GE Hitachi Nuclear Energy

Richard E. Kingston
Vice President, ESBWR Licensing

P.O. Box 780
3901 Castle Hayne Road, M/C A-65
Wilmington, NC 28402 USA

T 910.819.6192
F 910.362.6192
rick.kingston@ge.com

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Subject: **Partial Response to NRC RAI Letter No. 330 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.9 – Mechanical Systems and Components; RAI Number 3.9-253 and DCD Tier 2 Section 3.10 – Seismic and Dynamic Qualification of Mechanical and Electrical Equipment; RAI Number 3.10-9**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) partial response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) letter number 330 sent by NRC letter dated April 13, 2009 (Reference 1). RAI Numbers 3.9-253 and 3.10-9 are addressed in Enclosure 1. The affected DCD text associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

Reference:

1. MFN 09-261 Letter from U.S. Nuclear Regulatory Commission to J. G. Head, GEH, *Request For Additional Information Letter No. 330 Related to ESBWR Design Certification* dated April 13, 2009

Enclosure:

1. Response to Portion of NRC Request for Additional Information Letter No. 330 Related to ESBWR Design Certification Application - DCD Tier 2 Section 3.9 – Mechanical Systems and Components; RAI Numbers 3.9-253 and DCD Tier 2 Section 3.10 – Seismic and Dynamic Qualification of Mechanical and Electrical Equipment; RAI Number 3.10-9

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0101-2668 (RAI 3.9-253 and 3.10-9)

Enclosure 1

MFN 09-294

Response to Portion of NRC Request for Additional Information Letter No. 330 Related to ESBWR Design Certification Application

DCD Tier 2 Section 3.9 – Mechanical Systems and Components

RAI Number 3.9-253

And

DCD Tier 2 Section 3.10 – Seismic and Dynamic Qualification of Mechanical and Electrical Equipment

RAI Number 3.10-9

NRC RAI 3.9-253

Tier 2 Designation*

The staff requests that the text in the sections identified below are marked as Tier 2 information in the ESBWR DCD:*

[Text is not repeated because of the length.]

GEH Response

The text identified in the RAI will be marked as Tier 2* material.

DCD Impact

DCD Tier 2, Section 3.9 will be revised as noted in the attached markup.

NRC RAI 3.10-9

Tier 2 designation*

The staff requests that the following text in Section 3.10.1.1, Selection of Qualification Method is identified as Tier 2 information in the ESBWR DCD:*

"The qualification of Seismic Category I mechanical and electrical equipment is accomplished by test, analysis, or a combination of testing and analysis. Qualification by actual seismic experience, as permitted by IEEE 344-1987 is not utilized."

GEH Response

The text identified in the RAI will be marked as Tier 2* material.

DCD Impact

DCD Tier 2, Section 3.10 will be revised as noted in the attached markup.

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 multiple supports with different dynamic motions, an upper bound envelope of all the individual response spectra for these locations is used to calculate maximum inertial responses of items with multiple supports.

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

Supports

Subsections 3.9.3.7 and 3.9.3.8 address analyses or tests that are performed for component supports to assure their structural capability to withstand the seismic and other dynamic excitations.

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

[The major reactor internal components within the vessel are subjected to extensive testing, coupled with dynamic system analyses, to properly evaluate the resulting FIV phenomena during normal reactor operation and from anticipated operational transients.

In general, the vibration forcing functions for operational flow transients and steady-state conditions are not predetermined by detailed analysis. The vibration forcing functions for operational flow transients and steady state conditions are determined by first postulating the source of the forcing function, such as forces due to flow turbulence, symmetric and asymmetric vortex shedding, pressure waves from steady state and transient operations. Based on these postulates, prior startup and other test data from similar or identical components are examined for the evidence of the existence of such forcing functions. Special analysis of the response signals measured for reactor internals of many similar designs is performed to obtain the parameters, which determine the amplitude and modal contributions in the vibration responses. Based on these examinations, the magnitudes of the forcing functions and/or response amplitudes are derived. These magnitudes are then used to calculate the expected ESBWR responses for each component of interest during steady state and transient conditions. This study provides useful predictive information for extrapolating the results from tests of components with similar designs to components of different designs. This vibration prediction method is appropriate where standard hydrodynamic theory cannot be applied due to complexity of the structure and flow conditions. Elements of the vibration prediction method are outlined as follows:

- *Dynamic modal analysis of major components and subassemblies is performed to identify vibration modes and frequencies. The analysis models used for Seismic Category I structures are similar to those outlined in Subsection 3.7.2.*
- *Data from previous plant vibration measurements are assembled and examined to identify predominant vibration response modes of major components. In general, response modes are similar but response amplitudes vary among BWRs of differing size and design.*

- *Parameters are identified which are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions.*
- *Correlation functions of the variable parameters are developed which, multiplied by response amplitudes, tend to minimize the statistical variability between plants. A correlation function is obtained for each major component and response mode.*
- *Predicted vibration amplitudes for components of the prototype plants are obtained from these correlation functions based on applicable values of the parameters for the prototype plants. The predicted amplitude for each dominant response mode is stated in terms of a range, taking into account the degree of statistical variability in each of the correlations. The predicted mode and frequency are obtained from the dynamic modal analyses.*

The dynamic modal analysis forms the basis for interpretation of the initial startup test results (Subsection 3.9.2.4). Modal stresses are calculated and relationships are obtained between sensor response amplitudes and peak component stresses for each of the lower normal modes.

Details of the special signal analyses of the vibration sensors are given below:

The test data from sensors (accelerometers, strain gages, and pressure sensors) installed on reactor internal components are first analyzed through signal processing equipment to determine the spectral characteristics of these signals. The spectral peak magnitudes and the frequencies at the spectral peaks are then determined. These spectral peak frequencies are then classified as natural frequencies or forced frequencies. If a spectral peak is classified as being from a natural frequency, its amplitude is then determined using a band-pass filter if deemed necessary. The resultant amplitude is then identified as the modal response at that frequency. This process is used for all frequencies of interest. Thus the modal amplitudes at all frequencies of interest are determined. If a spectral peak is identified are being from a forced frequency, the source (such as a vane passing frequency of a pump) is identified. Again, its magnitude is determined using a band-pass filter if deemed necessary.

The modal amplitudes and the forced response amplitudes are then used to calculate the expected ESBWR amplitudes for the same component. These ESBWR expected amplitudes are determined by calculating the expected changes in the forcing function magnitudes from the test component to the ESBWR component. For example, for flow turbulence excited components, the magnitudes are determined by rationing with the flow velocity squared.

A flow chart of the above process is shown in Figure 3.9-6.

The allowable amplitude in each mode is that which produces a peak stress amplitude of ±68.95 MPa (±10,000 psi). For the steam dryer and its components, a higher allowable peak stress limit is used as explained in the following paragraphs.

Vibratory loads are continuously applied during normal operation and the stresses are limited to ±68.95 MPa (±10,000 psi), with the exception of the steam dryer, in order to prevent fatigue failure. Prediction of vibration amplitudes, mode shapes, and frequencies of normal reactor operations are based on statistical extrapolation of actual measured results on the same or similar components in reactors now in operation.

Extensive predictive evaluations have been performed for the steam dryer loading and structural evaluation. These evaluations are described in Appendix 3L.4. The fatigue analysis performed for the ESBWR steam dryer uses a fatigue limit stress amplitude of 93.7 MPa (13,600 psi). For the outer hood component, which is subjected to higher pressure loading in the region of the main steamlines, the fatigue limit stress amplitude of 74.4 MPa (10,800 psi). The higher limit is justified because the dryer is a nonsafety-related component, performs nonsafety-related functions, and is only required to maintain its structural integrity (no loose parts generated) for normal, transient and accident conditions.

The dynamic loads caused by FIV of the steam separators had been determined using a full-scale separator test under reactor conditions. During the test, the flow rate through the steam separator was 226,000 kg/hr (499,000 lbm/hr) at 7% quality. This is higher than the ESBWR maximum separator flow of 100,700 kg/hr (222,000 lbm/hr) at rated power. Test results show a maximum FIV stress of less than 48.6 MPa (7200 psi), well below the GE acceptance criteria of 68.9 MPa (10,000 psi). Thus it can be concluded that separator FIV effects are acceptable. Jet impingement from feedwater flow has no significant effect on the steam separator assembly since the separator outer-most cylindrical structure (also referred to as the separator "skirt") is above the feedwater flow impingement area.]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.2.4 Initial Startup Flow Induced Vibration Testing of Reactor Internals

A reactor internals vibration measurement and inspection program is conducted only during initial startup testing. This meets the guidelines of RG 1.20 with the exception of those requirements related to preoperational testing which cannot be performed for a natural circulation reactor.

Initial Startup Testing

Vibration measurements are made during reactor startup at conditions up to 100% rated flow and power. Steady state and transient conditions of natural circulation flow operation are evaluated. The primary purpose of this test series is to verify the anticipated effect of single- and two-phase flow on the vibration response of internals. Details of the initial startup vibration test program are described in Subsection 3L.4.6 for the steam dryer and Section 3L.5 for other reactor internals. A brief summary is given below.

Vibration sensor types may include strain gauges, displacement sensors (linear variable transformers), and accelerometers.

Accelerometers are provided with double integration signal conditioning to give a displacement output. Sensor locations ~~include the following:~~are provided in Appendix 3L.

- ~~Steam dryer, bending strain and accelerations;~~[JD67]
- ~~Chimney~~ [EA68]~~and partitions, lateral displacements and accelerations;~~
- ~~Chimney~~ [EA69]~~head, lateral displacements and accelerations;~~
- [JD70]~~Standby Liquid Control (SLC) internal piping, bending strain, lateral.~~

license applicant, or the applicant's authorized agent, in accordance with the responsibilities outlined under the ASME Code, Section III. The ASME Code design reports include the record of as-built reconciliations, for example, the evaluations of changes to piping support locations, the pre-operational testing and results, and reported construction deviation resolutions, and also includes the small-bore piping analysis.

3.9.3.1 Loading Combinations, Design Transients and Stress Limits

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 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.

*[Specific load combinations and acceptance criteria for Class 1 piping are shown in Table 3.9-9. Also for Class 1 piping, 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.

The COL Applicant will provide a milestone for completing the required equipment stress reports, per ASME Code, Subsection NB, for equipment segments identified in Subsection 3.9.3.1 that are subject to loadings that could result in thermal or dynamic fatigue and for updating the FSAR, as necessary, to address the results of the analysis (COL 3.9.9-2-A).

[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. For ESBWR, these locations include the SRV discharge line going to the quencher and the feedwater pipe within the steam tunnel at the reactor water cleanup (RWCU) junction.]* ~~(See COL item 3.9.9-2-H).~~

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.1.1 Plant Conditions

All events that the plant might credibly experience during a reactor year are evaluated to establish design basis for plant equipment. These events are divided into four plant conditions. The plant conditions described in the following paragraphs are based on event probability (i.e., frequency of occurrence as discussed below and correlated to service levels for design limits defined in the ASME B&PV Code Section III as shown in Tables 3.9-1 and 3.9-2.

Normal Condition

Normal conditions are any conditions in the course of system startup, operation in the design power range, normal hot standby (with condenser available), and system shutdown other than upset, emergency, faulted, or testing.

Upset Condition

An upset condition is any deviation from normal conditions anticipated to occur often enough that design should include a capability to withstand the conditions without operational impairment. The upset conditions include system operational transients, i.e., AOOs, as defined in 10 CFR 50, Appendix A, which result from any single operator error or control malfunction, from a fault in a system component requiring its isolation from the system, or from a loss of load or power. Hot standby with the main condenser isolated is an upset condition.

Emergency Condition

An emergency condition includes deviations from normal conditions that require shutdown for correction of the condition(s) or repair of damage in the RCPB. Such conditions have a low probability of occurrence but are included to provide assurance that no gross loss of structural integrity results as a concomitant effect of any damage developed in the system. Emergency condition events include but are not limited to infrequent operational transients (IOT), e.g., infrequent events, as defined in Subsection 15.0.1.2, caused by one of the following: (a) a multiple valve blowdown of the reactor vessel; (b) LOCA from a small break or crack (SBL) which does not depressurize the reactor systems, does not automatically actuate the Gravity-Driven Cooling System (GDCS) and Automatic Depressurization System (ADS), and does not result in leakage beyond normal make-up system capacity, but which requires the safety-related functions of isolation of containment and shutdown and may involve inadvertent actuation of the ADS; (c) improper assembly of the core during refueling; or (d) depressurization valve (DPV) blowdown. An Anticipated Transient Without Scram (ATWS) or reactor overpressure with delayed scram (Tables 3.9-1 and 3.9-2) is a special event, as defined in Subsection 15.0.1.2, that is classified as an emergency condition.

Faulted Condition

A faulted condition is any of those combinations of conditions associated with extremely low-probability postulated events whose consequences are such that the integrity and operability of the system may be impaired to the extent that considerations of public health and safety are involved. Faulted conditions encompass events, such as a LOCA, that are postulated because their consequences would include the potential for the release of significant amounts of radioactive material. These events are the most drastic that must be considered in the design and thus represent limiting design bases. Faulted condition events include but are not limited to one of the following: (a) a fuel-handling accident; (b) a MSL or feedwater line break; (c) the combination of any SBL or IBL with the SSE, and a loss of off-site power; or (d) the SSE plus LBL plus a loss of off-site power.

The IBL classification covers those breaks for which the GDCS operation occurs during the blowdown. The LBL classification covers the sudden, double ended severance of a MSL inside or outside the containment that results in transient reactor depressurization, or any pipe rupture of equivalent flow cross sectional area with similar effects.

Correlation of Plant Condition with Event Probability

The probability of an event occurring per reactor year associated with the plant conditions is listed below. This correlation identifies the appropriate plant conditions and assigns the appropriate ASME Section III service levels for any hypothesized event or sequence of events.

[Plant Condition	*ASME Code Service Level*	*Event Encounter Probability per Reactor Year*
Normal (planned)	*A*	*1.0*
Upset (moderate probability)	*B*	$1.0 > P \geq 10^{-2}$
Emergency (low probability)	*C*	$10^{-2} > P \geq 10^{-4}$
Faulted (extremely low probability)	*D*	$10^{-4} > P > 10^{-6}$]*

Safety-Related Functional Criteria

For any normal or upset design condition event, safety-related equipment and piping (Subsection 3.2.1) is capable of accomplishing its safety-related function as required by the event and incurring no permanent changes that could deteriorate its ability to accomplish its safety-related function as required by any subsequent design condition event.

For any emergency or faulted design condition event, safety-related equipment and piping is capable of accomplishing its safety-related function as required by the event but repairs could be required to ensure its ability to accomplish its safety-related function as required by any subsequent design condition event.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.1.2 Inspections/Testing Following the Reactor Coolant System Exceeding Service Level B Pressure Limit

[*If any abnormal event causes the pressure within reactor coolant system to exceed 110% of its design value (i.e., exceed the ASME Code Service Level B pressure limit), an inspection program should be satisfactorily completed, before normal plant operations may proceed. Within ASME Code, Section XI, Subarticles IWB-2400 and IWB-2500 there are inspection specifications that can determine the structural integrity of the reactor coolant system components directly affected by the pressurization event. Therefore, if the pressure of the reactor coolant system exceeds its ASME Code Service Level B pressure limit, then an inspection program will be established based on an assessment of all potentially affected safety-related reactor coolant system components, and subsequent inspections and/or testing per the appropriate portions of ASME Code, Section XI, Subarticles IWB-2400 and IWB-2500 will be performed and evaluated against the code acceptance criteria, prior to commencement of normal power operations.*]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.2 Reactor Pressure Vessel Assembly

The reactor vessel assembly includes: (1) the RPV boundary out to and including the nozzles and housings for FMCRD and in-core instrumentations; (2) vessel sliding support, and (3) shroud support.

[*The RPV, vessel sliding support, and shroud support are designed and constructed in accordance with the Code. The shroud support consists of support legs and a support ring. The RPV assembly components are classified as ASME Class 1. Complete stress reports on these components are prepared in accordance with the Code requirements. The guidance from NUREG-0619 and associated Generic Letters 80-95 and 81-11 is factored into the feedwater nozzle and sparger design . The feedwater nozzle/sparger design does not allow incoming feedwater flow to have direct contact with the nozzle bore region, and the double thermal sleeve design adds further protection against thermal cycling on the nozzle.*]* Also see Subsection 3.9.5.2 for additional information.

[*The stress analysis is performed on the RPV, vessel sliding support, and shroud support for various plant operating conditions (including faulted conditions) by using the elastic methods, except as noted in Subsection 3.9.1.4.*]* Loading conditions, design stress limits, and methods of stress analysis for the core support structures and other reactor internals are discussed in Subsection 3.9.5.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.3 Main Steam System Piping

[*The piping systems extending from the RPV to and including the outboard MSIV are designed and constructed in accordance with the ASME B&PV 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 MS Class 1 piping, the thermal loads per*

Equation 12 of NB-3600 are less than 2.4 S_m, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600.

The MS system piping extending from the outboard MSIV to the turbine stop valve is constructed in accordance with the Code, Class 2 Criteria.]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.4 Other Components

Standby Liquid Control (SLC) Accumulator

The standby liquid control accumulator is designed and constructed in accordance with the requirements of the Code, Class 2 component.

SLC Injection Valve

The SLC injection valve is designed and constructed in accordance with the requirements for the Code, Class 1 component.

GDCS Piping and Valves

The GDCS valves connected with the RPV, including squib valves, and up to and including the biased-open check valve are designed and constructed in accordance with the requirements of the Code, Class 1 components. Other valves in the system are Class 2 components.

Main Steamline Isolation, Safety Relief, and Depressurization Valves

[*The MSIVs, SRVs, and DPVs are designed and constructed in accordance with the Code, NB-3500 requirements for Class 1 components.*]*

Safety Relief Valve Piping

The relief valve discharge piping extending from the relief valve discharge flange to the vent wall penetration is designed and constructed in accordance with the Code requirements for Class 3 components. The relief valve discharge piping extending from the diaphragm floor penetration to the quenchers is designed and constructed in accordance with the Code requirements for Class 3 components.

Isolation Condenser System (ICS) Condenser and Piping

The ICS piping inside the primary containment between the RPV and the condenser isolation valve is designed and constructed in accordance with the Code requirements for Class 1 piping. The isolation condenser and piping outside containment is designed and constructed in accordance with Class 2 requirements.

RWCU/SDC System Pump and Heat Exchangers

The RWCU/SDC pump and heat exchangers (regenerative and nonregenerative) are not part of a safety system. However, the pumps and heat exchanger are Seismic Category I equipment. The Code requirements for Class 3 components are used in the design and construction of the RWCU System pump and heat exchanger components.

ASME Class 2 and 3 Vessels

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

ASME Class 1, 2 and 3 Valves

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

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

ASME Class 1, 2 and 3 Piping

[*The Class 1, 2 and 3 piping (all piping not previously discussed) is constructed in accordance with the Code. For Class 1 piping, stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the Code, and fatigue usage is in accordance with RG 1.207 and NUREG/CR-6909.*]* 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 is performed. Table 3.9-9 shows the specific load combinations and acceptance criteria for Class 1 piping systems. [*For the Class 1 piping that experiences the most significant stresses during operating conditions, the thermal loads per Equation 12 of NB-3600 are less than 2.4 S_m, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600. The piping considered in this category is the RWCU/SDC, feedwater, MS, 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 is included in the Design Report for the piping system.

For submerged piping and associated supports, the applicable direct external loads (e.g. hydrodynamic etc.) applied to the submerged components is included in the analysis.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.5 Valve Operability Assurance

This subsection discusses operability assurance of active Code valves, including actuators (Subsection 3.9.2.2).

[*Valves that perform an active safety-related function are functionally qualified to perform their required functions. For valve designs developed for the ESBWR that were not previously qualified, the qualification programs meet the requirements of QME-1-2007. For valve designs previously qualified to standards other than ASME QME-1-2007, the following approach is used.*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.5.1 Major Active Valves

Some of the major safety-related active valves (Tables 6.2-21, 6.2-42 and 3.2-1) discussed in this subsection for illustration are the MSIVs and SRVs, and SLC valves and DPVs. These valves are designed to meet the Code requirements and perform their mechanical motion in conjunction with a dynamic (SSE and other RBV) load event. These valves are supported entirely by the piping (i.e., the valve operators are not used as attachment points for piping supports) (Subsection 3.9.3.7). The dynamic qualification for operability is unique for each valve type; therefore, each method of qualification is detailed individually below.

Main Steam Isolation Valves

The MSIVs described in Subsection 5.4.5.2 are evaluated by analysis and test for capability to operate under the design loads that envelop the predicted loads during a design basis accident (DBA) and SSE.

The valve body is designed, analyzed and tested in accordance with the Code, Class 1 requirements. The MSIVs are modeled mathematically in the MSL system analysis. The loads, amplified accelerations and resonance frequencies of the valves are determined from the overall steamline analysis. The piping supports (snubbers, rigid restraints, etc.) are located and designed to limit amplified accelerations of and piping loads in the valves to the design limits.

As described in Subsection 5.4.5.3, the MSIV and associated electrical equipment (wiring, solenoid valves, and position switches) are dynamically qualified to operate during an accident condition.

Main Steam Safety Relief Valves

The typical SRV design described in Subsection 5.2.2.2 is qualified by type test to IEEE 344 for operability during a dynamic event. Structural integrity of the configuration during a dynamic event is demonstrated by both the Code Class 1 analysis and test.

- The valve is designed for maximum moments on inlet and outlet, which may be imposed when installed in service. These moments are resultants due to dead weight plus dynamic loading of both valve and connecting pipe, thermal expansion of the connecting pipe, and reaction forces from valve discharge.
- A production SRV is demonstrated for operability during a dynamic qualification (shake table) type test with moment and “g” loads applied greater than the required equipment’s design limit loads and conditions.

A mathematical model of this valve is included in the MSL system analysis, as with the MSIVs. This analysis ensures the equipment design limits are not exceeded.

Standby Liquid Control Valve (Injection Valve)

The typical SLC injection valve design is qualified by type test to IEEE 344. The valve body is designed, analyzed and tested per the Code, Class 1. The qualification test demonstrates the ability to remain operable after the application of the horizontal and vertical dynamic loading exceeding the predicted dynamic loading.

3.9.3.6 Design and Installation of Pressure Relief Devices

Main Steam Safety Relief Valves

SRV lift in the 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 RPV 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 MS 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 MSL, 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 MS 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 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 the SRVs.

ESBWR SRVs and vacuum breakers are designed and manufactured in accordance with the Code requirements.

[*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, Subsection 3.9.3, Paragraph II.2 and those identified under 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 a 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 MSL, 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 MS, stub tube, and DPV discharge piping.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.7 Component Supports

[*The establishment of the design/service loadings and limits is in accordance with the ASME Section III, Division 1, Article NCA-2000 and Subsection NF. These loadings and stress limits apply to the structural integrity of components and supports when subjected to combinations of loadings derived from plant and system operating conditions and postulated plant events. The combination of loadings and stress limits are included in the Design Specification of each component and support. Where the design and service stress limits specified in the code do not necessarily provide direction for the proper consideration of operability requirements for conditions which warrant consideration, Section II.3 and Appendix A of SRP 3.9.3, and Regulatory Guides 1.124 and 1.130 are used for guidance.*]* Where these stress limits apply, the treatment of functional capability, including collapse, deformation and deflection limits are evaluated and appropriate information is developed for inclusion into the Design Specification.

[*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.

The design and installation of all anchor bolts is performed in accordance with Appendix B to ACI 349 "Anchoring to Concrete", subject to the conditions and limitations specified in RG 1.199.]*

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

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.7.1 Piping Supports

[*Supports and their attachments for safety-related Code Class 1, 2, and 3 piping are designed in accordance with Subsection NF up to the interface of the building structure, with jurisdictional boundaries as defined by Subsection NF. The design of the nuclear power plant structures, systems, and components will provide access for the performance of inservice testing and inservice inspection as required by the applicable ASME Code. The building structure component supports (connecting the NF support boundary component to the existing building structure) 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. 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.*]*

Maximum calculated static and dynamic deflections of the piping at support locations do not exceed the allowable limits specified in the piping design specification.

[*Seismic Category II pipe supports are designed so that the SSE would not cause unacceptable structural interaction or failure. Support design follows the intent and general requirement specified in ASME-III, Nonmandatory Appendix F. This is used to evaluate the total design load condition with respect to the requirements of the SSE condition to ensure the structural integrity of the pipe supports are maintained.*]*

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

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

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

[*For the design of piping supports, a deflection limit of 1.6 mm (1/16 in.) 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 (1/8 in.).*

For frame type supports, the total gap is limited to 3.2 mm (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 is evaluated to assure that no thermal binding occurs. The

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 program for inservice examination and testing of snubbers in the completed ESBWR construction is prepared in accordance with the requirements of ~~ASME Section XI Code and~~ ASME OM Code, Subsection ISTD, and the applicable industry and regulatory guidance including RG 1.192. The intervals for visual examination are the subject of Code Case OMN-13, which is accepted under the RG 1.192. The preparation and submittal of a program for the inservice testing and examination of snubbers is addressed in Subsection 3.9.9.*]*

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.

A thermal motion monitoring program is established for verification of snubber movement, adequate clearance and gaps, including motion measurements and acceptance criteria to assure compliance with ASME Section III Subsection NF.

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 ASME Section III Code, Subsection NF and consider the following:

- Design requirements include analysis for normal, upset, emergency and faulted loads. Calculated loads are then compared against allowable loads as established by snubber vendor.
- Swing angles, as supplied by the snubber vendor, are incorporated into the design. Pipe movements in the horizontal and vertical direction are taken into account to prevent end bracket/paddle plate binding.
- Snubber stiffness, as supplied by the snubber vendor, is included in the piping analysis. Other support components such as the pipe clamp/extension piece/transition tube and structural auxiliary steel stiffness values are incorporated into the final determination of the stiffness value used in the analysis.

In multiple snubber applications where mismatch of end fitting clearance and lost motion could possibly exist, the synchronism of activation level or release rate is evaluated, if deemed necessary, in the piping analysis model when this application could be considered critical to the functionality of the system, such as a multiple snubber application located near rotating equipment. Equal load sharing of multiple snubber supports is not assumed if a mismatch in end fitting clearances exists and is evaluated as a part of this assessment.

(ii) A list of snubbers on systems which experience sufficient thermal movement to measure cold to hot position is provided as part of the testing program after the piping analysis has been completed.

(iii) 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. Production and qualification test programs for both hydraulic and mechanical snubbers are carried out by the snubber vendors in accordance with the snubber installation instruction manual required to be furnished by the snubber supplier. Acceptance criteria to assure compliance with ASME Section III Subsection NF, and other applicable codes, standards and requirements are as follows:

– Snubber production and qualification test programs are carried out by strict adherence to the manufacturer's snubber installation and instruction manual, which is prepared by the snubber manufacturer and subjected to review by the applicant for compliance with the applicable provisions of the ASME Pressure Vessel and Piping Code of record. The test program is periodically audited during implementation by the applicant for compliance.

– All snubbers will be inspected and tested for compliance with the design drawings and functional requirements of the procurement specifications.

– [*All snubbers are inspected and tested. No sampling methods may be used in the qualification tests.*

– *All snubbers are load rated by testing in accordance with the snubber manufacturer's testing program and in compliance with the applicable sections of ASME QME-1-2007, Subsection QDR and ASME OM Code, Subsection ISTD.*

– *Design compliance of the snubbers per ASME Section III Paragraph NF-3128, and Subparagraphs NF-3411.3 and NF-3412.4.*

– *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. The functional parameters cited in Subparagraph NF-3412.4 are included in the snubber qualification and testing program. Other parameters in accordance with applicable ASME QME-1-2007 and the ASME OM Code will be incorporated.*

– *The codes and standards used for snubber qualification and production testing are as follows:*
  - *ASME B&PV Code Section III (Code of Record date) and Subsection NF.*
  - *ASME QME-1-2007, Subsection QDR and ASME OM Code, Subsection ISTD.*

– *All large bore hydraulic snubbers include full Service Level D load testing, including verifying bleed rates, control valve closure within the specified velocity ranges and drag forces/breakaway forces are acceptable in accordance with ASME, QME-1-2007 and ASME OM Codes.*]*

(iv) All safety-related components which utilize snubbers in their support systems will be identified and inserted into the Final Safety Analysis Report in table format and will include the following:

– identification of systems and components

– number of snubbers utilized in each system and on that component

– snubber type (s) – (hydraulic or mechanical) – and name of supplier

– constructed to ASME Code Section III, Subsection NF or other

– snubber use such as shock, vibration, or dual purpose

– those snubbers identified as dual purpose or vibration arrestor type, will include an indication if both snubber and component were evaluated for fatigue strength

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 Preservice and Inservice Examination and Testing

Preservice Examination and Testing

The preservice examination plan for snubbers is prepared in accordance with the requirements of the ASME Code for Operation and Maintenance of Nuclear Power Plants (OM Code), Subsection ISTD, and the additional requirements of this section. The preservice examinations are made after snubber installation but not more than 6 months prior to initial system pre-operational testing. The preservice 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 load rating, 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 preservice 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.

Inservice Examination and Testing

[*The inservice examination and testing plan for snubbers is prepared in accordance with the requirements of the ASME OM Code, Subsection ISTD and is in conformance with the relevant requirements of 10 CFR 50 Part B, Appendix A, GDC 1.*]* The COL Applicant will provide a full description of the snubber preservice and inservice inspection and test programs and a milestone for program implementation. See COL item 3.9.9-4-A.

f. Snubber support data

The COL Holder will prepare a plant-specific table to be included as part of the inspection and test program for snubbers (see Subsection 3.9.9) that will include the following information:

(i) the general functional requirement (i.e. shock, vibration, dual purpose) for each system and component using snubbers including the number and location of each snubber. If either dual-purpose or arrestor type indicate whether the snubber or component was evaluated for fatigue strength,

(ii) operating environment,

(iii) applicable codes and standards,

(iv) list type of snubber (i.e. hydraulic, mechanical), materials of construction, standards for hydraulic fluids and lubricants, and the corresponding supplier,

(v) environmental, structural, and performance design verification tests,

(vi) production unit functional verification tests and certification,

(vii) packaging, shipping, handling, and storage requirements,

(viii) description of provisions for attachments and installation, and 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, NF-3000.

Frame type pipe supports are passive supports, requiring little maintenance and inservice 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.

Any hot or cold gaps required by the qualifying pipe stress analysis results are incorporated in the design. Where friction between the pipe and frame support occurs as a result of sliding, an appropriate coefficient of friction is used in order to calculate friction loading on the support. Seismic inertia loads as well as static seismic loads are considered in the design of frame supports covered by ASME Section III Subsection NF.

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 are not used

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.7.2 Reactor Pressure Vessel Sliding Supports

[*The ESBWR RPV sliding supports are sliding supports as defined by NF-3124 of the Code and are designed as an ASME Code Class 1 component support per the requirements of the Code, Subsection NF.*]* The loading conditions and stress criteria are given in Tables 3.9-1 and 3.9-2, and the calculated stresses 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.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.7.3 Reactor Pressure Vessel Stabilizer

The RPV stabilizer is designed as a safety-related linear type component support in accordance with the requirements of ASME B&PV Code Section III, Subsection NF. The stabilizer provides a reaction point near the upper end of the RPV to resist horizontal loads caused by effects such as earthquake, pipe rupture, and RBV. The design loading conditions and stress criteria are given in Table 3.9-2, and the calculated stresses meet the Code allowable stresses in the critical support areas for various plant operating conditions.

3.9.3.7.4 Floor-Mounted Major Equipment

Because the major active valves are supported by piping and not tied to building structures, valve "supports" do not exist (Subsection 3.9.3.7).

The Isolation Condenser heat exchangers are analyzed to verify the adequacy of their support structure under various plant operating conditions. In all cases, the load stresses in the critical support areas are within ASME Code allowables.

3.9.3.8 Other ASME III Component Supports

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 up to the interface with the building structure. The intermediate building structural steel component supports are designed in accordance with the codes as specified in Section 3.8. 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.

3.9.3.9 Threaded Fasteners – ASME Code Class 1, 2 and 3

3.9.3.9.1 Material Selection

[*Material used for threaded fasteners complies with the requirements of ASME B&PV Code Section III NB-2000, NC-2000, ND-2000 or NF-2000 as appropriate. Fracture toughness testing is performed in accordance with ASME B&PV Code Section III NB-2300, NC-2300 or ND-2300, as appropriate.*]* For verification of conformance to the applicable Code requirements, a chemical analysis is required for each heat of material and testing for mechanical properties is required on samples representing each heat of material and, where applicable, each heat treat lot.

The criteria of ASME B&PV Code Section III NB-2200, NC-2200 or ND-2200 rather than the material specification criteria applicable to the mechanical testing shall be applied if there is a conflict between the two sets of criteria. For safety-related threaded fasteners, documentation related to fracture toughness (as applicable) and certified material test reports are provided as part of the ASME Code records that are provided at the time the parts are shipped, and are part of the required records that are maintained at the site.

Threaded fasteners are selected for compatibility with the materials of the component being joined and the piping system fluids. The selection process considers deterioration which may occur during service as a result of corrosion, radiation effects, or instability of material.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.9.2 Special Materials Fabrication Processes and Special Controls

[*The design of threaded fasteners complies with ASME Code Section III NB-3000, NC-3000 or ND-3000, as appropriate. Fabrication of threaded fasteners complies with ASME Code Section III NB-4000, NC-4000 or ND-4000, as appropriate. Inspection of threaded fasteners complies with ASME Code Section III NB-2500, NC-2500 or ND-2500, as applicable.*]*

Lubricants with deliberately added halogens, sulfur, or lead are not used for any RCPB components or other components in contact with reactor water. Lubricants containing molybdenum sulfide (disulfide or polysulfide) are not to be used for any safety-related application. For ferritic steel threaded fasteners, conversion coatings, such as the Parkerizing process are suitable and may be used. If fasteners are plated, low melting point materials, such as zinc, tin, cadmium, etc., are not used.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.3.9.3 Preservice and Inservice Inspection Requirements

[*Preservice Inspection (PSI) and Inservice inspection is performed in accordance with ASME Code, Section XI.*]* The requirements for pressure retaining Class 1 bolting are addressed as Category B-G-1 for bolting greater than 2 inches in diameter and B-G-2 for bolting with diameters 2 inches and less. The Class 1 pressure retaining bolting sample is limited to the bolting on the heat exchangers, piping, pumps, and valve that are selected for examination in the in-service inspection program.

Category B-G-2 requires visual, VT-1, examination of the selected bolting. For Class 1, 2 and 3 systems, the bolted connections are examined for leakage (VT-2) during the system pressure tests required by ASME Section XI. For safety-related threaded fasteners, documentation related PSI is provided as part of the ASME Code records that are provided at the time the parts are shipped, and are part of the required records that are maintained at the site.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.9.4 Control Rod Drive System

This subsection addresses the CRD system as discussed in SRP 3.9.4. The CRD system consists of the control rods and the related mechanical components that provide the means for mechanical movement. As discussed in GDC 26 and 27, the CRD system provides one of the independent reactivity control systems. The rods and the drive mechanism are capable of reliably controlling reactivity changes either under conditions of AOOs, or under postulated accident conditions. A

[Table 3.9-2

Load Combinations and Acceptance Criteria for Safety-Related, ASME Code Class 1, 2 and 3 Components, Component Supports, and Class CS Structures

Plant Event	***Service Loading Combination*** *(1), (2), (3)*	***ASME Service Level*** *(4)*
1. Normal Operation (NO)	*N*	*A*
2. Plant/System Operating Transients (SOT)	*(a) N + TSV* *(b) N + SRV(5)*	*B* *B*
3. NO + SSE	*N + SSE*	*B(11), (12)*
4. Infrequent Operating Transient (IOT), ATWS, DPV	*(a) N(6) + SRV(5)* *(b) N + DPV(7)*	*C(13)* *C(13)*
5. SBL	*N + SRV(8) + SBL*	*C(13)*
6. SBL or IBL + SSE	*N + SBL (or IBL) + SSE + SRV(8)*	*D(13)*
7. LBL + SSE	*N + LBL + SSE*	*D(13)*
8. NLF	*N + SRV(5) + TSV(10)*	*D(13)*

Notes:

(1) See Legend on the following pages for definition of terms. Refer to Table 3.9-1 for plant events and cycles information.

The service loading combination also applies to Seismic Category I Instrumentation and electrical equipment (refer to Section 3.10).

(2) For vessels, loads induced by the attached piping are included as identified in their design specification.

For piping systems, water (steam) hammer loads are included as identified in their design specification.

(3) The method of combination of the loads is in accordance with NUREG-0484, Revision 1.

(4) The service levels are as defined in appropriate subsection of ASME Section III, Division 1.

(5) The most limiting load combination case among SRV(1), SRV(2) and SRV (ALL). For MS and branch piping evaluation, additional loads associated with relief line clearing and blowdown into the suppression pool are included.

(6) The RCPB is evaluated using in the load combination the maximum pressure expected to occur during ATWS.

(7) This applies only to the MS and Isolation Condenser systems. The loads from this event are combined with loads associated with the pressure and temperature concurrent with the event.

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

(9) (Deleted)

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

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

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

a. ASME Code Class 1 Piping

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

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

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

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

SSE inertia and seismic anchor motion loads are included in the calculation of ASME Code NB-3600 Equations (10) and (11).

b. For ASME Code Class 2 and 3 piping:

$$S_{SAM} = i \frac{M_c}{Z} \le 3.0 S_h \quad (\le 2.0 S_y) \qquad \text{Eq. (12b)}$$

Where: S_{SAM} *and* M_c *are defined in (a) above.*

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

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

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

Load Definition Legend for Table 3.9-2	
Normal (N)	*Normal and/or abnormal loads associated with the system operating conditions, including thermal loads, depending on acceptance criteria.*
SOT	*System Operational Transient (Subsection 3.9.3.1).*
IOT	*Infrequent Operational Transient (Subsection 3.9.3.1).*
ATWS	*Anticipated Transient Without Scram.*
TSV	*Turbine stop valve closure induced loads in the MS piping and components integral to or mounted thereon.*
RBV Loads	*Dynamic loads in structures, systems and components because of RBV induced by a dynamic event.*
NLF	*Non-LOCA Fault.*
SSE	*RBV loads induced by safe shutdown earthquake.*
SRV(1), SRV(2)	*RBV loads induced by safety relief valve (SRV) discharge of one or two adjacent valves, respectively.*
SRV (ALL)	*RBV loads induced by actuation of all safety relief valves, which activate within milliseconds of each other (e.g., turbine trip operational transient).*
SRV (ADS)	*RBV loads induced by the actuation of safety relief valves in Automatic Depressurization System operation, which actuate within milliseconds of each other during the postulated small or intermediate break LOCA, or SSE.*
DPV	*Depressurization Valve opening induced loads in the stub tubes and Main Steam system piping and pipe-mounted equipment.*
LOCA	*The loss-of-coolant-accident associated with the postulated pipe failure of a high-energy reactor coolant line. The load effects are defined by LOCA1 through LOCA7. LOCA events are grouped in three categories, SBL, IBL or LBL, as defined here.*
LOCA1	*Pool swell drag/fallback loads on safety-related piping and components located between the main vent discharge outlet and the suppression pool water upper surface.*
LOCA2	*Pool swell impact loads acting on safety-related piping and components located above the suppression pool water upper surface.*
LOCA3	*(a) Oscillating pressure induced loads on submerged safety-related piping and components during main vent clearing (VLC), condensation oscillations (COND), or chugging (CHUG), or* *(b) Jet impingement (JI) load on safety-related piping and components as a result of a postulated IBL or LBL event. Piping and components are defined safety-related, if they are required for shutdown of the reactor or to mitigate consequences of the postulated pipe failure without off-site power (refer to introduction to Section 3.6).*
LOCA4	*RBV load from main vent clearing (VLC).*
LOCA5	*RBV loads from condensation oscillations (COND).*
LOCA6	*RBV loads from chugging (CHUG).*

Load Definition Legend for Table 3.9-2	
LOCA7	*Annulus pressurization (AP) loads due to a postulated line break in the annulus region between the RPV and shieldwall. Vessel depressurization loads on reactor internals (Subsection 3.9.2.4) and other loads due to reactor blowdown reaction and jet impingement and pipe whip restraint reaction from the broken pipe are included with the AP loads.*
SBL	*Loads induced by small break LOCA (Subsection 3.9.3.1); the loads are: LOCA3(a), LOCA4 and LOCA6.*
IBL	*Loads induced by intermediate break LOCA (Subsection 3.9.3.1); the loads are: LOCA3(a) or LOCA3(b), LOCA4, LOCA5 and LOCA6.*
LBL	*Loads induced by large break LOCA (Subsection 3.9.3.1); the loads are: LOCA1 through LOCA7.*]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

[Table 3.9-9

Load Combinations and Acceptance Criteria for Class 1 Piping Systems

Condition	***Load Combination for all terms***(1) (2)(3)	***Acceptance Criteria***
Design	*PD + WT*	*Eq 9* $\leq 1.5\ S_m$ *NB-3652*
Service Level A & B	*PP, TE,* $\Delta T1$, $\Delta T2$ *, TA-TB,* RV_1, RV_2I, RV_2D, *TSV, SSEI, SSED*	*Eq 12 & 13* $\leq 2.4\ S_m$ *Fatigue - NB-3653:* $U < 0.40$(4)
Service Level B	*PP + WT + (TSV)* *PP + WT +* (RV_1) *PP + WT +* (RV_2I)	*Eq 9* $\leq 1.8\ S_m$*, but not greater than 1.5* S_y *Pressure not to exceed* $1.1P_a$ *(NB-3654)*
Service Level C	$PP + WT + [(CHUGI)^2 + (RV_1)^2]^{1/2}$ $PP + WT + [(CHUGI)^2 + (RV_2I)^2]^{1/2}$	*Eq 9* $\leq 2.25\ S_m$*, but not greater than 1.8* S_y *Pressure not to exceed 1.5* P_a *(NB-3654)*
Service Level D	$PP + WT + [(SSEI)^2 + (TSV)^2]^{1/2}$ $PP + WT + [(SSEI)^2 + (CHUGI)^2 + (RV_1)^2]^{1/2}$ $PP + WT + [(SSEI)^2 + (CHUGI)^2 + (RV_2I)^2]^{1/2}$ $PP + WT + [(SSEI)^2 + (CONDI)^2 + (RV_1)^2]^{1/2}$ $PP + WT + [(SSEI)^2 + (CONDI)^2 + (RV_2I)^2]^{1/2}$ $PP + WT + [(SSEI)^2 + (API)^2]^{1/2}$	*Eq 9* $\leq 3.0\ S_m$ *but not greater than 2.0* S_y *Pressure not to exceed 2.0* P_a *(NB-3654)*

(1) RV1 and TSV loads are used for MS Lines only

(2) RV2 represents RV2 ALL (all valves), RV2SV (single Valve) and RV2 AD (Automatic Depressurization operation)

(3) For the SRV discharge piping, all direct loads for SRV and LOCA loads are evaluated for submerged piping.

(4) In conjunction with compliance with RG 1.207, the fatigue usage limit of $\leq$ *0.40 will be used as the criteria for piping locations exempt from pipe break consideration.*

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)]**

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

[Table 3.9-10

Snubber Loads

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

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

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

Where: *TSV = Turbine Stop Valve closure loads*

RV_1 = SRV Opening Loads (Acoustic Wave)

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

RV_2D = SRV Building 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)]**

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

[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	$WT + TE + (TSV)$ $WT + TE + (RV_1)$ $WT + TE + [(RV_2I)^2 + (RV_2D)^2]^{1/2}$	*Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS)*
Service Level C	$WT + TE + [(CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$ $WT + TE + [(CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$	*Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS)*
Service Level D	$WT + TE + [(SSEI)^2 + (SSED)^2 + (TSV)^2]^{1/2}$ $WT + TE + [(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_1)^2]^{1/2}$ $WT + TE + [(SSEI)^2 + (SSED)^2 + (CHUGI)^2 + (CHUGD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$ $WT + TE + [(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_1)^2]^{1/2}$ $WT + TE + [(SSEI)^2 + (SSED)^2 + (CONDI)^2 + (CONDD)^2 + (RV_2I)^2 + (RV_2D)^2]^{1/2}$ $WT + TE + [(SSEI)^2 + (SSED)^2 + (API)^2 + (APD)^2]^{1/2}$	*Vendor Load Capacity Datasheet (LCD) or Vendor Design Report Summary (DRS)*

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

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

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

Where:
- *TSV = Turbine Stop Valve closure loads*
- *WT = Dead Weight*
- *TE = Thermal Expansion*
- *RV_1 = SRV Opening Loads (Acoustic Wave)*
- *RV_2I = SRV Building Acceleration Loads (Inertia Effect) (all valves)*
- *RV_2D = SRV Building 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)]**

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

[Table 3.9-12

Linear Type (Anchor and Guide) Main Steam Piping Support

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

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

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

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

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

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

Where: *TSV = Turbine Stop Valve closure loads*
WT = Dead Weight
TE = Thermal Expansion
RV_1 = SRV Opening Loads (Acoustic Wave)
RV_2I = SRV Building Acceleration Loads (Inertia Effect) (all valves)
RV_2D = SRV Building 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)]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.10.1 Seismic and Dynamic Qualification Criteria

3.10.1.1 Selection of Qualification Method

*[The qualification of Seismic Category I mechanical and electrical equipment is accomplished by test, analysis, or a combination of testing and analysis. Qualification by actual seismic experience, as permitted by IEEE 344-1987 is not utilized.]**

In general, analysis is used to supplement test data although simple components may lend themselves to dynamic analysis in lieu of full scale testing. The deciding factors for choosing between tests or analysis include:

- Magnitude and frequency of seismic and RBV dynamic loadings;
- Environmental conditions (Appendix 3H) associated with the dynamic loadings;
- Nature of the safety-related function(s);
- Size and complexity of the equipment;
- Dynamic characteristics of expected failure modes (structural or functional); and
- Partial test data upon which to base the analysis.

The selection of qualification method to be used is largely a matter of engineering judgment; however, tests, and/or analyses of assemblies are preferable to tests or analyses on separate components (e.g., a motor and a pump, including the coupling and other appurtenances should be tested or analyzed as an assembly).

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.10.1.2 Input Motion

The input motion for the qualification of equipment and supports is defined by response spectra. The Required Response Spectra (RRS) are generated from the building dynamic analysis, as described in Section 3.7. They are grouped by buildings and by elevations. This RRS definition incorporates the contribution of RBV dynamic loads as specified by the load combinations in Table 3.9-2 and 3.9-3. When one type of equipment is located at several elevations and/or in several buildings, the governing response spectra are specified.

3.10.1.3 Dynamic Qualification Program

The dynamic qualification program is described in Section 4.4 of GEH's EQ Program (Reference 3.10-2). The program conforms to the requirements of IEEE 323 as modified and endorsed by the RG 1.89, and meets the criteria contained in IEEE 344 as modified and endorsed by RG 1.100.

3.10.1.4 Dynamic Qualification Report

The Dynamic Qualification Report (DQR) identifies all Seismic Category I electrical and mechanical equipment and their supports. The DQR contains the following: