3600 Equation (9), Service Levels A and B and Equations (10) and (11).

(13) ASME Code Class 1, 2 and 3 Piping systems, which are essential for safe shutdown under the postulated events are designed to meet the requirements of NUREG-1367. Piping system dynamic moments can be calculated using an elastic response spectrum or time history analysis.

| Load Definition Legend for Table 3.9-2 | |
|---|---|
| Normal (N) | Normal and/or abnormal loads associated with the system operating conditions, including thermal loads, depending on acceptance criteria. |
| SOT | System Operational Transient (Subsection 3.9.3.1). |
| IOT | Infrequent Operational Transient (Subsection 3.9.3.1). |
| ATWS | Anticipated Transient Without Scram. |

7 *[For ASME Code 1,2 and 3 piping the following changes and additions to ASME Code Section III Subsections NB-3600, NC-3600 and ND-3600 are necessary and shall be evaluated to meet the following stress limits:*

*(a) ASME Code Class 1 Piping:*

$$S_{SAM} = C_2 \frac{D_0}{2I} M_c \leq 6.0Sm \qquad \text{Eq. (12a)}$$

*where:* $S_{SAM}$ *is the nominal value of seismic anchor motion stress*

$M_c$ *is the combined moment range equal to the greater of (1) the resultant range of thermal and thermal anchor movements plus one-half the range of the SSE anchor motion, or (2) the resultant range of moment due to the full range of the SSE anchor motions alone.*

$C_2$, $D_0$ *and I are defined in ASME Code Subsection NB-3600*

*SSE inertia and seismic anchor motion loads shall be included in the calculation of ASME Code Subsection NB-3600 equations (10) and (11).*

*(b) ASME Code Class 2 and 3 Piping:*

$$S_{SAM} = i\frac{M_c}{Z} \leq 3.0S_h \quad (\leq 2.0S_y) \qquad \text{Eq. (10b)}$$

*where:* $S_{SAM}$ *and* $M_c$ *are as defined in (a) above, and*

*i and Z are defined in ASME Code Subsections NC/ND-3600*

*SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsections NC/ND-3600 Equation (9), Service Levels A and B and Equations (10) and (11)]*[*]

8 The reactor coolant pressure boundary is evaluated using in the load combination the maximum pressure expected to occur during ATWS.

9 *[All ASME Code Class 1,2 and 3 Piping systems which are essential for safe shutdown under the postulated events are designed to meet the requirements of NUREG-1367 (Reference 3.9-7)]*[*] Piping system dynamic moments can be calculated using an elastic response spectrum or time history analysis.

10 The most limiting load combination case among SRV(1), SRV(2) and SRV (ADS). See Note (5) for main steam and branch piping.

11 The piping systems that are qualified to the leak-before-break criteria of Subsection 3.6.3 are excluded from the pipe break events to be postulated for design against LOCA dynamic effects, viz., SBL, IBL and LBL.

12 *[For active Class 2 and 3 pumps (and active Class 1,2 and 3 valves), the stresses are limited by criteria:* $\sigma m < 1.2S$ *(or 0.75 Sy), and* $(\sigma m \text{ or } \sigma L) + \sigma b \leq 1.8S$ *(or 1.1 Sy), where the notations are as defined in the ASME Code, Section III, Subsections NB and NC or ND, respectively.]*[†]

---

[*] See Subsection 3.9.1.7.

[†] See Section 3.10.

**NRC RAI 3.12-20**

*In DCD Tier 2, Section 3.7.2.7, the cutoff frequency for modal responses is defined as the frequency at which the spectral acceleration approximately returns to the ZPA of the input response spectrum. Define this cutoff frequency quantitatively for seismic and other building dynamic loads applicable to the piping analysis for the ESBWR.*

**GE Revised Response**

In section 3.7.2.7: The ZPA cut-off frequency is 100 Hz or the $f_{ZPA}$ rigid frequency as defined in figures 1, 2 and 3 of RG 1.92 rev. 2.

In section 3.7.3.1: For equipment analysis, refer to requirements of Step 1 of section 3.7.2.7 for ZPA determination.

Reviewed chapters 1, 3, 4, 5, 6, 15 and chapter 3 appendices for use of DG-1127, RG-1.92 in addition to references to 33 Hz for seismic and 60 Hz for hydrodynamic ZPA in the DCD. In addition to 3.7.2.7 and 3.7.3.1 above, occurrences evaluated for Table 1.9-21, 1.9-21a, Table 3.7-1 (footnote changed in response to RAI 3.12-19), 3.9.1.4, 3.9.2.2.1, 3.9.2.2.2, 3.10, 3D.4.1.

**DCD/LTR Impact**

DCD Tier #2 sections 3.7.2.7, 3.7.3.1, 3.9.1.4, 3.9.2.2.1, 3.9.2.2.2, 3.10 and tables Table 1.9-21 and 1.9-21a will be revised as noted in the attached markup.

### *3.7.2.7 Combination of Modal Responses*

This section addresses the applicable methods for the combination of modal responses when the response spectrum method is used for response analysis.

If the modes are not closely spaced (two consecutive modes are defined as closely spaced if their frequencies differ from each other by 10% or less of the lower frequency), the total response is obtained by combining the peak modal responses by the SRSS method as:

$$R = \left( \sum_{k=1}^{n} R_k^2 \right)^{1/2} \qquad (3.7\text{-}10)$$

where

| | | |
|---|---|---|
| $R$ | = | total response |
| $R_k$ | = | peak response of kth mode |
| $n$ | = | number of modes considered in the analysis |

If some or all of the modes are closely spaced, any one of the three methods (grouping method, 10% method, and double sum method) presented in Regulatory Guide 1.92 is applicable for the combination of modal responses.

For modal combination involving high-frequency modes, the following procedure applies:

**Step 1** — Determine the modal responses only for those modes that have natural frequencies less than that at which the spectral acceleration approximately returns to the ZPA of the input response spectrum. The ZPA cutoff frequency is 100 Hz or $f_{ZPA}$ ~~the rigid frequency~~ as defined in Figures 1,2 and 3~~Figure 3~~ of Regulatory Guide 1.92. It is applicable to seismic and other building dynamic loads. Combine such modes in accordance with the methods described above.

**Step 2** — For each degree of freedom (DOF) included in the dynamic analysis, determine the fraction of DOF mass included in the summation of all of the modes included in Step 1. This fraction $d_i$ for each DOFi is given by:

$$d_i = \sum_{n=1}^{N} \Gamma_n \times \phi_{n,i} \qquad (3.7\text{-}11)$$

where

| | | |
|---|---|---|
| $n$ | = | order of the mode under consideration |
| $N$ | = | number of modes included in Step 1 |
| $\phi_{n,i}$ | = | mass-normalized mode shape for mode n and DOFi |
| $\Gamma_n$ | = | participation factor for mode n (see Equation 3.7-3 for expression). |

**NRC RAI 3.12-21**

*For the analyses of vibratory loads (other than seismic) with significant high-frequency input (e.g., above 33 Hz), describe:*

*(a) The modal combination method to be used for the high frequency modes above the cutoff frequency for vibratory loads.*

*(b) The nonlinear analysis method to be used to account for large gaps between the pipe and its supports.*

**GE Response**

(a) The modal combination to be used for the high frequency modes above the cutoff frequency for vibratory loads is performed according to Appendix A of SRP 3.7.2.

(b) In general, the clearance of the supports considered in the piping analysis is sufficiently small so that a non-linear analysis is not needed. ~~If this case should happen, a detailed analysis would be carried out with finite elements using the appropriate evaluation tools.~~ Therefore, no provisions for non-linear analysis is provided in the DCD, and no non-linear analysis will be allowed.

NRC RAI 3.12-22 (OPEN ITEM)

*DCD Tier 1, Section 3.1, "Piping design," states that Class 1 piping systems will be analyzed for fatigue with environmental effects. Provide the analysis and design methods that will be used to perform the fatigue evaluation, including the environmental effects, for the ESBWR Class 1 piping systems.*

GE Response

GE WILL REVISE RESPONSE TO ACCEPT ENVIRONMENTAL EFFECTS UNDER THE CONDITION THAT THE PIPE BREAK CRITERIA IS REVISED.

Requirements contained in ASME III NB-3653. The load combinations contained in Table 3.9-9, and the plant event cycles contained in Table 3.9-1 of the DCD, define the design conditions that are inputs to the fatigue analysis. Additionally, GE has additional design criteria for carbon steel and stainless steel materials that are intended to address environmental issues that have been applied to prior BWR applications, and are likewise being applied to the ESBWR piping design. Additionally, class 1 piping using a fatigue limit of 0.1 instead of the ASME Code acceptance limit of 1.0 in conjunction with a stress ratio limit of 0.80 for Equations 12 and 13 of the ASME Code in order to limit the number of pipe whip restraints within the containment. DCD paragraphs 3.9.3.3 and 3.9.3.4 will be revised in DCD Revision 2 to reflect this commitment as follows:

"Additionally, a fatigue usage limit of 0.10 is used as a design criteria for all Class 1 piping."

Evaluations have also determined that the ASME Code has conservative methods that provide additional margins. Specifically, the ASME Code adds stresses that include P, Ma, Mb, Mc, DT1, DT2, and Dtab by absolute sum when in actuality the direction and signs of the stresses are different. Reference (1) has performed a detail finite element analysis to compare against the results of a NB-3600 analysis and found that the fatigue usage based on NB-3600 is about 10 times more conservative.

This design criteria that is being used for ESBWR is consistent with the design methods used on previous BWR product lines that have successfully operated for the last 40 years without piping fatigue issues. Data from fatigue usage monitors from operating plants have also confirmed that the design criteria specified by GE in the original plant design was conservative.

The simplified NB-3600 analysis has been used for last 40 years successfully. If newly developed environmental fatigue curves are used, high fatigue usage factors are predicted and pipe break locations will be postulated throughout the plant. The economical cost to the plant is huge, and any gain of safety is questionable.

It is recommended that the environmental fatigue design curves should not be used without substantial simultaneous changes in analytical methodology and the ASME Code.

Ref.1. "Fatigue Usage Factor Evaluation For An Integrally Reinforced Branch Connection Using NB-3600 And NB-3200 Analysis Methods" by Henry L. Hwang, PE, General Electric Nuclear Energy, Jack R. Cole, PE, David M. Bosi, PE, Design Engineering, Washington Public Power Supply System. PVP Vol. 313-2, page 139 through 156.

**NRC RAI 3.12-24**

*NRC Bulletin 88-08 addresses unisolable sections of piping connected to the RCS (including the RPV) that may be subjected to temperature oscillations induced by leaking valves. Identify unisolable piping segments directly connected to the RCS and describe the analysis method to mitigate problems identified in Bulleting 88-08, including Supplements 1, 2 and 3.*

**GE Revised Response**

Theoretically, the problem of thermal fatigue in unisolable sections of piping connected to the RCS caused by cold water leaks through a normally closed block valve, with the pressure upstream of the valve greater than the RCS and the temperature upstream of the valve significantly lower than the RCS temperature, could occur in the following cases:

1.1 Standby Liquid Control System (C41) Squib Valves. In this case the problem of leaks does not exist due to the design of the squib valves.

1.2 The Gravity-Driven cooling system (E50) squib valves. In this case the problem of leaks does not exist due to the design of the squib valves.

1.3 Nuclear Boiler system (B21) RPV head vent piping drain isolation valve. If the physical location of the valve is close to the RPV, there is the potential for having a thermal oscillation problem. The design of the pipe routing will be completed to prevent this from occurring. ~~If a concern remains when the routing is completed, thermocouples will be added to the line to monitor piping temperatures.~~

NRC RAI 3.12-27 (OPEN ITEM)

*DCD Tier 2, Section 3.7.3.12, discusses the effect of differential building movement on piping systems that are anchored and restrained to floors and walls of buildings that may have differential movements during a dynamic event. SRP 3.9.2 Section II.2.g states that the responses due to the inertial effect and relative displacement for multiply-supported equipment and components with distinct inputs should be combined by the absolute sum method. Provide the combination methods that are to be used in the design of ESBWR piping systems for the inertial responses and SAM responses caused by relative displacements for all analysis methods (including ISM).*

GE Response

DCD Tier 2, Section 3.7.3.12, discusses the effect of differential building movement on piping systems that are anchored and restrained to floors and walls of buildings that may have differential movements during a dynamic event. In general, the piping systems are anchored and restrained to floors and walls of buildings that may have differential movements during a seismic event. The movements may range from insignificant differential displacements between rigid walls of a common building at low elevations to relatively large displacements between separate buildings at a high seismic activity site.

Piping system is different from multiply-supported equipment. For piping system, the induced displacements in compliance with NB 3653 are treated differently than the inertia displacements. The SRSS method is a standard industrial practice to combine the inertial responses and SAM responses caused by relative displacements.

**NRC RAI 3.12-30**

*DCD Tier 2, Section 3.9.3.7.1, states: "The building structure component supports are designed in accordance with ANSI/AISC N690, Nuclear Facilities-Steel Safety-Related Structures for Design, Fabrication and Erection, or the AISC specification for the Design, Fabrication, and Erection of Structural Steel for buildings, correspond to those used for design of the supported pipe." Clarify what this sentence means, particularly the phrase "correspond to those used for design of the supported pipe." Also, identify the edition of these specifications because the titles do not match the corresponding specifications given in Tables 3.8-6 and 3.8-9 of the DCD.*

**GE Revised Response** (NO CHANGE TO RAI REQUIRED)

The paragraph "The building structure...supported pipe" will be modified in DCD Revision 2 as shown below.

"Supports and their attachments for ASME Code Class 1, 2 and 3 piping are designed in accordance with Subsection NF up to the interface of the building structure, with jurisdiction boundaries as defined by Subsection NF. The applicable loading combinations and allowables used for design of supports are shown in new Tables 3.9-10, -11, and -12

**DCD/LTR Impact**

DCD Tier #2 section 3.9.3.7.1 will be revised and tables 3.9-10, 3.9-11 and 3.9-12 will be added as noted in the attached markup.

## Table 3.9-10

## Snubber Loads

| Condition | Load Combination(1)(2) | Acceptance Criteria |
|---|---|---|
| Service Level B | $(TSV)$<br>$(RV_1)$<br>$[(RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |
| Service Level C | $[(CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>$[(CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |
| Service Level D | $[(SSEI)^2 + (SSED)^2 + (TSV)^2]^{1/2}$<br>$[(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>$[(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>$[(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_1)^2]^{1/2}$<br>$[(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>$[(SSEI)^2 + (SSED)^2 + (API)^2 + (APD)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |

(1) $RV_1$ and TSV loads are used for MS Lines

(2) $RV_2$ represents $RV_2$ ALL (all valves), $RV_2SV$ (single valve) and $RV_2$ AD (Automatic Depressurization Operation).

Where: TSV = Turbine Stop Valve closure loads

$RV_1$ = SRV Opening Loads (Acoustic Wave)

$RV_2I$ = SRV Building~~Basemat~~ Acceleration Loads (Inertia Effect) (all valves)

$RV_2D$ = SRV Building~~Basemat~~ Acceleration Loads (Anchor Displacement Loads) (all valves)

CHUGI = Chugging Load (Inertia Effect)

CHUGD = Condensation Oscillation (Anchor Displacement Loads)

SSEI = Safe Shutdown Earthquake (Inertia Effect)

SSED = Safe Shutdown Earthquake (Anchor Displacement Loads)

CONDI = Condensation Oscillation (Inertia Load)

CONDD = Condensation Oscillation (Anchor Displacement Loads)

API = Annulus Pressurization Loads (Inertia Effect)

APD = Annulus Pressurization Loads (Anchor Displacement Loads)

## Table 3.9-11

## Strut Loads

| Condition | Load Combination(1)(2)(3) | Acceptance Criteria |
|---|---|---|
| Service Level A | WT + TE | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |
| Service Level B | WT + TE + (TSV)<br>$WT + TE + (RV_1)$<br>$WT + TE + [(RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |
| Service Level C | $WT + TE + [(CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>$WT + TE + [(CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |
| Service Level D | $WT + TE + [(SSEI)^2 + (SSED)^2 + (TSV)^2]^{1/2}$<br>$WT + TE + [(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>$WT + TE + [(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>$WT + TE + [(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_1)^2]^{1/2}$<br>$WT + TE + [(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>$WT + TE + [(SSEI)^2 + (SSED)^2 + (API)^2 + (APD)^2]^{1/2}$ | Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS) |

(1) $RV_1$ and TSV loads are used for MS Lines

(2) $RV_2$ represents $RV_2$ ALL (all valves), $RV_2SV$ (single valve) and $RV_2$ AD (Automatic Depressurization Operation)

(3) TE = Thermal expansion case associated with the transient

Where: TSV = Turbine Stop Valve closure loads

WT = Dead Weight

TE = Thermal Expansion

$RV_1$ = SRV Opening Loads (Acoustic Wave)

$RV_2I$ = SRV Building~~Basemat~~ Acceleration Loads (Inertia Effect) (all valves)

$RV_2D$ = SRV Building~~Basemat~~ Acceleration Loads (Anchor Displacement Loads) (all valves)

CHUGI = Chugging Load (Inertia Effect)

CHUGD = Condensation Oscillation (Anchor Displacement Loads)

SSEI = Safe Shutdown Earthquake (Inertia Effect)

SSED = Safe Shutdown Earthquake (Anchor Displacement Loads)

## Table 3.9-12

## Linear Type (Anchor and Guide) ~~Main Steam~~ Piping Support

| Condition | Load Combination(1)(2)(3) | Acceptance Criteria(4)(5) |
|---|---|---|
| Service Level A | WT + TE | Table NF-3131(a)-1 for Linear Supports~~3623(b)-1~~ |
| Service Level B | WT + TE + (TSV)<br>WT + TE + $(RV_1)$<br>WT + TE + $[(RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Table NF-3131(a)-1 for Linear Supports~~3623(b)-1~~ |
| Service Level C | WT + TE + $[(CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>WT + TE + $[(CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$ | Table NF-3131(a)-1 for Linear Supports~~3623(b)-1~~ |
| Service Level D | WT + TE + $[(SSEI)^2 + (SSED)^2 + (TSV)^2]^{1/2}$<br>WT + TE + $[(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$<br>WT + TE + $[(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>WT + TE + $[(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_1)^2]^{1/2}$<br>WT + TE + $[(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$<br>WT + TE + $[(SSEI)^2 + (SSED)^2 + (API)^2 + (APD)^2]^{1/2}$ | Appendix F Subarticle F-1334 |

(1) $RV_1$ and TSV loads are used for MS Lines

(2) $RV_2$ represents $RV_2$ ALL (all valves), $RV_2SV$ (single valve) and $RV_2$ AD (Automatic Depressurization Operation)

(3) TE = Thermal expansion case associated with the transient

(4) See Subsection 3.7.3.3.1 pertaining to the weight of the frame

(5) See Subsection 3.9.3.7.1 regarding friction forces induced by thermal in unrestrained direction

Where: TSV = Turbine Stop Valve closure loads

WT = Dead Weight

TE = Thermal Expansion

$RV_1$ = SRV Opening Loads (Acoustic Wave)

$RV_2I$ = SRV Building~~Basemat~~ Acceleration Loads (Inertia Effect) (all valves)

$RV_2D$ = SRV Building~~Basemat~~ Acceleration Loads (Anchor Displacement Loads) (all valves)

CHUGI = Chugging Load (Inertia Effect)

CHUGD = Condensation Oscillation (Anchor Displacement Loads)

SSEI = Safe Shutdown Earthquake (Inertia Effect)

SSED = Safe Shutdown Earthquake (Anchor Displacement Loads)

CONDI = Condensation Oscillation (Inertia Load)

**NRC RAI 3.12-31**

*(1) DCD Tier 2, Section 3.9.3.7, states that concrete anchor bolts used in pipe supports are designed to the factors of safety defined in IE Bulletin 79-02, Revision 1 and pipe support base plate flexibility will be accounted for in accordance with IE Bulleting 79-02. Clarify that all aspects of the anchor bolt design (not just the factor of safety) will follow IE Bulletin 79-02, Revision 2 (not Revision 1).*

*(2) Indicate whether the design and installation of all anchor bolts will also be performed in accordance with Appendix B to ACI 349-01- "Anchoring to Concrete," subject to the conditions and limitations specified in RG 1.199.*

*(3) Define the term Seismic Category IIA used in DCD Tier 2, Section 3.9.3.7, and explain how it differs from Category II.*

**GE Revised Response** (NO CHANGE TO RAI REQUIRED)

(1) Concrete expansion anchor bolts, with regard to safety factor and anchor plates flexibility, will follow all aspects IE Bulletin 79-02 Rev 2 dated November 8, 1979. Expansion anchor bolts shall not be used for any safety related system components.

(2) The design and installation of all anchor bolts will be performed in accordance with Appendix B to ACI 349-01 "Anchoring to Concrete", subject to the conditions and limitations specified in RG 1.199 and all applicable requirement of IE Bulletin 79-02 Rev. 2 dated November 8, 1979.

(3) Seismic Category IIA does not exist. The paragraph with this information will be modified.

**DCD/LTR Impact**

DCD Tier #2 section 3.9.3.7 will be revised as noted in the attached markup.

defined to act in each of the three orthogonal directions, the responses are combined by the SRSS method. The momentary unbalanced forces acting on the piping system are calculated and analyzed using the methods described in Subsection 3.9.3.6 for SRV lift analysis.

The resulting loads on the DPV, the main steamline, and the DPV piping are combined with loads due to other effects as specified in Subsection 3.9.3.1. In accordance with Tables 3.9-1 and 3.9-2, the code stress limits for service levels corresponding to load combination classification as normal, upset, emergency, and faulted are applied to the main steam, stub tube, and DPV discharge piping.

### *3.9.3.7 Component Supports*

ASME Section III component supports shall be designed, manufactured, installed and tested in accordance with all applicable codes and standards. Supports include hangers, snubbers, struts, spring hangers, frames, energy absorbers and limit stops. Pipe whip restraints are not considered as pipe supports.

The design of bolts for component supports is specified in the Code, Subsection NF. Stress limits for bolts are given in NF-3225. The rules and stress limits which must be satisfied are those given in NF-3324.6 multiplied by the appropriate stress limit factor for the particular service loading level and stress category specified in Table NF-3225.2-1.

Moreover, on equipment which is to be, or may be, mounted on a concrete support, sufficient holes for anchor bolts are provided to limit the anchor bolt stress to less than 68.95 MPa (10,000 psi) on the nominal bolt area in shear or tension.

Concrete expansion anchor bolts, with regard to safety factor and anchor plates flexibility, will follow all aspects of IE Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Revision 2 dated November 8, 1979. Expansion anchor bolts shall not be used for any safety related system components. The design and installation of all anchor bolts will be performed in accordance with Appendix B to ACI 349-01 "Anchoring to Concrete", subject to the conditions and limitations specified in RG 1.199 and all applicable requirements of IE Bulletin 79-02, Rev. 2.

It is preferable to attach pipe supports to embedded plates; however, surface-mounted base plates with undercut anchor bolts can be used in the design and installation of supports for safety related piping.

Pipe support base plate flexibility shall be accounted for in calculation of concrete anchor bolt loads, in accordance with IE Bulleting 79-02.

Mortar grout used for shim on the pipe support, when placed in contention areas, must be free of organic links in its composition.

#### 3.9.3.7.1 Piping Supports

Supports and their attachments for essential Code Class 1, 2, and 3 piping are designed in accordance with Subsection NF up to the interface of the building structure, with jurisdictional boundaries as defined by Subsection NF. The applicable loading combinations and allowables used for design of supports are shown on Tables 3.9-10, -11, and –12. The stress limits are per ASME III, Subsection NF and Appendix F. Supports are generally designed either by load

**NRC RAI 3.12-35**

*DCD Tier 2, Section 3.9.3.7, describes the criteria and design requirements for piping supports of ESBWR piping. The DCD does not provide any description of the development and specification of hot and cold gaps to be used between the pipe and the box frame type supports. Provide this information.*

**GE Revised Response**

Current industry practice is to limit the total gap of 1/8 inch for frame type pipe supports for loaded directions. In general this gap will be adequate for the radial thermal expansion of the pipe to avoid any thermal binding. For large pipe with much higher temperature, this gap will be evaluated to assure no thermal binding. The minimum total gap will be specified to ensure that it is adequate for the thermal radial expansion of the pipe to avoid any thermal binding.

**DCD/LTR Impact**

DCD Tier #2 section 3.9.3.7.1 will be revised as noted in the attached markup.

rating method per paragraph NF-3280 or by the stress limits for linear supports per paragraph NF-3143. The critical buckling loads for the Class 1 piping supports subjected to faulted loads that are more severe than normal, upset and emergency loads, are determined by using the methods discussed in Appendices F and XVII of the Code. To avoid buckling in the piping supports, the allowable loads are limited to two thirds of the determined critical buckling loads.

Maximum calculated static and dynamic deflections of the piping at support locations do not exceed the allowable limits specified in the piping design specification. ~~The purpose of the allowable limits is to preclude failure of the pipe supports due to piping deflections.~~

The design of supports for the non-nuclear piping satisfies the requirements of ASME/ANSI B31.1 Power Piping Code, Paragraphs 120 and 121.

For the major active valves identified in Subsection 3.9.3.5, the valve operators are not used as attachment points for piping supports.

The friction loads caused by unrestricted motion of the piping due to thermal displacements are considered to act on the support with a friction coefficient of 0.3, in the case of steel-to-steel friction. For stainless steel, Teflon, and other materials, the friction coefficient could be less. The friction loads are not considered during seismic or dynamic loading evaluation of pipe support structures.

For the design of piping supports, a deflection limit of 1.6 mm for erection and operation loadings is used, based on WRC-353 paragraph 2.3.2. For the consideration of loads due to SSE and in the cases involving springs, the deflection limit is increased to 3.2 mm.

For frame type supports for directions that are loaded, the total gap is limited to 1/8 inch. In general, this gap is adequate to avoid thermal binding due to radial thermal expansion of the pipe. For large pipes with higher temperatures, this gap will be evaluated to assure that no thermal bending occurs. The minimum total gap shall be specified to ensure that it is adequate for the thermal radial expansion of the pipe to avoid any thermal binding.

The small bore lines (e.g. small branch and instrumentation lines) are supported taking into account the flexibility, and thermal and dynamic motion requirements of the pipe to which they connect. Subsection 3.7.3.16 provides details for the support design and criteria for instrumentation lines 50 mm and less where it is acceptable practice by the regulatory agency to use piping handbook methodology.

The design criteria and dynamic testing requirements for the ASME III piping supports are as follows:

(1) Piping Supports—All piping supports are designed, fabricated, and assembled so that they cannot become disengaged by the movement of the supported pipe or equipment after they have been installed. All piping supports are designed in accordance with the rules of Subsection NF of the Code up to the building structure interface as defined by the jurisdictional boundaries in Subsection NF.

(2) Spring Hangers—The operating load on spring hangers is the load caused by dead weight. The hangers are calibrated to ensure that they support the operating load at both their hot and cold load settings. Spring hangers provide a specified down travel and up travel in excess of the specified thermal movement.

**NRC RAI 3.12-37**

*DCD Tier 2, Section 3.9.3.7, describes the criteria and design requirements for piping supports of ESBWR piping. The DCD indicates that maximum calculated static and dynamic deflections of the piping at support locations do not exceed the allowable limits specified in the "suspension design specification". The purpose of the allowable limits is to preclude failure of the pipe supports due to piping deflections. Provide an additional discussion of the "suspension design specification." Also, describe how the deflection limits are developed.*

**GE Revised Response** (NO CHANGE TO RAI REQUIRED)

For ESBWR the design of piping supports considers a deflection limit of 1.6 mm for erection and operation loadings is used, based on WRC-353 paragraph 2.3.2. For the consideration of loads due to SSE and in the cases of springs, the deflection limit is increased to 3.2 mm. "Suspension Design Specification" will be changed to "Piping Design Specification" in the DCD Revision 2.

**DCD/LTR Impact**

DCD Tier #2 section 3.9.3.7.1 will be revised as noted in the attached markup.

rating method per paragraph NF-3280 or by the stress limits for linear supports per paragraph NF-3143. The critical buckling loads for the Class 1 piping supports subjected to faulted loads that are more severe than normal, upset and emergency loads, are determined by using the methods discussed in Appendices F and XVII of the Code. To avoid buckling in the piping supports, the allowable loads are limited to two thirds of the determined critical buckling loads.

Maximum calculated static and dynamic deflections of the piping at support locations do not exceed the allowable limits specified in the piping design specification. ~~The purpose of the allowable limits is to preclude failure of the pipe supports due to piping deflections.~~

The design of supports for the non-nuclear piping satisfies the requirements of ASME/ANSI B31.1 Power Piping Code, Paragraphs 120 and 121.

For the major active valves identified in Subsection 3.9.3.5, the valve operators are not used as attachment points for piping supports.

The friction loads caused by unrestricted motion of the piping due to thermal displacements are considered to act on the support with a friction coefficient of 0.3, in the case of steel-to-steel friction. For stainless steel, Teflon, and other materials, the friction coefficient could be less. The friction loads are not considered during seismic or dynamic loading evaluation of pipe support structures.

For the design of piping supports, a deflection limit of 1.6 mm for erection and operation loadings is used, based on WRC-353 paragraph 2.3.2. For the consideration of loads due to SSE and in the cases involving springs, the deflection limit is increased to 3.2 mm.

For frame type supports for directions that are loaded, the total gap is limited to 1/8 inch. In general, this gap is adequate to avoid thermal binding due to radial thermal expansion of the pipe. For large pipes with higher temperatures, this gap will be evaluated to assure that no thermal bending occurs. The minimum total gap shall be specified to ensure that it is adequate for the thermal radial expansion of the pipe to avoid any thermal binding.

The small bore lines (e.g. small branch and instrumentation lines) are supported taking into account the flexibility, and thermal and dynamic motion requirements of the pipe to which they connect. Subsection 3.7.3.16 provides details for the support design and criteria for instrumentation lines 50 mm and less where it is acceptable practice by the regulatory agency to use piping handbook methodology.

The design criteria and dynamic testing requirements for the ASME III piping supports are as follows:

(1) Piping Supports—All piping supports are designed, fabricated, and assembled so that they cannot become disengaged by the movement of the supported pipe or equipment after they have been installed. All piping supports are designed in accordance with the rules of Subsection NF of the Code up to the building structure interface as defined by the jurisdictional boundaries in Subsection NF.

(2) Spring Hangers—The operating load on spring hangers is the load caused by dead weight. The hangers are calibrated to ensure that they support the operating load at both their hot and cold load settings. Spring hangers provide a specified down travel and up travel in excess of the specified thermal movement.

**NRC RAI 3.12-38**

*Include the direct loading of safety relief valve (SRV) discharge and loss of coolant accidents (LOCA) on submerged components in the suppression pool. Include these loads in the DCD tables and the main steam (MS)/SRV analysis.*

**GE Response**

The SRV discharge piping will be anchored at the air space to the wetwell. Therefore, there will be no wetwell loadings transferred to the main steam piping ans SRV discharge in the drywell. There will be load combinations for the wetwell piping to include all the loss of coolant accident (LOCA) loads on submerged components similar to the ABWR analysis

A requirement will be added to DCD Subsection 3.9.3.4 that applicable direct external loads applied to submerged piping shall be included in the analysis if applicable.

**DCD Impact**

DCD Tier 2 Subsection 3.9.3.4 has been revised as noted in the attached markup.~~No DCD change will be made in response to this RAI.~~.

**ASME Class 2 and 3 Vessels**

The Class 2 and 3 vessels (all vessels not previously discussed) are constructed in accordance with the Code. The stress analysis of these vessels is performed using elastic methods.

**ASME Class 1, 2 and 3 Valves**

The Class 1, 2, and 3 valves (all valves not previously discussed) are constructed in accordance with the Code.

All valves and their extended structures are designed to withstand the accelerations due to seismic and other RBV loads. The attached piping is supported so that these accelerations are not exceeded. The stress analysis of these valves is performed using elastic methods. Refer to Subsection 3.9.3.5 for additional information on valve operability.

**ASME Class 1, 2 and 3 Piping**

The Class 1, 2 and 3 piping (all piping not previously discussed) is constructed in accordance with the Code. For Class 1 piping, stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the Code. For Class 2 and 3 piping, stresses are calculated on an elastic basis and evaluated in accordance with NC/ND-3600 of the Code. In the event that a NB-3600 analysis is performed for Class 2 or 3 pipe, all the analysis requirements for Class 1 pipe as specified in this document and the ASME code will be performed. Table 3.9-9 shows the specific load combinations and acceptance criteria for Class 1 piping systems. For the Class 1 piping that experiences the most significant stresses during operating conditions, the thermal loads per Equation 12 of NB-3600 are less than 2.4 $S_{m}$, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600. The piping considered in this category is the RWCU/SDC, feedwater, main steam, and isolation condenser steam piping within the containment. These were evaluated to be limiting based on differential thermal expansion, pipe size, transient thermal conditions and high energy line conditions. If Code Case N-122-2 is used for analysis of a class 1 pipe, the analysis complying with this Case will be included in the Design Report for the piping system. For submerged piping and associated supports, the applicable direct external loads (e.g. hydrodynamic etc.) applied to the submerged components shall be included in the analysis.

### *3.9.3.5 Valve Operability Assurance*

Active mechanical (with or without electrical operation) equipment designed to perform a mechanical motion for its safety-related function is Seismic Category I. Equipment with faulted condition functional requirements includes active pumps and valves in fluid systems such as the RHR System, ECCS, and MS system.

This subsection discusses operability assurance of active Code valves, including the actuator that is a part of the valve (Subsection 3.9.2.2).

Safety-related valves are qualified by testing and analysis and by satisfying the stress and deformation criteria at the critical locations within the valves. Operability is assured by meeting the requirements of the programs defined in Subsection 3.9.2.2, Section 3.10, Section 3.11 and the following subsections.