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Supplement 1

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Subject: **Response to NRC Request for Additional Information Letter No. 16 Related to ESBWR Design Certification Application – Piping Design – RAI Numbers 3.12-1S1, 3.12-2S1, 3.12-4S1 through 3.12-10S1, 3.12-12S1, 3.12-13S1, 3.12-16S1, 3.12-19S1, 3.12-20S1, 3.12-23S1, 3.12-24S1 through 3.12-26S1, 3.12-28 S1 through 3.12-37S1 – Supplement 1**

Enclosure 1 contains GE's response to the subject NRC RAIs as discussed during the Piping Design and Analysis Audit conducted on May 22 through May 26, 2006. GE's original response to these RAIs was provided in the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Reference:

1. MFN 06-119, Letter from David H. Hinds to U.S. Nuclear Regulatory Commission, *Response to NRC Request for Additional Information Letter No. 16 Related to ESBWR Design Certification Application – Piping Design – RAI Numbers 3.12-1 through 3.12-37,* May 3, 2006

Enclosure:

1. MFN 06-119, Supplement 1 – Response to NRC Request for Additional Information Letter No. 16 Related to ESBWR Design Certification Application – Piping Design – RAI Numbers 3.12-1S1, 3.12-2S1, 3.12-4S1 through 3.12-10S1, 3.12-12S1, 3.12-13S1, 3.12-16S1, 3.12-19S1, 3.12-20S1, 3.12-23S1, 3.12-24S1 through 3.12-26S1, 3.12-28 S1 through 3.12-37S1 – Supplement 1

cc: AE Cubbage USNRC (with enclosures)
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eDRF 0000-0059-0246

**Enclosure 1**

**MFN 06-119, Supplement 1**

**Response to NRC Request for Additional Information**

**Letter No. 16 Related to ESBWR**

**Design Certification Application – Piping Design**

**RAI Numbers 3.12-1S1, 3.12-2S1, 3.12-4S1 through 3.12-10S1, 3.12-12S1, 3.12-13S1, 3.12-16S1, 3.12-19S1, 3.12-20S1, 3.12-23S1, 3.12-24S1, through 3.12-26S1, 3.12-28 S1 through 3.12-37S1**

**Supplement 1**

**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. 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, or to 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 because CC is not applicable to Seismic Category I internal structures.

**DCD/LTR Impact**

DCD Tier 2 Table 1.9-22 has been revised as noted in the attached markup.

**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 has been deleted. DCD Tier 2 Table 5.2-1 has been 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 has been deleted. DCD Tier 2 Subsection 3.7.1.2, Subsection 3.7.3.5 and Table 3.7-1 footnote has been 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 has been deleted. DCD Tier 2 Subsections 3.7.1.2 and 3.9.3.7.1(6) have been 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 has been deleted. DCD Tier 2 Table 5.2-1 has been 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 has been deleted. DCD Tier 2 Subsection 3.9.3.7.1 footnote, Subsection 3.9.3.7.2. footnote and Subsection 3.9.3.8 footnote have been 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 with the ASME Code requirements.

This code case has been deleted. DCD Tier #2 Table 5.2-1 has been 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 has been deleted. DCD Tier 2 Table 5.2-1 has been 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". 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 has been 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 has been 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 has been 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 has been 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, Subsection 3.7.1.2, Subsection 3.7.3.5, Table 3.7-1 footnote, Subsection 3.9.3.7.1(6), Subsection 3.9.3.7.1 footnote, Subsection 3.9.3.7.2. footnote, Subsection 3.9.3.8 footnote, and Subsection3.9.3.4 have been revised as noted in the attached markup.

**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**

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, Subsection 3.7.2.1.1 has been updated accordingly.

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

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.7.2.1.1 has been revised as noted in the attached markup.

## NRC RAI 3.12-5

*DCD Tier 2, Section 3.7.2.1.1, states that 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. It appears that this criterion is related to the Nyquist frequency for selection of the appropriate time step. Provide the technical justification why this approach is sufficiently accurate to capture the piping system response at the Nyquist frequency.*

## GE Response

Frequency domain solution is not used in the piping system response analysis. This analysis methodology applies to structural evaluations.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.7.2.1.1 has been revised as noted in the attached markup.

## 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 Subsection 3.7.2.9 has been revised as noted in the attached markup.

## NRC RAI 3.12-7

*DCD Tier 2, Section 3.7.2.1.3, provides a description of the static coefficient method of analysis. It states that the response loads are determined statically by multiplying the mass value by a static coefficient equal to 1.5 times the maximum spectral acceleration at the appropriate damping value of the input response spectrum. Indicate whether the use of the static coefficient method in the DCD also requires that (a) justification be provided that the system can be realistically represented by a simple model and the method produces conservative results and (b) the design and associated simplified analysis account for the relative motion between all points of support, as prescribed in SRP 3.9.2. If not, provide the technical justification.*

## GE Response

The use of the static coefficient method satisfies SRP 3.7.2 and 3.9.2 requirements.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.7.2.1.3 has been revised, and references 3.7-13 and 3.7-14 have been added as shown in the attached markup.

## NRC RAI 3.12-8

*The DCD did not provide any information on the use of inelastic analysis methods for the ESBWR piping design, except that discussed in DCD Tier 2, Section 3.9.1.4, for design of whip restraints against a postulated gross piping failure. Indicate if any ESBWR piping design, other than the whip restraints, includes any inelastic analysis method. Also, if such a method could be used, provide details of the analysis approach, its acceptance criteria, scope and extent of its application.*

## GE Response

Inelastic analysis methods are not used in the ESBWR piping design and analysis.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.9.1.4 under "Inelastic Analysis Methods" has been revised as noted in the attached markup.

**NRC RAI 3.12-9**

*DCD Tier 2, Section 3.7.3.13, did not give details on the analysis method and how the criteria are to be applied in the design of buried piping. Based on the criteria presented in DCD Tier 2, Section 3.7.3.13, describe the analysis method and design requirement that are used for buried piping. The design procedure should include the load components, categorization of seismic stress in the Code evaluation, and allowable stress limits.*

**GE Response**

There is no buried seismic Category I piping in the ESBWR design.

**DCD/LTR Impact**

DCD Tier #2 section 3.7.3.13 has been revised as noted in the attached markup.

DCD Tier #2 section 3.7.3.14, rather than deleting "or C-II" as shown in the attached mark-up, all text was removed and replaced with "There are no Seismic Category I concrete dams in the ESBWR design."

**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 has been deleted from DCD Tier 2, Subsections 3.7.3 and 3.7.2.9.

**DCD/LTR Impact**

DCD Tier 2 Subsections 3.7.3 and 3.7.2.9 has been revised as noted in the attached markup.

## 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

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 Subsection 3.7.3.3.1 has been revised as noted in the attached markup.

**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. .

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.7.3.3.3 has been revised as noted in the attached markup.

**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**

$S_y$ is a typo and has been changed to $S_m$ in DCD Tier 2 Subsections 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 Subsection 3.9.3.3 has been changed in DCD Tier 2, in addition to a sentence added to Subsection 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 Subsection 3.9.3.3, Subsection 3.9.3.4 and Table 3.9-9 has been revised as noted in the attached markup.

## NRC RAI 3.12-19

*DCD Tier 2, Section 3.7.1.2 and Table 3.7-1 specify damping values to be used in the seismic analysis of SSCs. The DCD indicates that ASME Code Case N-411-1 may be used as permitted by RG 1.84 in place of Regulatory Guide 1.61 damping values. As indicated in RAI 3.12-2, Code Case N-411 has been annulled by the ASME. The DCD also indicates that ASME Code Case N-411-1 damping cannot be used for analyzing linear energy absorbing supports designed in accordance with ASME Code Case N-420. Indicate whether the damping values, corresponding to Code Case N-411-1 and meeting the conditions listed in Table 4 of RG 1.84, Rev. 33, will be used for the independent support motion (ISM) method. If the Code Case N-411-1 will be used, then provide the technical basis for using these damping values with the ISM method.*

## GE Revised Response

References to ASME Code Case N-411-1 has been deleted from Section 3.7 in DCD Revision 2 Subsection 3.7.1.2, Subsection 3.7.3.5 and Table 3.7-1 footnote 1. To maintain this option in the ESBWR design, N-411-1 damping curve and associated conditions permitted by RG 1.84, including the limitations for use with the ISM method, will be explicitly described.

New figure 3.7-37 note 4 has been modified to address annulled Code Case N-420.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.7.1.2, Subsection 3.7.3.5 and Table 3.7-1 footnote 1 have been revised as noted in the attached markup.

**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 Subsection 3.7.2.7: The ZPA cut-off frequency is 100 Hz or the rigid frequency as defined in figure 2 and 3 of RG 1.92 rev. 2.

In Subsection 3.7.3.1: For equipment analysis, refer to requirements of Step 1 of Subsection 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 DCD Subsections 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), Subsections 3.9.1.4, 3.9.2.2.1, and 3.9.2.2.2, Section 3.10, and Subsection 3D.4.1.

**DCD/LTR Impact**

DCD Tier 2 sections Subsections 3.7.2.7, 3.7.3.1, 3.9.1.4, 3.9.2.2.1, and 3.9.2.2.2, Section 3.10 and Tables 1.9-21 and 1.9-21a have been revised as noted in the attached markup.

**NRC RAI 3.12-23**

*Provide the analysis method that will be used to perform the fatigue evaluation of ESBWR Class 2, 3, and Quality Group D piping systems that are subject to cyclic loadings. Also, discuss how the environmental effects are considered in the Code Class 2 and 3 piping for which a fatigue analysis is performed.*

**GE Revised Response**

The Class 2 and Class 3 analyses are performed in accordance with the stress limits specified in NC-3611.2. The allowable stress reduction coefficient, *f*, is in accordance with Table NC-3611.2-1. 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 the DCD and the ASME code will be performed.

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.9.3.4 has been revised as noted in the attached markup.

## 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.

The problem of injection of cold water through the stem seal connection of a normally closed gate valve could theoretically occur in the following cases:

2.1 Nuclear Boiling System (B21) RPV head vent piping drain line isolation valves. In the ESBWR globe type valves with bellow seals are provided to prevent leaking from occurring.

## DCD/LTR Impact

No DCD changes will be made in response to this RAI.

## NRC RAI 3.12-25

*The effects of thermal stratification have been observed in both BWR and PWR feedwater piping as discussed in NRC Information Notice (IN) 84-87 and NRC IN 91-38. Described the method of analysis used in the ESBWR feedwater piping design to include the thermal stratification effects.*

## GE Revised Response

IN 84-87 and IN 91-38 deal with the thermal stratification in Washington Nuclear Plant Unit 2, WNP-2 (BWR) and in Beaver Valley Unit 1, BV-1 (PWR). As indicated in IN 91 38, the three-loop design of BV 1 is especially prone to global thermal stratification in the feedwater pipes, which typically include long horizontal sections. Additionally, BWR plants are sensitive to the stratification effect during start-up when cold water is fed through preheated pipes.

The ABWR feedwater piping circumferential temperatures has been measured at various locations during startup and shutdown tests. The testing also included various designed operation transients. These test data, plus conservatisms, have been incorporated into the design duty cycle diagrams. Therefore, all the stratifications data are parts of the feedwater design requirements.

PISYS computer program has been written to calculate the piping forces and moments due to stratification. The solution has been benchmarked with ANSYS computer program results and exact solution by hand calculation for simple cases. The results of the stratification are included in the thermal cases. For ABWR feedwater piping analyses, there are 46 thermal cases calculated. Therefore, the thermal stratification effects have been incorporated in Equations 10 through 14 of NB-3650.

Furthermore, ESBWR have been designed to minimize the thermal stratification. In the case of WNP-2 (IN 84-87), an unusual design feature of the WNP-2 plant allows the feedwater system to be heated by the reactor water cleanup system (RWCU). The RWCU return lines join two 24-inch feedwater lines upstream from two isolation check valves, but downstream from normally open motor-operated valves. In many boiling water reactors, the RWCU enters the feedwater system between the inboard and outboard isolation check valves so that reverse flow of the RWCUS into the feedwater system is impossible. In the case of the ESBWR, the RWCU/SDC feeds water into the Nuclear Boiler System (NBS) in the feedwater section between two check valves (Figure 5.1-2 Nuclear Boiler System Schematic Diagram), so reverse flow of the RWCU/SDC into the feedwater system is impossible. {See NEDC-33084P Revision 1 page 3.1-27, GE proprietary information}.

In the case of the BV-1 (IN 91-38), the longest horizontal section in the ESBWR design is of approximate 50 ft. In addition, this section has the anti-stratification RWCU/SDC connection. Furthermore, within the containment, the feedwater line has seven direction changes before the connection to the RPV.

To confirm that the thermal stratification inputs to the piping analysis are conservative, the initial ESBWR plant will be required to perform thermal stratification testing on the feedwater system piping. Additional stratification testing has been added to DCD Tier 2 Subsection 3.9.2.1.2.

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.9.2.1.2 has been revised as noted in the attached markup.

## NRC RAI 3.12-26

*Describe the SRV design parameters and criteria that will need to be specified to the COL applicant to ensure that the specific piping configuration and SRVs purchased and installed at the COL applicant stage will match the test and design parameters used at the design certification state. An example is the minimum rise time for the SRV valve operation; this can greatly affect the transient loads imposed on the piping system analysis. Also, any change in the discharge piping system configuration may affect the SRV loadings.*

## GE Revised Response

Many of the SRV design parameters and criteria are specified in Sections 5.2 and 15.2 of the DCD. The procurement specification for the SRV, that will be prepared by GE, will define the SRV requirements that are necessary to be consistent with the SRV parameters used in the steam line stress analysis that supports the ESBWR certification.

The SRV opening time for forcing function analysis (20 msec) is defined in the piping design specification 26A6910 "ASME Code, Section III Class-1 Main Steam Piping System", Subsection 5.2.2.4..

## DCD/LTR Impact

DCD Tier 2 Subsection 3.9.3.6 has been revised as noted in the attached markup.

## NRC RAI 3.12-28

*The DCD did not indicate whether piping thermal analyses of piping systems will be performed for all temperature conditions above ambient. If this is not the case, then provide the minimum temperature at which an explicit piping thermal expansion analysis would be required. Also, provide the technical basis for the selected minimum temperature.*

## GE Revised Response

For Class 1 piping, all the operating temperatures above ambient or below ambient are included in the fatigue analysis. Even the ambient temperature is included as a load set with defined cycles. The stress free state of a piping system is defined as a temperature of 21°C (70°F) for Class 1, 2, 3 or B31.1 piping. For Class 2, 3 or B31.1 piping, no thermal expansion analysis will be performed for piping with system operating temperature of 65°C (150°F) or less.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.9.3.1 has been revised as noted in the attached markup.

## NRC RAI 3.12-29

*DCD Tier 2, Appendix 3K, Section 3K.2, acknowledges that, as part of the resolution of the intersystem LOCA issue, the staff requires in addition to other requirements, that periodic surveillance and leak rate testing of the pressure isolation valves via Technical Specifications, as part of the ISI program. Indicate where in the DCD is the requirement that the COL applicant must perform this periodic surveillance and leak rate testing.*

## GE Revised Response

DCD Tier 2 Appendix 3K, Section 3K2 describes NRC positions related to the design of low pressure piping system that interface with reactor coolant pressure boundary. These positions, which were developed during NRC review of ABWR, were taken into consideration in the development of ESBWR design.

The question describes an NRC requirement on surveillance and leak rate testing of the pressure isolation valve between reactor coolant pressure boundary and a low pressure system. Because there is no such kind of pressure isolation valves identified in ESBWR, this NRC requirement is not applied in the ESBWR design. This was the conclusion that was reached in reviewing the individual systems in conjunction with the conditions identified in NUREG 0677 that must exist in order for an Intersystem LOCA to occur. In every case, where closed valves exist in a system that provide a transition from high to low pressure, there are upstream (high pressure side) isolation valves that are available to isolate a leak or failure in the closed pressure transition valve. Additionally, there are relief valves on the low pressure side of the piping to provide pressure relief in the event of leakage or failure. The evaluation of individual systems is contained in Appendix 3K of the DCD.

For clarification, the following statement has been added in Section 3K2 of the next revision of DCD Tier 2. "The periodic surveillance and leak rate testing requirements for high-pressure to low-pressure isolation valves are not applicable to the ESBWR, because, as shown in this appendix, the ESBWR design does not contain a pressure isolation valve between the reactor coolant pressure boundary and a low pressure piping system."

## DCD/LTR Impact

DCD Tier 2 section 3.K.2 has been revised as noted in the attached markup.

## 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

The paragraph "The building structure...supported pipe" has been 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 Subsection 3.9.3.7.1 has been revised and Tables 3.9-10, 3.9-11 and 3.9-12 has been added as noted in the attached markup.

**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**

(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 Subsection 3.9.3.7 has been revised as noted in the attached markup.

## NRC RAI 3.12-32

*DCD Tier 2, Section 3.7.3.3.1, provides some limited information about modeling the stiffness of guides and snubbers by using representative stiffness values. Some additional information about snubbers is provided in DCD Tier 2, Section 3.9.3.7.1, which describes the procedures to ensure that the spring constant achieved by the snubber supplier matches the spring constant used in the piping system model. However, the DCD does not adequately describe how the representative stiffness values are developed for all supports other than snubbers. Therefore, describe (1) the approach used to develop the representative stiffness values, (2) the procedure that will be imposed to ensure that the final designed supports match the stiffness values assumed in the piping analysis, (3) the procedure used to consider the mass (along with the support stiffness) if the pipe support is not dynamically rigid, and (4) the same information [(1), (2), and (3) above] for the building steel/structure (i.e., beyond the NF jurisdictional boundary) and for equipment to which the piping may be connected to.*

## GE Revised Response

(1) Standard stiffness values developed for a ABWR project will be used.

(2) Pipe supports will be designed and qualified to satisfy stiffness values used in the piping analysis. For struts, snubbers, the stiffness to consider is the combined stiffness of strut, snubber, pipe clamp and piping support steel.

(3) In general, pipe support component weights, which are directly attached to a pipe such as a Clamp, Strut, Snubber and Trapeze are considered in piping analysis. Frame type supports will be designed to carry it's own mass and will be subjected to deflection requirements. A maximum deflection of 1/16 inch is used for normal operating conditions, and 1/8 inch is used for abnormal conditions. For other types of supports, either demonstrate that the support is dynamically rigid, or demonstrate that one half of the support mass is less than 10% of the mass of the straight pipe segment of the span at the support location, to preclude amplification. Otherwise, the contribution of the support weight amplification is added into the piping analysis.

(4) The stiffness for the building steel/structure (i.e., beyond the NF jurisdictional boundary) are not considered in pipe support overall stiffness. Response spectra input to the piping system includes flexibility of the building structure. When attachment to a major building structure is not possible, any intermediate structures included in the analysis of the pipe support.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.7.3.3.1 has been revised as noted in the attached markup.

## NRC RAI 3.12-33

*DCD Tier 2, Section 3.7.3 and 3.9.3 do not provide a description of the analysis methods or design requirements needed to evaluate the effects of seismic and other dynamic (support) self-weight excitation for ESBWR pipe supports. Provide this information, which is especially important for the larger and more massive type supports. The description should consider these effects on the support structure and anchorage. In addition, the description should consider all loads transmitted from the piping to the support and the support internal loads caused by self-weight, thermal, and inertia effects due to the support mass.*

## GE Revised Response

The ESBWR pipe supports will be designed to meet the stiffness values used in the piping analysis.

In general, pipe support weight, such as snubber clamp or strut clamp on the pipe, is considered in piping analysis. The larger and more massive type supports will be evaluated to include the impact of self-weight excitation on support structure and anchorage in detail along with piping analyzed loads.

Pipe supports will be evaluated to include the impact of self-weighted excitation on support structure and anchorage in detail along with piping analyzed loads where this effect may be significant.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.7.3.3.1 has been revised as noted in the attached markup.

## NRC RAI 3.12-34

*DCD Tier 2, Section 3.9.3.7, describes the criteria and design requirements for piping supports of ESBWR piping. However, the DCD does not describe how friction loads imparted on pipe*

## GE Revised Response

The friction loads caused by unrestricted motion of the piping due to piping 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 piping support structures.

## DCD/LTR Impact

DCD Tier 2 Subsection 3.9.3.7.1 has been revised as noted in the attached markup.

**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.

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.9.3.7.1 has been revised as noted in the attached markup.

**NRC RAI 3.12-36**

*DCD Tier 2, Section 3.9.3.7, describes the criteria and design requirements for piping supports of ESBWR piping. However, the DCD does not provide any information on the analysis and design criteria for information line supports. Provide this information*

**GE Response**

The small bore lines (e.g. small branch and instrumentation lines) will be supported taking into account the flexibility and thermal and dynamic motion requirements of the pipe to which they connect. DCD Tier 2 Rev. 1 Subsection 3.7.3.16 details 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.

**DCD/LTR Impact**

DCD Tier 2 Subsection 3.9.3.7.1 has been revised as noted in the attached markup.

**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**

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 Subsection 3.9.3.7.1 has been revised as noted in the attached markup.

**Table 1.9-21**

**NRC Regulatory Guides Applicability to ESBWR**

| RG No. | Regulatory Guide Title | Appl. Rev. | Issued Date | ESBWR Appli-cable? | Comments |
|---|---|---|---|---|---|
| 1.88 | Collection, Storage, and Maintenance of Nuclear Power Plant Quality Assurance Records | | Super-ceded | | See Table 1.9-21b. Withdrawn 07/31/1991 |
| 1.89 | Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants | 1 | 06/1984 | Yes | Source term requirements superceded by RG 1.183. |
| 1.90 | Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons | 1 | 08/1977 | No | Reinforced Concrete used |
| 1.91 | Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants | 1 | 02/1978 | — | COL |
| 1.92 | Combining Modal Responses and Spatial Components in Seismic Response Analysis | 2~~1~~ | ~~02/1976~~ 07/2006 | Yes | URD optimization – see Table 1.9-21a. ~~See also proposed Rev 2 published 08/2001 as DG-1108.~~ |
| 1.93 | Availability of Electric Power Sources | 0 | 12/1974 | Part | No safety-related diesels. Therefore, only DC portion (Item 5) is applicable. URD intent: see Table 1.9-21a |

**Table 1.9-21a**

**EPRI Intent and Optimization Topics**

| Reg. Guide | Topic Type | URD* Section | Comment |
|---|---|---|---|
| 1.75 | Intent | 4.20.3 | Safe shutdown relies only upon DC-derived power and will meet the design requirements for physical independence. |
| 1.76 | Optim | 2.1.2.2 | Basis will be from National Severe Storms Forecast Center (NSSFC) for a 147.5 m/s (330 mph) tornado. |
| 1.92 | Optim | 2.1.1.2 | Revise analysis method to permit algebraic combination of high frequency modes for vibratory loads with significant high frequency input ~~33~~ above 100 Hz or the rigid frequency as defined in Figure 2 and Figure 3. Reference to OBE provisions deleted. |
| 1.93 | Intent | 4.22 | The ESBWR is designed to shut down safely without reliance on offsite or diesel-generator-derived AC power. |
| 1.96 | Optim | 2.3.1.2 | Leakage control not required. |
| 1.96 | Optim | 2.5.2 | Use a passive plant-specific physically-based source term. |
| 1.97 | Optim | 2.3.2.2 | PASS simplification. |
| 1.97 | Optim | 2.1.3.3 | Offsite Emergency planning simplification. |
| 1.99 | Optim | 2.1.1.2 | Revise for equipment to remain functional for "continued operation of the plant" and for OBE classification. |
| 1.108 | Intent | 4.23 | The ESBWR is designed with passive safety systems to maintain core cooling and containment integrity without reliance on offsite or diesel-generator-derived AC power. |
| 1.122 | Optim | 2.1.1.2 | Revised to allow spectral shifting techniques as an alternative. |
| 1.137 | Intent | 4.24 | The ESBWR is designed to shut down safely without reliance on offsite or diesel-generator-derived AC power. |
| 1.139 | Optim | 2.5.6 | Passive decay heat removal system without Cold Shutdown requirement. The NRC, in a June 30, 1994 staff requirements memorandum (SRM), has approved the position proposed in SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs." This position accepts 215.6°C (420°F) or below, rather than the cold shutdown specified in RG 1.139, "Guidance for Residual Heat Removal," as the safe stable condition that the passive decay heat removal system must be capable of achieving and maintaining following non-LOCA events. |

## Table 1.9-22

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

| Code or Standard Number | Year | Title |
|---|---|---|
| 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 |
| 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 | ~~2004~~2001 including Addenda through 2003 | Boiler & Pressure Vessel Code (BPVC) Section I, Rules for Construction of Power Boilers |
| BPVC Sec II | ~~2004~~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 | ~~2004~~2001 including Addenda through 2003 | BPVC Section III, Rules for Construction of Nuclear ~~Power Plant~~Facility Components<br><br>Division 1: NB, NC, ~~NCA,~~ ND, ~~NE,~~ NF, NG<br>~~Division 2: CC, NCA~~<br>~~Code for Concrete Reactor Vessels and Containments~~ |
| BPVC Sec V | ~~2004~~2001 including Addenda through 2003 | BPVC Section V: Nondestructive Examination |
| BPVC Sec VIII | ~~2004~~2001 including Addenda through 2003 | BPVC Section VIII: Rules for Construction of Pressure Vessels<br>Div. 1 ~~Rules for Construction of Pressure Vessels~~<br>Div. 2 ~~Pressure Vessel,~~ Alternative Rules |
| BPVC Sec IX | ~~2004~~2001 including Addenda through 2003 | BPVC Section IX, ~~Qualification Standard for~~ Welding and Brazing Qualifications~~Procedures Welder, Brazers and Welding and Brazing Operators~~ |
| BPVC Sec XI | ~~2004~~2001 including Addenda through 2003 | BPVC Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components |

## Table 1.9-22

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

| Code or Standard Number | Year | Title |
|---|---|---|
| BPVC OM Code | ~~2004~~2001 including Addenda through 2003 | BPVC Code for Operation and Maintenance of Nuclear Power Plants |
| ASME Steam Tables | 1967 | Thermodynamic and Transport Properties of Steam |
| American Society for Testing and Materials (ASTM) | | |
| A36/A36M-04 | 2004 | Standard Specification for Carbon Structural Steel |
| A106/A106M-04b | 2004 | Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service |
| A126-04 | 2004 | Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings |
| A240/A240M-05 | 2005 | Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications |
| A307-04 | 2004 | Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength |
| A325-04b | 2004 | Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength |
| A370-05 | 2005 | Standard Test Methods and Definitions for Mechanical Testing of Steel Products |
| A395/A395M-99 | 1999 (R 2004) | Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures |
| A513-00 | 2000 | Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing |
| A516/A516M-05e1 | 2005 | Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service |
| A519-03 | 2003 | Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing |
| A530/A530M-04a | 2004 | Standard Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe |
| A536-84 | 1984 (R 2004) | Standard Specification for Ductile Iron Castings |
| A572/A572M-04 | 2004 | Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel |
| A576-90b | 1990 (R 2000) | Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality |
| A615/A615M-05a | 2005 | Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement |
| A709/A709M-05 | 2005 | Standard Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges |

**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~~1~~ | Stress Indices for Structure Attachments, Class 1, Section III, Division 1. | Piping | Accepted per RG 1.84 |
| ~~N-247~~ | ~~Certified Design Report Summary for Component Standard Supports, Section III, Division 1, Classes 1, 2, 3 and MC.~~ | ~~Component Support~~ | ~~Accepted per RG 1.84~~ |
| 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 | ~~Conditionally~~ 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 |

**Table 5.2-1**

**Reactor Coolant Pressure Boundary Components (Applicable Code Cases)**

| Number | Title | Applicable Equipment | Remarks |
|---|---|---|---|
| N-392-3 | Procedure for Evaluation of the Design of Hollow Circular Cross-Section Welded Attachments on Classes 2 and 3 Piping, Section III, Division 1. | Piping | Accepted per RG 1.84 |
| N-580-1 | Use of Alloy 600 With Columbium Added, Section III, Division 1. | Core Support | Accepted per RG 1.84 |
| ~~N-608~~ | ~~Applicable Code Edition and Addenda, NCA-1140(a)(2), Section III, Division 1.~~ | ~~All Code Components~~ | ~~Accepted per RG 1.84~~ |
| N-632 | Use of ASTM A 572, Grades 50 and 65 for Structural Attachments to Class CC Containment Liners, Section III, Division 2. | Containment | Accepted per RG 1.84 |
| N-634 | Alternatives to the Provisions of CC-2511 for Structural Attachments to Class CC Containment Liners, Section III, Division 2. | Containment | Not Listed in RG 1.84 |
| N-236-1 | Repair and Replacement of Class MC Vessels | Containment | Conditionally Accepted Per RG 1.147 |
| N-307-2 | Revised Examination Volume for Class 1 Bolting, Table IWB-2500-1, Examination Category B-G-1, when the Examinations are Conducted from the Drilled Hole | RPV Studs | Accepted per RG 1.147 |
| N-416-3~~2~~ | Alternative Rules for Hydrostatic Testing of Repair or Replacement of Class 2 Piping | Piping | ~~Conditionally~~ Accepted Per RG 1.147 |
| N-435-1 | Alternative Examination Requirements for Vessels with | Class 2 Vessels | Accepted Per RG 1.147 |

**Table 5.2-1**

**Reactor Coolant Pressure Boundary Components (Applicable Code Cases)**

| Number | Title | Applicable Equipment | Remarks |
|---|---|---|---|
| | Wall Thicknesses 2 in. or Less | | |
| N-457 | Qualification Specimen Notch Location for Ultrasonic Examination of Bolts and Studs | Bolts and Studs | Accepted Per RG 1.147 |
| N-460 | Alternative Examination Coverage for Class 1 and 2 Welds | Class 1 & 2 Components and Piping | Accepted Per RG 1.147 |
| ~~N-463-1~~ | ~~Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514-2~~ | ~~Piping~~ | ~~Accepted Per RG 1.147~~ |
| ~~N-479-1~~ | ~~Boiling Water Reactor (BWR) Main Steam Hydrostatic Test~~ | ~~Main Steam System~~ | ~~Accepted Per RG 1.147~~ |
| N-491-2 | Alternative Rules for Examination of Class 1, 2, 3 and MC Component Supports of Light Water Cooled Power Plants | Component Supports | Not Listed in RG 1.147 |

**DCD Markup for Section 3.7**

**[NOTES IN GREEN HIGHLIGHT ADJACENT TO SUBSECTION HEADINGS THAT CONTAINED CHANGES]**

# 3.7 SEISMIC DESIGN

## 3.7.1 Seismic Design Parameters

### *3.7.1.1 Design Ground Motion*

### *3.7.1.2 Percentage of Critical Damping Values[RAI 3.12-2(a), 3.12-19]*

Damping values of various structures and components are shown in Table 3.7-1 for use in SSE dynamic analysis. These damping values are consistent with Regulatory Guide 1.61 SSE damping except for the damping value of cable trays and conduits.

The damping values shown in Table 3.7-1 and Figure 3.7-36 for cable trays and conduits are based on the results of over 2000 individual dynamic tests conducted by Bechtel/ANCO for a variety of raceway configurations (Reference 3.7-5). The damping value of cable tray systems (including supports) depends on the level of input motion and the amount of cable fill. In the acceleration range of interest to the ESBWR design, the damping value is 7% for empty trays, and it increases to 20% for 50% to fully loaded trays. For trays loaded to less than 50% the damping value can be obtained by linear interpolation. The damping value of conduit systems (including supports) is 7% constant. For HVAC ducts and supports the damping value is 7% for companion angle or pocket lock construction and is 4% for welded construction.

For ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems, damping values specified in Figure 3.7-37 may be used.~~ of ASME Code Case N-411-1 may be used as permitted by Regulatory Guide 1.84, in place of Regulatory Guide 1.61 damping. ASME Code Case N-411-1 damping cannot be used for analyzing linear energy absorbing supports designed in accordance with ASME Code Case N-420~~. The damping values shown in Table 3.7-1 are applicable to all modes of a structure or component constructed of the same material. Damping values for systems composed of subsystems with different damping properties are obtained using the procedures described in Subsection 3.7.2.13.

## 3.7.2 Seismic System Analysis

### *3.7.2.1 Seismic Analysis Methods*

#### 3.7.2.1.1 Time History Method [RAI 3.12-4, 3.12-5]

The response of a multi-degree-of-freedom linear system subjected to external forces and/or uniform support excitations is represented by the following differential equations of motion in the matrix form:

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

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 approach for selecting the time step, Δt, is 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,

$$\{u\} = [\phi]\{q\} \tag{3.7-2}$$

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 the mode shapes (note that the orthogonality condition of the damping matrix is assumed). For systems subjected to base acceleration excitation, $\ddot{x}_g$, the equation of motion for the jth mode is

$$\ddot{q}_j + 2\lambda_j\omega_j\dot{q}_j + \omega_j^2 q_j = -\Gamma_j\ddot{x}_g \qquad (3.7\text{-}3)$$

where

$q_j$ = generalized coordinate of jth mode

$\lambda_j$ = damping ratio of jth mode, expressed as fraction of critical damping

$\omega_j$ = undamped circular frequency of jth mode

$\Gamma_j$ = modal participation factor of jth mode

= $\{\phi_j\}^T[M]\{1\} / (\{\phi_j\}^T[M]\{\phi_j\})$

The final solution for each mode is obtained by the transformation from the generalized coordinates back to the physical coordinates. The total response is the superposition of the modal responses. All modes with frequencies up to the zero period acceleration (ZPA) frequency are included in the modal superposition and the residual rigid response due to the missing mass is accounted for in accordance with the methods described in Subsection 3.7.2.7. Alternatively, the cutoff frequency may be selected to ensure that the number of modes included is sufficient such that inclusion of all truncated modes does not result in more than a 10% increase in total response.

The system equation of motion (Equation 3.7-1) can be solved directly using the direct integration method in the time domain without the need to revert to decoupling by the coordinate transformation for mode superposition.

The system equation of motion (Equation 3.7-1) can also be solved in the frequency domain using the complex frequency response method. This method requires that the transfer functions be determined first and the applied forces be transformed into frequency domain. The transfer functions can be computed directly from the system equations of motion or from the normal mode approach. The Fast Fourier Transform (FFT) algorithm is commonly used for the transformation between the time domain and frequency domain. To facilitate the FFT operation, the total number of digitized points of the excitation time history is a power of 2, which can always be achieved by adding trailing zeros to the actual record. For damped systems, these trailing zeros also serve as a quiet zone, which allows the transient response motions to die out at the end of the duration to avoid cyclic overlapping in the discrete Fourier transform procedure.

For multi-supported systems subjected to independent support motion, the ISM method of analysis described in Response Spectrum Method can also be performed using the time history method.

The frequency domain solution is not used in the piping system response analysis.

#### 3.7.2.1.2 Response Spectrum Method

#### 3.7.2.1.3 Static Coefficient Method [RAI 3.12-7]

This is an alternative method of analysis that allows a simpler technique in return for added conservatism. This method does not require determination of natural frequencies. The response loads are determined statically by multiplying the mass value by a static coefficient equal to 1.5 times the maximum spectral acceleration at appropriate damping value of the input response spectrum. A static coefficient of 1.5 is intended to account for the effect of both multi-frequency excitation and multi-mode response for linear frame-type structures, such as members physically similar to beams and columns, which can be represented by a simple model similar to those shown to produce conservative results (References 3.7-13 and 3.7-14). A factor of less than 1.5 may be used if justified. If the fundamental frequency of the structure is known, the highest spectral acceleration value at or beyond the fundamental frequency can be multiplied by a factor of 1.5 to determine the response. A factor of 1.0 instead of 1.5 can be used if the component is simple enough such that it behaves essentially as a single-degree-of-freedom system. When the component is rigid, it is analyzed statically using the Zero Period Acceleration (ZPA) as input. Structures, systems, and components are considered rigid when the fundamental frequency is equal to or greater than the frequency at which the input response spectrum returns to approximately the ZPA. Relative displacements between points of support are also considered and the resulting response is combined with the response calculated using the equivalent static method.

### 3.7.2.2 *Natural Frequencies and Responses*

### 3.7.2.3 *Procedures Used for Analytical Modeling*

### *3.7.2.4 Soil-Structure Interaction*

### *3.7.2.5 Development of Floor Response Spectra*

### *3.7.2.6 Three Components of Earthquake Motion*

### *3.7.2.7 Combination of Modal Responses [RAI 3.12-20]*

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 cut-off frequency is 100 Hz or the rigid frequency as defined in Figure 2 and 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:

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

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). |

Next, determine the fraction of DOF mass not included in the summation of these modes ($e_i$):

$$e_i = |d_i - \delta_{ij}| \quad (3.7\text{-}12)$$

where $\delta_{ij}$ is the Kronecker delta, which is one if DOFi is in the direction of the input motion and zero if DOFi is a rotation or not in the direction of the input motion. If, for any DOFi, the absolute value of this fraction $e_i$ exceeds 0.1, one should include the response from higher modes with those included in Step 1.

**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~~

~~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 $1/(1\pm0.15)$ 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 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 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 representative stiffness. The equivalent linear stiffness of the snubbers is based on actual dynamic tests performed on prototype snubber assemblies or on data provided by the vendor. ~~The stiffness of the supporting structures is included in the analysis, unless the supporting structure can be shown to be rigid.~~

Pipe supports will be designed and qualified to satisfy stiffness values used in the piping analysis. For struts, snubbers, the stiffness to consider is the combined stiffness of strut, snubber, pipe clamp and piping support steel.

In general, pipe support component weights, which are directly attached to a pipe such as a Clamp, Strut, Snubber, and Trapeze are considered in the piping analysis. Frame type supports will be designed to carry its own mass and will be subjected to deflection requirements. A maximum deflection of 1/16 inch is used for normal operating conditions, and 1/8 inch is used for abnormal conditions. For other types of supports, either demonstrate that the support is dynamically rigid, or demonstrate that one half of the support mass is less than 10% of the mass of the straight pipe segment of the span at the support location, to preclude amplification. Otherwise, the contribution of the support weight amplification is added into the piping analysis. Piping supports will be evaluated to include the impact of self-weight excitation on support structure and anchorage in detail along with piping analyzed loads where this effect may be significant.

The stiffness of the building steel/structure (i.e., beyond the NF jurisdictional boundary) is not considered in pipe support overall stiffness. Response spectra input to the piping system includes flexibility of the building structure. When attachment to a major building structure is not possible, any intermediate structures are included in the analysis of the pipe support.

#### 3.7.3.3.2 Equipment

#### 3.7.3.3.3 Modeling of Special Engineered Pipe Supports [RAI 3.12-13]

Modifications to the normal linear-elastic piping analysis methodology used with conventional pipe supports are 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, ~~these special devices are used,~~ the modeling and analytical methodology will be based on applicable design codes and allowables approved by the NRC. ~~shall be in accordance with methodology reviewed and accepted by the regulatory agency at the time of certification or at the time of application, per the discretion of the applicant that is submitted by the COL applicant~~. 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*

### *3.7.3.5 Analysis Procedure for Damping [RAI 3.12-19, 3.12-2(a)]*

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 ~~of ASME Code Case N-411-1~~ specified in Figure 3.7-37 may be used ~~as permitted by Regulatory Guide 1.84~~. 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*

### *3.7.3.7 Combination of Modal Responses*

### *3.7.3.8 Interaction of Other Systems with Seismic Category I Systems*

### *3.7.3.9 Multiply-Supported Equipment and Components with Distinct Inputs*

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

### *3.7.3.11 Torsional Effects of Eccentric Masses*

### *3.7.3.12 Effect of Differential Building Movements*

### *3.7.3.13 Seismic Category I Buried Piping, Conduits and Tunnels [RAI 3.12-9]*

For Seismic Category I(C-I) ~~or C-II~~ buried ~~piping,~~ conduits, tunnels, and auxiliary systems, the following items are considered in the analysis:

- Two types of ground shaking-induced loadings are considered for design:
  - Relative deformations imposed by seismic waves traveling through the surrounding soil or by differential deformations between the soil and anchor points.
  - Lateral earthquake pressures and ground-water effects acting on structures.
- ~~The effects of static resistance of the surrounding soil on piping deformations or displacements, differential movements of piping anchors or equipment, and bent geometry and curvature changes, etc., are considered. When applicable, procedures using the principles of the theory of structures on elastic foundations can be used.~~

- When applicable, the effects caused by local soil settlements, soil arching, etc., are considered in the analysis.

For ESBWR, there is no buried Seismic Category I piping.

### *3.7.3.14 Methods for Seismic Analysis of Seismic Category I Concrete Dams [RAI 3.12-9]*

For Seismic Category C-I ~~or C-II~~ concrete dams, if applicable to the site, the seismic analysis takes into consideration the dynamic nature of forces (due to both horizontal and vertical earthquake loadings), the behavior of the dam material under earthquake loadings, soil-structure interaction effects, and nonlinear stress-strain relations for the soil. FEM is the usual analytical tool used.

## 3.7.4 Seismic Instrumentation

## 3.7.5 COL Information

## 3.7.6 References [RAI 3.12-7]


3.7-1 International Building Code – 2003 by International Code Council, Inc. (300-214-4321).

3.7-2 Dominion Nuclear North Anna, LLC, "North Anna Early Site Permit Application," Revision 4, May 2005.

3.7-3 Exelon Generation Company, LLC, "Clinton Early Site Permit Application," Revision 0, September 2003.

3.7-4 System Energy Resources, INC, "Grand Gulf Early Site Permit Application," Revision 0, October 2003.

3.7-5 P. Koss, "Seismic Testing of Electrical Cable Support Systems, Structural Engineers of California Conference," San Diego, September 1979.

3.7-6 L. K. Liu, "Seismic Analysis of the Boiling Water Reactor, symposium on seismic analysis of pressure vessel and piping components, First National Congress on Pressure Vessel and Piping," San Francisco, California, May 1971.

3.7-7 M. P. Singh, "Seismic Design Input for Secondary Systems, ASCE Mini-Conference on Civil Engineering and Nuclear Power," Vol. II, Boston, April 1979.

3.7-8 ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary."

3.7-9 R. W. Clough et al., "Dynamics of Structure," McGraw-Hill, 1975.

3.7-10 Electric Power Research Institute, "Guidelines for Nuclear Plant Response to an Earthquake," EPRI NP-6695, December 1989.

3.7-11 Electric Power Research Institute, "A Criterion for Determining Exceedance of the Operating Basis Earthquake," EPRI NP-5930, July 1988.

3.7-12 Electric Power Research Institute, "Standardization of Cumulative Absolute Velocity," EPRI TR-100082, December 1991.

3.7-13 Stevenson, J.D., and LaPay, W.S. "Amplification Factors to be Used in Simplified Seismic Dynamic Analysis of Piping Systems." Presented at the ASME Pressure Vessels and Piping Conference, Miami Beach, FL, June 1974.

3.7-14 Lin, C.W. and Esselman, T.C. "Equivalent Static Coefficients for Simplified Seismic Analysis of Piping Systems." Proc., 7th International Conference on Structural Mechanics in Reactor Technology, August 1983.

**(1) Table 3.7-1**

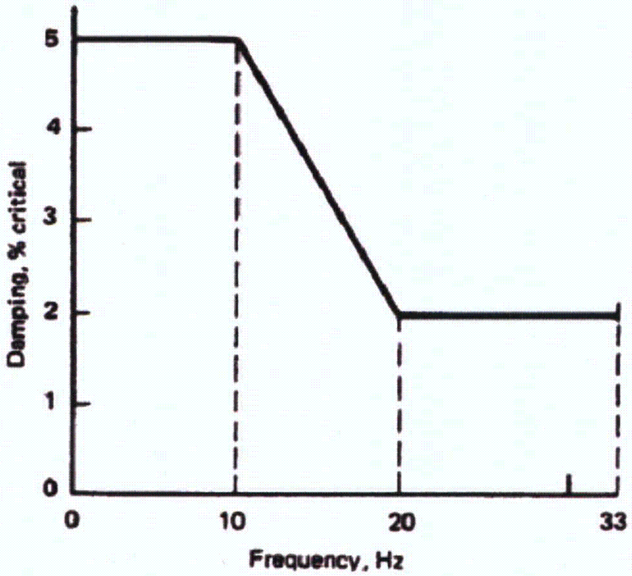
**Damping Values for SSE Dynamic Analysis**

| Components | Percent of Critical Damping |
|---|---|
| Reinforced concrete structures | 7.0 |
| Steel frame structures | 4.0 |
| Welded steel assemblies | 4.0 |
| Bolted steel assemblies | 7.0 |
| Equipment | 3.0 |
| Piping systems [1] | |
| - diameter greater than 305 mm (12 in) | 3.0 |
| - diameter less than or equal to 305 mm (12 in) | 2.0 |
| RPV, skirt, shroud, chimney, and separators | 4.0 |
| Control rod guide tubes and CRD housings | 2.0 |
| Fuel assemblies | 6.0 |
| Cable Trays | 20 (max)<br>(See Figure 3.7-36) |
| Conduits | 7.0 |
| HVAC ductwork | |
| - companion angle | 7.0 |
| - pocket lock | 7.0 |
| - welded | 4.0 |

[RAI 3.12-19, 3.12-2(a)]

[1] See Figure 3.7-37 for alternative ~~D~~damping values for response spectra analysis of ~~ASME Code Case N-411-1 may be used, as permitted by the USNRC Regulatory Guide 1.84, for~~ ASME Section III, Division 1, Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems. ~~These damping values are applicable in analyzing piping response for seismic and other dynamic loads filtering through building structures in high frequency range beyond 33 Hz.~~

[RAI 3.12-19]




Notes:

(1) The damping values specified should be used completely and consistently, if used at all.

(2) The damping values specified may be used only in those analysis in which current seismic spectra and procedures have been employed. Such use is to be limited only to response spectral analyses (similar to that used in the study supporting its acceptance, NUREG/CR-3526). The use with independent support motion or time history method is not permitted.

(3) When used for reconciliation work or for support optimization of existing designs, the effects of increased motion on existing clearances and on-line mounted equipment should be checked.

(4) The damping values specified are not used for analyzing the dynamic response of piping systems using linear energy absorbing supports designed to dissipate energy by yielding.

(5) The damping values specified are not applicable to piping in which stress corrosion cracking has occurred unless a case-specific evaluation is made and is reviewed by the NRC staff.

(6) The damping values specified are applicable in analyzing piping response for seismic and other dynamic loads filtering through building structures in high frequency range beyond 33 Hz.

**Figure 3.7-37. Alternative Damping Values for Response Spectra Analysis of ASME Section III, Division I Class 1, 2, and 3, and ASME/ANSI B31.1 Piping Systems.**

**DCD Markup for section 3.9**

[COMMENTS HIGHLIGHTED IN GREEN ADJACENT TO SUBSECTION HEADINGS THAT CONTAINED CHANGES]

## 3.9 MECHANICAL SYSTEMS AND COMPONENTS

### 3.9.1 Special Topics for Mechanical Components

#### *3.9.1.1 Design Transients*

#### *3.9.1.2 Computer Programs Used in Analyses*

#### *3.9.1.3 Experimental Stress Analysis*

#### *3.9.1.4 Considerations for the Evaluation of Faulted Condition*

[ONLY CHANGE TO PARAGRAPHS BELOW]

**Fuel Storage and Refueling Equipment** [RAI 3.12-20]

Refueling and servicing equipment and other equipment, which in the case of a failure would degrade a safety-related component, are defined in Section 9.1, and are classified per Table 3.2-1. These components are subjected to an elastic dynamic finite-element analysis to generate loadings. This analysis utilizes appropriate floor response spectra and combines loads at frequencies up to ~~33 Hz for seismic loads and up to 60 Hz for other dynamic loads~~ ZPA defined in subsection 3.7.2.7 in three directions. Imposed stresses are generated and combined for normal, upset, and faulted conditions. Stresses are compared, depending on the specific equipment, to Industrial Codes (ASME, ANSI), or Industrial Standards (AISC) allowables.

**Inelastic Analysis Methods** [RAI 3.12-8]

Inelastic analysis is only applied to ESBWR components to demonstrate the acceptability of two types of postulated events. Each event is an extremely low-probability occurrence and the equipment affected by these events would not be reused. These two events are as follows:

- postulated gross piping failure; and
- postulated blowout of a CRD housing caused by a weld failure.

The loading combinations and design criteria for pipe whip restraints utilized to mitigate the effects of postulated piping failures are provided in Subsection 3.6.2. Except for pipe whip restraints, inelastic analysis methods are not used in the ESBWR piping design and analysis.

The mitigation of the CRD housing attachment weld failure relies on components with regular functions to mitigate the weld failure effect. The components are specifically:

- core support plate;
- control rod guide tube;
- control rod drive housing;

- control rod drive outer tube; and
- bayonet fingers.

Only the bodies of the control rod guide tube, control rod drive housing and control rod drive outer tube are analyzed for energy absorption by inelastic deformation.

Inelastic analyses for the CRD housing attachment weld failure, together with the criteria used for evaluation, are consistent with the procedures described in Subsection 3.6.2 for the different components of a pipe whip restraint. Figure 3.9-1 shows the stress-strain curve used for the inelastic analysis.

## 3.9.2 Dynamic Testing and Analysis of Systems, Components and Equipment

### *3.9.2.1 Piping Vibration, Thermal Expansion and Dynamic Effects*

#### 3.9.2.1.1 Vibration and Dynamic Effects Testing

#### 3.9.2.1.2 Thermal Expansion Testing [RAI 3.12-25, only adding 3rd introductory paragraph]

A thermal expansion preoperational and startup testing program verifies that normal unrestrained thermal movement occurs in specified safety-related high- and moderate-energy piping systems. The testing is performed through the use of visual observation and remote sensors. The purpose of this program is to ensure the following:

- The piping system during system heatup and cooldown is free to expand and move without unplanned obstruction or restraint in the x, y, and z directions.
- The piping system does shake down after a few thermal expansion cycles.
- The piping system is working in a manner consistent with the predictions of the stress analysis.
- There is adequate agreement between calculated values and measured values of displacements.
- There is consistency and repeatability in thermal displacements during heatup and cooldown of the systems.

The general requirements for thermal expansion testing of piping systems are specified in Regulatory Guide 1.68, " Initial Test Programs for Water-Cooled Nuclear Power Plants." More specific requirements are defined in ASME OM S/G Part 7 "Requirements for Thermal Expansion Testing of Nuclear Power Plant Piping Systems." Detailed test specifications are prepared in full accordance with this standard and address such issues as prerequisites, test conditions, precautions, measurement techniques, monitoring requirements, test hold points and acceptance criteria. The development and specification of the types of measurements required, the systems and locations to be monitored, the test acceptance criteria, and the corrective actions that may be necessary are discussed in more detail below.

In addition to thermal expansion testing, the initial ESBWR plant shall also perform thermal stratification testing for the feedwater system piping. This testing shall be performed using external thermocouples on the pipe to confirm that the thermal stratification inputs to the piping analysis were conservative.

**DCD Markup for section 3.9**

***3.9.2.2 Seismic Qualification of Safety-Related Mechanical Equipment (Including Other RBV Induced Loads)***

**3.9.2.2.1 Tests and Analysis Criteria and Methods [3.12-20]**

The ability of equipment to perform its safety function during and after the application of a dynamic load is demonstrated by tests and/or analysis. The analysis is performed in accordance with Section 3.7. Selection of testing, analysis or a combination of the two is determined by the type, size, shape, and complexity of the equipment being considered. When practical, operability is demonstrated by testing. Otherwise, operability is demonstrated by mathematical analysis or by a combination between analysis and test.

Equipment, which is large, simple, and/or consumes large amounts of power, is usually qualified by analysis or static bend tests to show that the loads, stresses and deflections are less than the allowable maximum. Analysis and/or static bend testing is also used to show there are no natural frequencies below ~~33 Hz for seismic loads and 60 Hz for other RBV loads~~ZPA defined in subsection 3.7.2.7. If a natural frequency lower than ZPA defined in subsection 3.7.2.7 ~~33 Hz in the case of seismic loads and 60 Hz~~ in the case of other RBV induced loads is discovered, dynamic tests and/or mathematical dynamic analyses may be used to verify operability and structural integrity at the required dynamic input conditions.

When the equipment is qualified by dynamic test, the response spectrum or time history of the attachment point is used in determining input motion.

Natural frequency may be determined by running a continuous sweep frequency search using a sinusoidal steady-state input of low magnitude. Dynamic load conditions are simulated by testing, using random vibration input or single frequency input (within equipment capability) over the frequency range of interest. Whichever method is used, the input amplitude during testing envelops the actual input amplitude expected during the dynamic loading condition.

The equipment being dynamically tested is mounted on a fixture, which simulates the intended service mounting and causes no dynamic coupling to the equipment. Other interface loads (nozzle loads, weights of internal and external components attached) are simulated.

Equipment having an extended structure, such as a valve operator, is analyzed by applying static equivalent dynamic loads at the center of gravity of the extended structure. In cases where the equipment structural complexity makes mathematical analysis impractical, a static bend test is used to determine spring constant and operational capability at maximum equivalent dynamic load conditions.

[Only changes in above paragraph]

**3.9.2.2.2 Qualification of Safety-Related Mechanical Equipment**

[ONLY CHANGE TO PARAGRAPHS BELOW]

**DCD Markup for section 3.9**

**Other ASME Code Section III Equipment** [RAI 3.12-20]

Other equipment, including associated supports, is qualified for seismic and other RBV loads to ensure its functional integrity during and after the dynamic event. The equipment is tested, if necessary, to ensure its ability to perform its specified function before, during, and following a test.

Dynamic load qualification is done by a combination of test and/or analysis as described in Subsection 3.9.2.2. Natural frequency, when determined by an exploratory test, is in the form of a single-axis continuous-sweep frequency search using a sinusoidal steady-state input at the lowest possible amplitude, which is capable of determining resonance. The search is conducted on each principal axis with a minimum of two continuous sweeps over the frequency range of interest at a rate no greater than one octave per minute. If no resonances are located, then the equipment is considered rigid and single frequency tests at every 1/3 octave frequency interval are acceptable. Also, if all natural frequencies of the equipment are greater than ~~33 Hz for seismic loads and 60 Hz for other RBV loads~~ZPA defined in subsection 3.7.2.7, the equipment may be considered rigid and analyzed statically as such. In this static analysis, the dynamic forces on each component are obtained by concentrating the mass at the center of gravity and multiplying the mass by the appropriate floor acceleration. The dynamic stresses are then added to the operating stresses and a determination made of the adequacy of the strength of the equipment. The search for the natural frequency is done analytically if the equipment shape can be defined mathematically and/or by prototype testing.

If the equipment is a rigid body while its support is flexible, the overall system can be modeled as a single-degree-of-freedom system consisting of a mass and a spring. The natural frequency of the system is computed; then the acceleration is determined from the floor response spectrum curve using the appropriate damping value. A static analysis is then performed using this acceleration value. In lieu of calculating the natural frequency, the peak acceleration from the spectrum curve is used. The critical damping values for welded steel structures from Table 3.7-1 are employed.

If the equipment cannot be considered as a rigid body, it can be modeled as a multi-degree-of-freedom system. It is divided into a sufficient number of mass points to ensure adequate representation. The mathematical model can be analyzed using modal analysis technique or direct integration of the equations of motion. Specified structural damping is used in the analysis unless justification for other values can be provided. A stress analysis is performed using the appropriate inertial forces or equivalent static loads obtained from the dynamic analysis of each mode.

For a multi-degree-of-freedom modal analysis, the modal response accelerations can be taken directly from the applicable floor response spectrum. The maximum spectral values within ±10% band of the calculated frequencies of the equipment are used for computation of modal dynamic response inertial loading. The total dynamic stress is obtained by combining the modal stresses. The dynamic stresses are added to the operating stresses using the loading combinations stipulated in the specific equipment specification and then compared with the allowable stress levels.

If the equipment being analyzed has no definite orientation, the worst possible orientation is considered. Furthermore, equipment is considered to be in its operational configuration (i.e., filled with the appropriate fluid and/or solid). The investigation ensures that the point of maximum stress is considered. Lastly, a check is made to ensure that partially filled or empty equipment does not result in higher response than the operating condition. The analysis includes evaluation of the effects of the calculated stresses on mechanical strength, alignment, electrical performance (microphonics, contact bounce, etc.) and non-interruption of function. Maximum displacements are computed and interference effects determined and justified.

Individual devices are tested separately, when necessary, in their operating condition. Then the component to which the device is assembled is tested with a similar but inoperative device installed upon it.

The equipment, component, or device to be tested is mounted on the vibration generator in a manner that simulates the final service mounting. If the equipment is too large, other means of simulating the service mounting are used. Support structures such as consoles, racks, etc., may be vibration tested without the equipment and/or devices being in operation provided they are performance tested after the vibration test. However, the components are in their operational configuration during the vibration test. The goal is to determine that, at the specified vibratory accelerations, the support structure does not amplify the forces beyond that level to which the devices have been qualified.

Alternatively, equipment may be qualified by presenting historical performance data, which demonstrates that the equipment satisfactorily sustains dynamic loads which are equal to greater than those specified for the equipment and that the equipment performs a function equal to or better than that specified for it.

Equipment for which continued function is not required after a seismic and other RBV loads event, but whose postulated failure could produce an unacceptable influence on the performance of systems having a primary safety function, are also evaluated. Such equipment is qualified to the extent required to ensure that an SSE including other RBV loads, in combination with normal operating conditions, would not cause unacceptable failure. Qualification requirements are satisfied by ensuring that the equipment in its functional configuration, complete with attached appurtenances, remains structurally intact and affixed to the interface. The structural integrity of internal components is not required; however, the enclosure of such components is required to be adequate to ensure their confinement. Where applicable, fluid or pressure boundary integrity is demonstrated. With a few exceptions, simplified analytical techniques are adequate for this purpose.

Historically, it has been shown that the main cause for equipment damage during a dynamic excitation has been the failure of its anchorage. Stationary equipment is designed with anchor bolts or other suitable fastening strong enough to prevent overturning or sliding. The effect of friction on the ability to resist sliding is neglected. The effect of upward dynamic loads on overturning forces and moments is considered. Unless specifically specified otherwise, anchorage devices are designed in accordance with the requirements of the Code, Subsection NF, or ANSI/AISC - N690 and ACI 349.

Dynamic design data are provided in the form of acceleration response spectra for each floor area of the equipment. Dynamic data for the ground or building floor to which the equipment is attached are used. For the case of equipment having supports with different dynamic motions, the most severe floor response spectrum is applied to all of the supports.

Refer to Subsection 3.9.3.5 for additional information on the dynamic qualification of valves.

### *3.9.2.3 Dynamic Response of Reactor Internals Under Operational Flow Transients and Steady-State Conditions*

### *3.9.2.4 Initial Startup Flow-Induced Vibration Testing of Reactor Internals*

### *3.9.2.5 Dynamic System Analysis of Reactor Internals Under Faulted Conditions.*

### *3.9.2.6 Correlations of Reactor Internals Vibration Tests with the Analytical Results*

## 3.9.3 ASME Code Class 1, 2 and 3 Components, Component Supports and Core Support Structures

### *3.9.3.1 Loading Combinations, Design Transients and Stress Limits [RAI 3.12-28]*

This section delineates the criteria for selection and definition of design limits and loading combination associated with normal operation, postulated accidents, and specified seismic and other reactor building vibration (RBV) events for the design of safety-related ASME Code components (except containment components which are discussed in Section 3.8).

This section discusses the ASME Class 1, 2, and 3 equipment and associated pressure-retaining parts and identifies the applicable loadings, calculation methods, calculated stresses, and allowable stresses. A discussion of major equipment is included on a component-by-component basis to provide examples. Design transients and dynamic loading for ASME Class 1, 2 and 3 equipment are covered in Subsection 3.9.1.1. Seismic-related loads and dynamic analyses are discussed in Section 3.7. The suppression pool-related RBV loads are described in Appendix 3B. Table 3.9-1 presents the plant events to be considered for the design and analysis of all ESBWR ASME Code Class 1, 2, and 3 components, component supports, core support structures and equipment. Specific loading combinations considered for evaluation of each specific equipment are derived from Table 3.9-2 and are contained in the design specifications and/or design reports of the respective equipment (see Subsection 3.9.9.4 for COL information).

Specific load combinations and acceptance criteria for Class 1 piping are shown in Table 3.9-9. Also for Class 1 piping, all the operating temperatures above ambient or below ambient are included in the fatigue analysis. Even the ambient temperature is included as a load set with defined cycles. The stress free state for the piping system is defined as a temperature of 21°C (70°F) for Class 1, 2, 3 or B31.1 piping. For Class 2,3 or B31.1 piping, no thermal expansion analysis will be performed for a piping system operating at 65°C (150°F) or less.

The design life for the ESBWR Standard Plant is 60 years. A 60-year design life is a requirement for all major plant components with reasonable expectation of meeting this design life. However, all plant operational components and equipment except the reactor vessel are designed to be replaceable, design life not withstanding. The design life requirement allows for refurbishment and repair, as appropriate, to assure that the design life of the overall plant is achieved. In effect, essentially all piping systems, components and equipment are designed for a 60-year design life. Many of these components are classified as ASME Class 2 or 3 or Quality Group D.

**DCD Markup for section 3.9**

In the event any non-Class 1 component is subjected to cyclic loadings of a magnitude and/or duration so severe that the 60-year design life cannot be assured by required Code calculations, applicants referencing the ESBWR design shall identify these components and either provide an appropriate analysis to demonstrate the required design life, or provide designs to mitigate the magnitude or duration of the cyclic loads. For example, thermal sleeves may be required to protect the pressure boundary from severe cyclic thermal stress, at points where mixing of hot and cold fluids occur.

### *3.9.3.2 Reactor Pressure Vessel Assembly*

### *3.9.3.3 Main Steam (MS) System Piping [RAI 3.12-16]*

The piping systems extending from the reactor pressure vessel to and including the outboard main steam isolation valve are designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 1 criteria. Stresses are calculated on an elastic basis for each service level and evaluated in accordance with NB-3600 of the Code. Table 3.9-9 shows the specific load combinations and acceptance criteria for Class 1 piping that apply to this piping. For the main steam Class 1 piping, the thermal loads per Equation 12 of NB-3600 are less than 2.4 $S_{my}$, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600.

The MS system piping extending from the outboard main steam isolation valve to the turbine stop valve is constructed in accordance with the Code, Class 2 Criteria.

### *3.9.3.4 Other Components [RAI 3.12-16, 3.12-2(b)]*

[ONLY change to ASME Class 1, 2 and 3 Piping Section]

**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 $S_{my}$, 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.

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### *3.9.3.5 Valve Operability Assurance*

**3.9.3.5.1 Major Active Valves**

**3.9.3.5.2 Other Active Valves**

### *3.9.3.6 Design and Installation of Pressure Relief Devices*

**Main Steam Safety/Relief Valves [RAI 3.12-26]**

SRV lift in the main steam (MS) piping system results in a transient that produces momentary unbalanced forces acting on the MS and SRV discharge piping system for the period from opening of the SRV until a steady discharge flow from the reactor pressure vessel to the suppression pool is established. This period includes clearing of the water slug from the end of the discharge piping submerged in the suppression pool. Pressure waves traveling through the main steam and discharge piping following the relatively rapid opening of the SRV cause this piping to vibrate.

The analysis of the MS and discharge piping transient due to SRV discharge consists of a stepwise time-history solution of the fluid flow equation to generate a time history of the fluid properties at numerous locations along the pipe. The fluid transient properties are calculated based on the maximum set pressure specified in the steam system specification and the value of the Code flow rating, increased by a factor to account for the conservative method of establishing the rating. Simultaneous discharge of all valves in a MS line is assumed in the analysis because simultaneous discharge is considered to induce maximum stress in the piping. Reaction loads on the pipe are determined at each location corresponding to the position of an elbow. These loads are composed of pressure-times-area, momentum-change, and fluid-friction terms.

The method of analysis applied to determine response of the MS piping system, including the SRV discharge line, to relief valve operation is time-history integration. The forces are applied at locations on the piping system where fluid flow changes direction, thus causing momentary reactions. The resulting loads on the SRV, the main steamline, and the discharge 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 and discharge pipe.

Many of the SRV design parameters and criteria are specified in Sections 5.2 and 15.2. The procurement specification for the SRV, that will be prepared by GE, define the SRV requirements that are necessary to be consistent with the SRV parameters used in the steam line stress analysis.

**Other Safety/Relief and Vacuum Breaker Valves**

An SRV is identified as a pressure relief valve or vacuum breaker. SRVs in the reactor components and subsystems are described and identified in Subsection 5.4.13.

The operability assurance program discussed in Subsection 3.9.3.5 applies to safety/relief valves.

ESBWR safety/relief valves and vacuum breakers are designed and manufactured in accordance with the Code requirements.

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The design of ESBWR SRVs incorporates SRV opening and pipe reaction load considerations required by ASME III, Appendix O, and including the additional criteria of SRP, Section 3.9.3, Paragraph II.2 and those identified under Subsection NB-3658 for pressure and structural integrity. Safety/relief and vacuum relief valve and vacuum relief operability is demonstrated either by dynamic testing or analysis of similarly tested valves or a combination of both in compliance with the requirements of SRP Subsection 3.9.3.

**Depressurization Valves**

The instantaneous opening of the DPV due to the explosion of the DPV operator results in a transient that produces impact loads and momentary unbalanced forces acting on the MS and DPV piping system. The impact load forcing functions associated with DPV operation used in the piping analyses are determined by test. From the test data a representative force time-history is developed and applied as input to a time-history analysis of the piping. If these loads are 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 [RAI 3.12-31]*

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, ~~which are used for pipe support base plates are designed to the applicable factors of safety, which are defined~~ will follow all aspects of ~~in~~ I~~&~~E Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Revision 2~~1~~ dated November 8,~~June 21~~, 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 Concete", 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, s~~S~~urface-mounted base plates with undercut anchor bolts can be used in the design and installation of supports for safety related piping. ~~shall preferably utilize bearing-type anchor bolts, and shall not be used in the design and installation of Seismic Category I and IIA pipe supports, which may be attached to steel embedments anchored in concrete walls or floor slabs.~~

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

[RAIs 3.12-2(a), 3.12-30, 3.12-34, 3.12-35, 3.12-36, 3.12-37]

Supports and their attachments for essential Code Class 1, 2, and 3 piping are designed in accordance with Subsection NF~~[1]~~ up to the interface of the building structure, with jurisdictional boundaries as defined by Subsection NF. ~~The building structure component supports 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. The component loading combinations are discussed in Subsection 3.9.3.1.~~ 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 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~~suspension~~ 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.

~~[1] Augmented by the following: (1) application of Code Case N-476, Supplement 89.1 which governs the design of single angle members of ASME Class 1, 2, 3 and MC linear component supports; and (2) when eccentric loads or other torsional loads are not accommodated by designing the load to act through the shear center or meet "Standard for Steel Support Design", analyses are performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual", Publication T114-2/83.~~

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 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.

(3) Snubbers—The operating loads on snubbers are the loads caused by dynamic events (e.g., seismic, RBV due to LOCA, SRV and DPV discharge, discharge through a relief valve line or valve closure) during various operating conditions. Snubbers restrain piping against response to the dynamic excitation and to the associated differential movement of the piping system support anchor points. The criteria for locating snubbers and ensuring adequate load capacity, the structural and mechanical performance parameters used for snubbers and the installation and inspection considerations for the snubbers are as follows:

a. Required Load Capacity and Snubber Location

The loads calculated in the piping dynamic analysis, described in Subsection 3.7.3.8, cannot exceed the snubber load capacity for design, normal, upset, emergency and faulted conditions.

Snubbers are generally used in situations where dynamic support is required because thermal growth of the piping prohibits the use of rigid supports. The snubber locations and support directions are first decided by estimation so that the stresses in the piping system have acceptable values. The snubber locations and support directions are refined by performing the dynamic analysis of the piping and support system as described above in order that the piping stresses and support loads meet the Code requirements.

The pipe support design specification requires that snubbers be provided with position indicators to identify the rod position. This indicator facilitates the checking of hot and cold settings of the snubber, as specified in the installation manual, during plant preoperational and startup testing.

b. Inspection, Testing, Repair and/or Replacement of Snubbers

The pipe support design specification requires that the snubber supplier prepare an installation instruction manual. This manual is required to contain complete instructions for the testing, maintenance, and repair of the snubber. It also contains inspection points and the period of inspection.

The pipe support design specification requires that hydraulic snubbers be equipped with a fluid level indicator so that the level of fluid in the snubber can be ascertained easily.

The spring constant achieved by the snubber supplier for a given load capacity snubber is compared against the spring constant used in the piping system model. If the spring constants are the same, then the snubber location and support direction become confirmed. If the spring constants are not in agreement, they are brought in agreement, and the system analysis is redone to confirm the snubber loads. This iteration is continued until all snubber load capacities and spring constants are reconciled.

c. Snubber Design and Testing

To assure that the required structural and mechanical performance characteristics and product quality are achieved, the following requirements for design and testing are imposed by the design specification:

(i) The snubbers are required by the pipe support design specification to be designed in accordance with the rules and regulations of the Code, Subsection NF. This design requirement includes analysis for the normal, upset, emergency, and faulted loads. These calculated loads are then compared against the allowable loads to make sure that the stresses are below the code allowable limit.

(ii) The snubbers are tested to ensure that they can perform as required during the seismic and other RBV events, and under anticipated operational transient loads or other mechanical loads associated with the design requirements for the plant. The following test requirements are included:

- Snubbers are subjected to force or displacement versus time loading at frequencies within the range of significant modes of the piping system.
- Dynamic cyclic load tests are conducted for hydraulic snubbers to determine the operational characteristics of the snubber control valve.
- Displacements are measured to determine the performance characteristics specified.
- Tests are conducted at various temperatures to ensure operability over the specified range.

- Peak test loads in both tension and compression are required to be equal to or higher than the rated load requirements.
- The snubbers are tested for various abnormal environmental conditions. Upon completion of the abnormal environmental transient test, the snubber is tested dynamically at a frequency within a specified frequency range. The snubber must operate normally during the dynamic test.

d. Snubber Installation Requirements

An installation instruction manual is required by the pipe support design specification. This manual is required to contain instructions for storage, handling, erection, and adjustments (if necessary) of snubbers. Each snubber has an installation location drawing that contains the installation location of the snubber on the pipe and structure, the hot and cold settings, and additional information needed to install the particular snubber.

e. Snubber Pre-service Examination

The pre-service examination plan of all snubbers covered by the plant-specific Technical Specifications is prepared. This examination is made after snubber installation but not more than 6 months prior to initial system pre-operational testing. The pre-service examination verifies the following:

(i) There are no visible signs of damage or impaired operability as a result of storage, handling, or installation.

(ii) The snubber location, orientation, position setting, and configuration (attachments, extensions, etc.) are according to design drawings and specifications.

(iii) Snubbers are not seized, frozen or jammed.

(iv) Adequate swing clearance is provided to allow snubber movements.

(v) If applicable, fluid is to the recommended level and is not to be leaking from the snubber system.

(vi) Structural connections such as pins, fasteners and other connecting hardware such as lock nuts, tabs, wire, cotter pins are installed correctly.

If the period between the initial pre-service examination and initial system pre-operational tests exceeds 6 months, reexamination of Items i, iv, and v is performed. Snubbers, which are installed incorrectly or otherwise fail to meet the above requirements, are repaired or replaced and re-examined in accordance with the above criteria.

(4) Struts — Struts are defined as ASME Section III, Subsection NF, Component Standard Supports. They consist of rigid rods pinned to a pipe clamp or lug at the pipe and pinned to a clevis attached to the building structure or supplemental steel at the other end. Struts, including the rod, clamps, clevises, and pins, are designed in accordance with the Code, Subsection NF-3000.

Struts are passive supports, requiring little maintenance and in-service inspection, and are normally used instead of snubbers where dynamic supports are required and the movement of the pipe due to thermal expansion and/or anchor motions is small. Struts are not used at locations where restraint of pipe movement to thermal expansion significantly increases the secondary piping stress ranges or equipment nozzle loads.

Because of the pinned connections at the pipe and structure, struts carry axial loads only. The design loads on struts may include those loads caused by thermal expansion, dead weight, and the inertia and anchor motion effects of all dynamic loads. As in the case of other supports, the forces on struts are obtained from an analysis, and are confirmed not to exceed the design loads for various operating conditions.

(5) Frame Type (Linear) Pipe Supports — Frame type pipe supports are linear supports as defined as ASME Section III, Subsection NF, Component Standard Supports. They consist of frames constructed of structural steel elements that are not attached to the pipe. They act as guides to allow axial and rotational movement of the pipe but act as rigid restraints to lateral movement in either one or two directions. Frame type pipe supports are designed in accordance with the Code, Subsection NF-3000.

Frame type pipe supports are passive supports, requiring little maintenance and in-service inspection, and are normally used instead of struts when they are more economical or where environmental conditions are not suitable for the ball bushings at the pinned connections of struts. Similar to struts, frame type supports are not used at locations where restraint of pipe movement to thermal expansion significantly increases the secondary piping stress ranges or equipment nozzle loads.

The design loads on frame type pipe supports include those loads caused by thermal expansion, dead weight, and the inertia and anchor motion effects of all dynamic loads. As in the case of other supports, the forces on frame type supports are obtained from an analysis, which are assured not to exceed the design loads for various operating conditions.

For insulated pipes, special pipe guides with one or two way restraint (two or four trunnions welded to a pipe clamp) may be used in order to minimize the heat loss of piping systems. For small bore pipe guides, it could be acceptable to cut the insulation around the support frame, although this must be indicated in the support specification.

(6) Special Engineered Pipe Supports — In an effort to minimize the use and application of snubbers there may be instances where special engineered pipe supports are used where either struts or frame-type supports cannot be applied. Examples of special engineered supports are Energy Absorbers, and Limit Stops.

~~Energy Absorbers — These are linear energy absorbing support parts designed to dissipate energy associated with dynamic pipe movements by yielding. When energy absorbers are used, they are designed to meet the requirements of ASME Section III Code Case N-420, Linear Energy Absorbing Supports for Subsection NF, Classes 1, 2, and 3 Construction, Section III, Division 1. The restrictions on location and application of struts and frame-type supports, discussed in (4) and (5) above, are also applicable to energy absorbers because energy absorbers allow thermal movement of the pipe only in its design directions.~~

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Limit Stops — are passive seismic pipe support devices consisting of limit stops with gaps sized to allow for thermal expansion while preventing large seismic displacements. Limit stops are linear supports as defined as ASME Section III, Subsection NF, and are designed in accordance with the Code, Subsection NF-3000. They consist of box frames constructed of structural steel elements that are not attached to the pipe. The box frames allow free movement in the axial direction but limit large displacements in the lateral direction.

Subsection 3.7.3.3.3 provides the analytical requirements for special engineered pipe supports. ~~The information required by Regulatory Guide 1.84 shall be provided to the regulatory agency, when Code Case N-420 is used to design linear energy absorbing supports.~~

### 3.9.3.7.2 Reactor Pressure Vessel Sliding Supports [RAI 3.12-2(a)]

The ESBWR RPV sliding supports are sliding supports as defined by section NF-3124 of the Code and are designed as an ASME Code Class 1 component support per the requirements of the Code, Subsection NF~~[2]~~. The loading conditions and stress criteria are given in Tables 3.9-1 and 3.9-2, and the calculated stresses shall meet the Code allowable stresses at all locations for various plant operating conditions. The stress level margins assure the adequacy of the RPV sliding supports.

### 3.9.3.7.3 Reactor Pressure Vessel Stabilizer

### 3.9.3.7.4 Floor-Mounted Major Equipment

### *3.9.3.8 Other ASME III Component Supports [RAI 3.12-2(a)]*

The ASME III component supports and their attachments (other than those discussed in the preceding subsection) are designed in accordance with Subsection NF of the Code~~[3]~~ up to the interface with the building structure. The building structure component supports are designed in accordance with the AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings. The loading combinations for the various operating conditions correspond to those used to design the supported component. The component loading combinations are discussed in Subsection 3.9.3.1. Active component supports are discussed in Subsection 3.9.3.5. The stress limits are per ASME III, Subsection NF and Appendix F. The supports are evaluated for buckling in accordance with ASME III.

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~~[2] Augmented by the following: (1) application of Code Case N-476, Supplement 89.1 which governs the design of single angle members of ASME Class 1, 2, 3 and MC linear component supports; and (2) when eccentric loads or other torsional loads are not accommodated by designing the load to act through the shear center or meet "Standard for Steel Support Design," analyses are performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual" Publication T114-2/83.~~

~~[3] Augmented by the following: (1) application of Code Case N-476, Supplement 89.1 which governs the design of single angle members of ASME Class 1, 2, 3 and MC linear component supports; and (2) when eccentric loads or other torsional loads are not accommodated by designing the load to act through the shear center or meet "Standard for Steel Support Design," analyses are performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual'" Publication T114-2/83.~~

[RAI 3.12-16 ]

**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 ≤ 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 ≤ ~~3.0~~2.4 $S_m$<br>U < 1.0 |
| Service Level B | PP + WT + (TSV)<br>PP + WT + ($RV_1$)<br>PP + WT + ($RV_2I$) | Eq 9 ≤ 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 ≤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 ≤ 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), $RV_2$SV (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)

[RAI 3.12-30]

**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 Basemat Acceleration Loads (Inertia Effect) (all valves)

$RV_2D$ = SRV 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)

[RAI 3.12-30]

## 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 Basemat Acceleration Loads (Inertia Effect) (all valves)

$RV_2D$ = SRV 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)

**DCD Markup for section 3.9**

CONDI = Condensation Oscillation (Inertia Load)

CONDD = Condensation Oscillation (Anchor Displacement Loads)

API = Annulus Pressurization Loads (Inertia Effect)

APD = Annulus Pressurization Loads (Anchor Displacement Loads)

[RAI 3.12-30]

## Table 3.9-12

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

| Condition | Load Combination(1)(2)(3) | Acceptance Criteria |
|---|---|---|
| Service Level A | WT + TE | Table NF-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-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-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<br>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

Where:
TSV = Turbine Stop Valve closure loads

WT = Dead Weight

TE = Thermal Expansion

$RV_1$ = SRV Opening Loads (Acoustic Wave)

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

$RV_2D$ = SRV 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)

**DCD Markup for section 3.9**

APD = Annulus Pressurization Loads (Anchor Displacement Loads)

**DCD Markup for Section 3.10**

## 3.10 SEISMIC AND DYNAMIC QUALIFICATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

This section addresses methods of test and analysis employed to ensure the operability of mechanical and electrical equipment (includes instrumentation and control) under the full range of normal and accident loadings (including seismic), to ensure conformance with the requirements of General Design Criteria (GDC) 1, 2, 4, 14 and 30 of Appendix A to 10 CFR 50, as well as Appendix B to 10 CFR Part 50 and Appendix A to 10 CFR 100, as discussed in SRP 3.10 Draft Revision 3 (Reference 3.10-1). Mechanical and electrical equipment are designed to withstand the effects of earthquakes, i.e., seismic Category I requirements, and other accident-related loadings. Mechanical and electrical equipment covered by this section include equipment associated with systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment. Also covered by this section is equipment (1) that performs the above functions automatically, (2) that is used by the operators to perform these functions manually, and (3) whose failure can prevent the satisfactory accomplishment of one or more of the above safety functions. Instrumentation that is needed to assess plant and environ conditions during and after an accident, as described in Regulatory Guide 1.97, are also covered by this section. Examples of mechanical equipment included in these systems are pumps, valves, fans, valve operators, snubbers, battery and instrument racks, control consoles, cabinets, and panels. Examples of electrical equipment are valve operator motors, solenoid valves, pressure switches, level transmitters, electrical penetrations, and pump and fan motors.

The methods of test and analysis employed to ensure the operability of mechanical and electrical equipment meet the relevant requirements of the following regulations:

(1) Code Federal Regulations (CFR):

a. 10 CFR 50 "General Design Criteria (GDC) for Nuclear Power Plants Appendix A (Criteria 1, 2, 4, 14 and 30)."

b. 10 CFR 50 "Quality Assurance Criteria for Nuclear Power Plants Appendix B and Fuel Reprocessing Plants."

c. 10 CFR 100 Appendix A "Seismic and Geological Siting Criteria for Nuclear Power Plants."

(2) Institute of Electrical and Electronic Engineers (IEEE):

a. IEEE-323-2003 "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations."

b. IEEE-382-1996 (R2004) "Standard for Qualification of Actuators for Power Operated Valve Assemblies with Safety Related Functions for Nuclear Power Plants."

c. IEEE-344-2004 "Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."

**DCD Markup for Section 3.10**

(3) American Society of Mechanical Engineers (ASME):

a. ASME B&PVC Section III-2001 "Rules for Construction of Nuclear Power Plant Components."

b. NQA-1, Addenda NQA-1a-1999 "Quality Assurance Requirements for Nuclear Facility Applications."

c. ASME B&PVC Section III, Division 1, Subsection NF-2001 "Rules for Construction of Nuclear Power Plant Components."

(4) U.S. Nuclear Regulatory Commission (NRC) Regulatory Guides:

a. Regulatory Guide 1.63-1987 "Electric Penetration Assemblies in Containment Structures of Nuclear Power Plants."

b. Regulatory Guide 1.122-1978 "Requirements for Required Response Spectra (RRS) Peak Broadening of +/-15%."

c. Regulatory Guide 1.61-1973 "Requirements for Damping Values for Seismic Design of Nuclear Power Plants."

d. Regulatory Guide 1.92 rev. 2 ~~-1976-~~"Combining Modal Response and Spatial Components in Seismic Response Analysis."

e. Regulatory Guide 1.29-1978 "Seismic Design Classification."

f. Regulatory Guide 1.100-1988 "Seismic Qualification of Electrical Equipment for Nuclear Power Plants."

The dynamic loads may occur because of the Reactor Building Vibration (RBV) excited by the suppression pool dynamics when a Loss-Of-Coolant-Accident (LOCA), a safety/relief valve (SRV) discharge or a depressurization valve (DPV) discharge occurs. The non-seismic RBV dynamic loads are described in Tables 3.9-2 and 3.9-3 and can be categorized as Service Level B, C, or D depending upon the excitation source.

Principal Seismic Category I structures, systems and components are identified in Table 3.2-1. Most of these items are safety-related as explained in Subsection 3.2.1. The safety-related functions are defined in Section 3.2, and include the functions essential to emergency reactor shutdown, containment isolation, reactor core cooling, reactor protection, containment and reactor heat removal, and emergency power supply, or otherwise are essential in preventing significant release of radioactive material to the environment.

The mechanical components and equipment and the electrical components that are integral to the mechanical equipment are dynamically qualified as described in Section 3.9. Seismic and dynamic qualification methodology in Section 4.4 of GE's Environmental Qualification Program (Reference 3.10-2) applies to mechanical as well as electrical equipment.

DCD mark-up for appendices 3D and 3K

## 3D.4 PIPING

### 3D.4.1 Piping Analysis Program - PISYS

PISYS is a computer code for analyzing piping systems subjected to both static and dynamic piping loads. Finite element models of a piping system formed by assembling stiffness matrices represent standard piping components. The piping elements are connected to each other via nodes called pipe joints. It is through these joints that the model interacts with the environment, and loading of the piping system becomes possible. PISYS is based on the linear elastic analysis in which the resultant deformations, forces, moments and accelerations at each joint are proportional to the loading and the superposition of loading is valid.

PISYS has a full range of static dynamic load analysis options. Static analysis includes dead weight, uniformly distributed weight, thermal expansion, externally applied forces, moments, imposed displacements and differential support movement (pseudo-static load case). Dynamic analysis includes mode shape extraction, response spectrum analysis, and time-history analysis by modal combination or direct integration. In the response spectrum analysis [i.e., uniform support motion response spectrum analysis (USMA) or independent support motion response spectrum analysis (ISMA)], the user may request modal response combination in accordance with Regulatory Guide 1.92. In the ground motion (uniform motion) or independent support time history analysis, the normal mode solution procedure is selected. In analysis involving time varying nodal loads, the step-by-step direct integration method is used.

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.

DCD mark-up for appendices 3D and 3K

## 3K.2 REGULATORY POSITIONS

In SECY-90-016 and SECY-93-087 (References 3 and 4), the NRC staff resolved the ISLOCA issue for advanced light water reactor plants by requiring that low-pressure piping systems that interface with the reactor coolant pressure boundary be designed to withstand reactor pressure to the extent practicable. However, the staff believes that for those systems that have not been designed to withstand full reactor pressure, evolutionary ALWRs should provide (1) the capability for leak testing the pressure isolation valves, (2) valve position indication that is available in the control room when isolation valve operators are de-energized and (3) high-pressure alarms to warn main control room operators when rising reactor pressure approaches the design pressure of attached low-pressure systems or when both isolation valves are not closed. The staff noted that for some low-pressure systems attached to the RCPB, it may not be practical or necessary to provide a higher system ultimate pressure capability for the entire low-pressure connected system. The staff will evaluate such exceptions on a case-by-case basis during specific design certification reviews.

GE provided a proposed implementation of the issue resolution for the ABWR in Reference 5 and again in Reference 6. The staff in the Civil Engineering and Geosciences Branch of the Division of Engineering completed its evaluation of the Reference 5 proposal. Specifically, as reported by Reference 2 and summarized below, the staff has evaluated the minimum pressure for which low-pressure systems should be designed to ensure reasonable protection against burst failure should the low-pressure system be subjected to full RCPB pressure.

The design pressure for the low-pressure piping systems that interface with the RCPB should be equal to 0.4 times the normal operating RCPB pressure, the minimum wall thickness of low-pressure piping should be no less than that of a standard weight pipe, and that Class 300 valves are adequate. The design is to be in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Subarticle NC/ND-3600. Furthermore, the staff will continue to require periodic surveillance and leak rate testing of the pressure isolation valves via Technical Specifications, as a part of the ISI program..

The periodic surveillance and leak rate testing requirements for high-pressure to low-pressure isolation valves are not applicable to the ESBWR because, as shown in this appendix, the ESBWR design does not contain a pressure isolation valve between the RCPB and a low pressure piping system.