GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

52-001

July 16, 1992

Mr. Giuliano DeGrassi
Building 475C
Brookhaven National Laboratory
Upton, NY 11973

Dear Giuliano:

Enclosed is a mark-up of the ABWR SSAR addressing the March 23-27, 1982 Piping Audit concerns. These revisions correspond to Amendment 21 of the ABWR SSAR. Also enclosed are the microfiche for three analyses of the SRVDL Wetwell portion for the "ADJQ" load using time steps of 0.0035, 0.001 and 0.0005 second.

Sincerely,

Jack N. Fox

Jack N. Fox
Advanced Reactor Programs

cc: Chet Poslusny

Enclosure

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SECTION 3.6

CONTENTS (Continued)

surge which in turn trips the main breaker), then a loss of offsite power occurs in a mechanistic time sequence with a SACF. Otherwise, offsite power is assumed available with a SACF.

(7) A whipping pipe is not capable of rupturing impacted pipes of equal or greater nominal pipe diameter, but may develop throughwall cracks in equal or larger nominal pipe sizes with thinner wall thickness.

(8) All available systems, including those actuated by operator actions, are available to mitigate the consequences of a postulated piping failure. In judging the availability of systems, account is taken of the postulated failure and its direct consequences such as unit trip and loss of offsite power, and of the assumed SACF and its direct consequences. The feasibility of carrying out operator actions are judged on the basis of ample time and adequate access to equipment being available for the proposed actions.

Although a pipe break event outside the containment may require a cold shutdown, up to eight hours in hot standby is allowed in order for plant personnel to assess the situation and make repairs.

(10) Pipe whip occurs in the plane defined by the piping geometry and causes movement in the direction of the jet reaction. If unrestrained, a whipping pipe with a constant energy source forms a plastic hinge and rotates about the nearest rigid restraint, anchor, or wall penetration. If unrestrained, a whipping pipe without a constant energy source (i.e., a break at a closed valve with only one side subject to pressure) is not capable of forming a plastic hinge and rotating provided its movement can be defined and evaluated.

(11) The fluid internal energy associated with the pipe break reaction can take into account any line restrictions (e.g., flow limiter) between the pressure source and break location and absence of energy reservoirs, as applicable.

3.6.1.1.4 Approach

To comply with the objectives previously described, the essential systems, components, and equipment are identified. The essential systems, components, and equipment, or portions thereof, are identified in Table 3.6-1 for piping failures postulated inside the containment and in Table 3.6-2 for outside the containment.

3.6.1.2 Description

The lines identified as high-energy per Subsection 3.6.2.1.1 are listed in Table 3.6-3 for inside the containment and in Table 3.6-4 for outside the containment. Moderate-energy piping defined in Subsection 3.6.2.1.2 is listed ⑥
in Table 3.6-5 for outside the containment. Pressure response analyses are performed for the subcompartments containing high-energy piping. A detailed discussion of the line breaks selected, vent paths, room volumes, analytical methods, pressure results, etc., is provided in Section 6.2 for primary containment subcompartments.

The effects of pipe whip, jet impingement, spraying, and flooding on required function of essential systems, components, and equipment, or portions thereof, inside and outside the containment are considered.

In particular, there are no high-energy lines near the control room. As such, there are no effects upon the habitability of the control room by a piping failure in the control building or elsewhere either from pipe whip, jet impingement, or transport of steam. Further discussion on control room habitability systems is provided in Section 6.4.

3.6.1.3 Safety Evaluation

3.6.1.3.1 General

An analysis of pipe break events is performed to identify those essential systems, components, and equipment that provide protective actions required to mitigate, to acceptable limits, the consequences of the pipe break event.

Pipe break events involving high-energy fluid

(c) The assemblies are subjected to a single pressure test at a pressure not less than its design pressure.

(d) The assemblies do not prevent the access required to conduct the inservice examination specified in item (7).

(7) A 100% volumetric inservice examination of all pipe welds would be conducted during each inspection interval as defined in IWA-2400, ASME Code, Section XI.

3.6.2.1.4.3 ASME Code Section III Class 1 Piping In Areas Other Than Containment Penetration

With the exception of those portions of piping identified in Subsection 3.6.2.1.4.2, breaks in ASME Code, Section III, Class 1 piping are postulated at the following locations in each piping and branch run:

(a) At terminal ends*

(b) At intermediate locations where the maximum stress range (see Subsection 3.6.2.1.4.2, Paragraph (1)(a)) as ~~calculated by Eq. (10) in NB-3653, ASME Code, Section III.~~

~~If the calculated maximum stress range of Eq.(10) exceeds the stress range~~ calculated by both Eq.(12) and Eq.(13) in Paragraph NB-3653, ASME Code, Section III ~~should meet~~ exceed the limit of 2.4 Sm.

(c) At intermediate locations where the cumulative usage factor exceeds 0.1.

As a result of piping re-analysis due to differences between the design configuration and the as-built configuration, the highest stress or cumulative usage factor locations may be shifted; however, the initially determined intermediate break locations need not be changed unless one of the following conditions exists:

(i) The dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.

(ii) A change is required in pipe parameters such as major differences in pipe size, wall thickness, and routing.

3.6.2.1.4.4 ASME Code Section III Class 2 and 3 Piping in Areas Other Than Containment Penetration

With the exceptions of those portions of piping identified in Subsection 3.6.2.1.4.2, breaks in ASME Codes, Section III, Class 2 and 3 piping are postulated at the following locations in those portions of each piping and branch run:

(a) At terminal ends (see Subsection 3.6.2.1.4.3, Paragraph (a))

(b) At intermediate locations selected by one of the following criteria:

(i) At each pipe fitting (e.g., elbow, tee, cross, flange, and nonstandard fitting), welded attachment, and valve. Where the piping contains no fittings, welded attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure.

(ii) At each location where stresses calculated (see Subsection 3.6.2.1.4.2, Paragraph (1)(d)) by the sum of Eqs. (9) and (10) in NC/ND-3653, ASME Code, Section III, exceed 0.8 times the sum of the stress limits given in NC/ND-3653.

As a result of piping re-analysis due to differences between the design configuration and the as-built configuration, the highest stress

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* *Extremities of piping runs that connect to structures, components (e.g., vessels, pumps, valves), or pipe anchors that act as rigid constraints to piping motion and thermal expansion. A branch connection to a main piping run is a terminal end of the branch run, except where the branch run is classified as part of a main run in the stress analysis and is shown to have a significant effect on the main run behavior. In piping runs which are maintained pressurized during normal plant conditions for only a portion of the run (i.e., up to the first normally closed valve) a terminal end of such runs is the piping connection to this closed valve.*

3.6.2.2 Analytic Methods to Define Blowdown Forcing Functions and Response Models.

3.6.2.2.1 Analytic Methods to Define Blowdown Forcing Functions.

The rupture of a pressurized pipe causes the flow characteristics of the system to change creating reaction forces which can dynamically excite the piping system. The reaction forces are a function of time and space and depend upon fluid state within the pipe prior to rupture, break flow area, frictional losses, plant system characteristics, piping system, and other factors. The methods used to calculate the reaction forces for various piping systems are presented in the following subsections.

The criteria that are used for calculation of [illegible]d blowdown forcing functions include:

(1) Circumferential breaks are assumed to result in pipe severance and separation amounting to at least a one-diameter lateral displacement of the ruptured piping sections unless physically limited by piping restraints, structural members, or piping stiffness as may be demonstrated by inelastic limit analysis (e.g., a plastic hinge in the piping is not developed under loading).

(2) The dynamic force of the jet discharge at the break location is based on the cross-sectional flow area of the pipe and on a calculated fluid pressure as modified by analytically- or experimentally-determined thrust coefficient. Line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs are taken into accounts, as applicable, in the reduction of jet discharge.

(3) All breaks are assumed to attain full size within one millisecond after break initiation.

The forcing functions due to the postulated pipe breaks near the reactor or at a branch connection are calculated by the solution of one-dimensional, compressible unsteady steam flow in the gas system. The numerical analysis is performed by the method of characteristics. The flow starts with steady flow from the RPV to the turbine. A pipe break causes the steam flow to reverse its direction and to flow from the turbine to the break location. The pipe segment force time histories are determined by calculating the momentum change in the pipe segments of a closed system. The broken pipe segment force time history is calculated in accordance with Appendix B of ANSI/ANS-58.2.

3.6.2.2.2 Pipe Whip Dynamic Response Analyses

The prediction of time-dependent and steady-thrust reaction loads caused by blowdown of subcooled, saturated, and two-phase fluid from ruptured pipe is used in design and evaluation of dynamic effects of pipe breaks. A discussion of the analytical methods employed to compute these blowdown loads is given in Subsection 3.6.2.2.1. Following is a discussion of analytical methods used to account for this loading.

The criteria used for performing the pipe whip dynamic response analyses include:

(1) A pipe whip analysis is performed for each postulated pipe break. However, a given analysis can be used for more than one postulated break location if the blowdown forcing function, piping and restraint system geometry, and piping and restraint system properties are conservative for other break locations.

(2) The analysis includes the dynamic response of the pipe in question and the pipe whip restraints which transmit loading to the support structures.

(3) The analytical model adequately represents the mass/inertia and stiffness properties of the system.

(4) Pipe whipping is assumed to occur in the plane defined by the piping geometry and configuration and to cause pipe movement in the direction of the jet reaction.

(5) Piping within the broken loop is no longer considered part of the RCPB. Plastic deformation in the pipe is considered as a potential energy absorber. Limits of strain are imposed which are similar to strain levels allowed in restraint plastic members. Piping systems are designed so that plastic instability does not occur in the pipe at the design dynamic and static loads unless damage studies are performed which show the consequences do not result in direct damage to any essential system or component.

(6) Components such as vessel safe ends and valves which are attached to the broken piping system, do not serve a safety-related function, or failure of which would not further escalate the consequences of the accident are not designed to meet ASME Code-imposed limits for essential components under faulted loading. However, if these components are required for safe shutdown or serve to protect the structural integrity of an essential component, limits to meet the Code requirements for faulted conditions and limits to ensure required operability will be met.

(7) The piping stresses in the containment penetration areas due to loads resulting from a postulated piping failure can not exceed the limits specified in Subsection 3.6.2.1.4.2(1)(c).

is performed using the

An analysis for pipewhip restraint selection PDA computer program, ~~and~~ a ~~pipe break modeling~~ program [redacted] as described in Appendix 3D, which predicts the response of a pipe subjected to the thrust force occurring after a pipe break. The program treats the situation in terms of generic pipe break configuration which involves a straight, uniform pipe fixed at one end and subjected to a time-dependent thrust force at the other end. A typical restraint used to reduce the resulting deformation is also included at a location between the two ends. Nonlinear and time-independent stress-strain relationships are used to model the pipe and the restraint. Using a plastic-hinge concept, bending of the pipe is assumed to occur only at result in wetting and spraying of essential structures, systems, and components.

(7) Reflected jets are considered only when there is an obvious reflecting surface (such as a flat plate) which directs the jet onto an essential equipment. Only the first reflection is considered in evaluating potential targets.

(8) Potential targets in the jet path are considered at the calculated final position of the broken end of the ruptured pipe. This selection of potential targets is considered adequate due to the large number of breaks analyzed and the protection provided from the effects of these postulated breaks.

The analytical methods used to determine which targets will be impinged upon by a fluid jet and the corresponding jet impingement load include:

(1) The direction of the fluid jet is based on the arrested position of the pipe during steady-state blowdown.

(2) The impinging jet proceeds along a straight path.

(3) The total impingement force acting on any cross-sectional area of the jet is time and distance invariant with a total magnitude equivalent to the steady-state fluid blowdown force given in Subsection 3.6.2.2.1 and with jet characteristics shown in Figure 3.6-3.

(4) The jet impingement force is uniformly distributed across the cross-sectional area of the jet and only the portion intercepted by the target is considered.

(5) The break opening is assumed to be a circular orifice of cross-sectional flow area equal to the effective flow area of the break.

(6) The jet impingement force is equal to the steady-state value of the fluid blowdown force calculated by the methods described in Subsection 3.6.2.2.1.

(7) The distance of jet travel is divided into two or three regions. Region 1 (Figure 3.6-3) extends from the break to the asymptotic area. Within this region the discharging fluid flashes and undergoes expansion from the break area pressure to the atmospheric pressure. In Region 2 the jet expands further. For partial-separation circumferential breaks, the area increases as the jet expands. In Region 3, the jet expands at a half angle of 10°. (Figures 3.6-3a and c.)

(8) The analytical model for estimating the asymptotic jet area for subcooled water and saturated water assumes a constant jet area. For fluids discharging from a break which are below the saturation temperature at the corresponding room pressure or have a pressure at the break area equal to the room pressure, the free expansion does not occur.

(9) The distance downstream from the break where the asymptotic area is reached (Region 2) is calculted for circumferential and longitudinal breaks.

(10) Both longitudinal and fully separated circumferential breaks are treated similarly. The value of fL/D used in the blowdown calculation is used for jet impingement also.

(11) Circumferential breaks with partial (i.e., $h < D/2$) separation between the two ends of the broken pipe not significantly offset (i.e., no more than one pipe wall thickness lateral displacement) are more difficult to

quantify. For these cases, the following assumptions are made.

(a) The jet is uniformly distributed around the periphery.

(b) The jet cross section at any cut through the pipe axis has the configuration depicted in Figure 3.6-3b and the jet regions are as therein delineated.

(c) The jet force F_j = total blowdown F.

(d) The pressure at any point intersected by the jet is:

$$P_j = \frac{F_j}{A_R}$$

where

A_R = the total 360° area of the jet at a radius equal to the distance from the pipe centerline to the target.

(e) The pressure of the jet is then multiplied by the area of the target submerged within the jet.

(12) Target loads are determined using the following procedures.

(a) For both the fully separated circumferential break and the longitudinal break, the jet is studied by determining target locations vs. ~~asymptomatic~~ asymptotic distance and applying ANSI/ANS-58.2, Appendices C and D.

(b) For circumferential break with limited separation, the jet is analyzed by using ~~different~~ the equations of ANSI/ANS 58.2, Appendices C and D and determing respective target and ~~asymptomatic~~ asymptotic locations.

Code Section III-imposed limits for essential components under faulted loading.

(2) If these components are required for safe shutdown or serve to protect the structural integrity of an essential component, limits to meet the ASME Code requirements for faulted conditions and limits to ensure required operability are met.

The methods used to calculate the pipe whip loads on piping components in the same run as the postulated break are described in Section 3.6.2.2.2.

3.6.2.3.2.2 Pipe Displacement Effects on Essential Structures, Other Systems, and Components

The criteria and methods used to calculate the effects of pipe whip on external components consists of the following:

(1) The effects on essential structures and barriers are evaluated in accordance with the barrier design procedures given in Subsection 3.5.3

(2) If the whipping pipe impacts a pipe of equal or greater nominal pipe diameter and equal or greater wall thickness, the whipping pipe does not rupture the impacted pipe. Otherwise, the impacted pipe is assumed to be ruptured.

(3) If the whipping pipe impacts other components (valve actuators, cable trays, conduits, etc.), it is assumed that the impacted component is unavailable to mitigate the consequences of the pipe break event.

(4) Damage of unrestrained whipping pipe on essential structures, components, and systems other than the ruptured one is prevented by either separating high energy systems from the essential systems or providing pipe whip restraints.

3.6.2.3.3 Loading Combinations and Design Criteria for Pipe Whip Restraint

Pipe whip restraints, as differentiated from piping supports, are designed to function and carry load for an extremely low-probability gross failure in a piping system carrying high-energy fluid. In the ABWR plant, the piping integrity does not depend on the pipe whip restraints for any piping design loading combination including earthquake but shall remain functional following an earthquake up to and including the SSE (See Subsection 3.2.1). When the piping integrity is lost because of a postulated break, the pipe whip restraint [illegible] to limit the movement of the broken p [illegible] an acceptable distance. The pipe whip restraints (i.e., those devices which serve only to control the movement of a ruptured pipe following gross failure) will be subjected to once-in-a-lifetime loading. For the purpose of the pipe whip restraint design, the pipe break is considered to be a faulted condition (See Subsection 3.9.3.1.1.4) and the structure to which the restraint is attached is also analyzed and designed accordingly. The pipe whip restraints are non-ASME Code components; however, the ASME Code requirements may be used in the design selectively to assure its safety-related function if ever needed. Other methods, i.e. testing, with reliable data base for design and sizing of pipe whip restraints can also be used.

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The pipe whip restraints utilize energy absorbing U-rods to attenuate the kinetic energy of a ruptured pipe. A typical pipe whip restraint is shown in Figure 3.6-6. The principal feature of these restraints is that they are installed with several inches of annular clearance between them and the process pipe. This allows for installation of normal piping insulation and for unrestricted pipe thermal movements during plant operation. Select critical locations inside primary containment are also monitored during hot functional testing to provide verification of adequate clearances prior to plant operation. The specific design objectives for the restraints are:

(1) The restraints shall in no way increase the reactor coolant pressure boundary stresses by their presence during any normal mode of reactor operation or condition;

(2) The restraint system shall function to stop the movement of a pipe failure (gross loss of piping integrity) without allowing damage to critical components or missile development; and

3.6.4 COL License Information

3.6.4.1 Details of Pipe Break Analysis Results and Protection Methods

The following shall be provided by the COL applicant (See Subsection 3.6.2.5):

(1) A summary of the dynamic analyses applicable to high-energy piping systems in accordance with Subsection 3.6.2.5 of Regulatory Guide 1.70. This shall include:

  (a) Sketches of applicable piping systems showing the location, size and orientation of postulated pipe breaks and the location of pipe whip restraints and jet impingement barriers.

  (b) A summary of the data developed to select postulated break locations including calculated stress intensities, cumulative usage factors and stress ranges as delineated in BTP MEB 3-1.

(2) For failure in the moderate-energy piping systems listed in Table 3.6-~~5~~6, descriptions showing how safety-related systems are protected from the resulting jets, flooding and other adverse environmental effects. 410.21

(3) Identification of protective measures provided against the effects of postulated pipe failures for protection of each of the systems listed in Tables 3.6-1 and 3.6-2. 410.22

(4) The details of how the MSIV functional capability is protected against the effects of postulated pipe failures. 410.26

(5) Typical examples, if any, where protection for safety-related systems and components against the dynamic effects of pipe failures include their enclosure in suitably designed structures or compartments (including any additional drainage system or equipment environmental qualification needs). 410.28

(6) The details of how the feedwater line check and feedwater isolation valves functional capabilities are protected against the effects of postulated pipe failures.

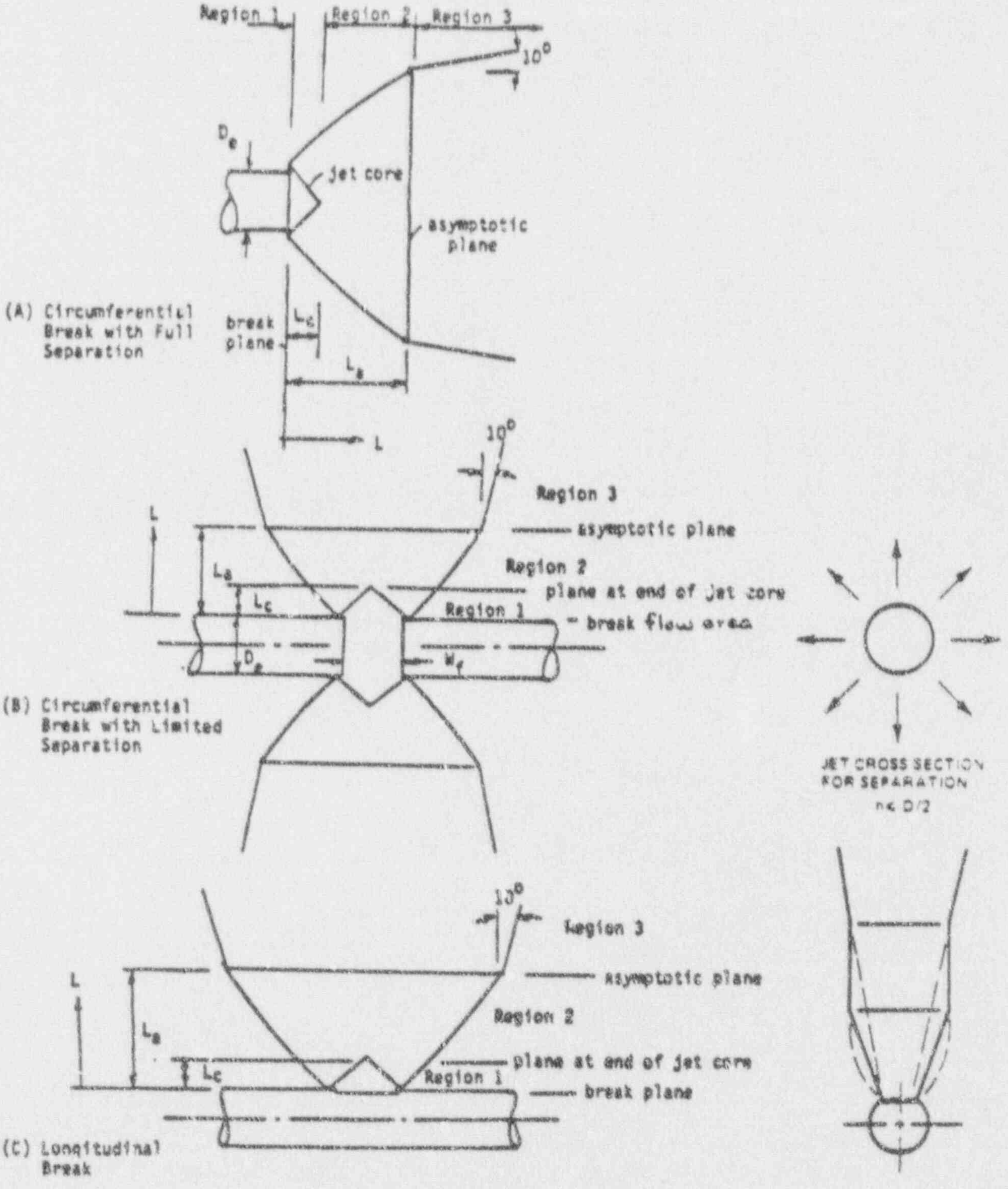

Figure 3.6-~~8~~ JET CHARACTERISTICS

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Values for $(v_H)_i$ and $(v_V)_i$ are computed as follows:

$$(v_H)_i^2 = (v_x)_i^2 + (v_H)_g^2 \tag{3.7-9}$$

$$(v_V)_i^2 = (v_z)_i^2 + (v_V)_g^2 \tag{3.7-10}$$

where $(v_H)_g$ and $(v_V)_g$ are the peak horizontal and vertical ground velocity, respectively, and $(v_x)_i$ and $(v_z)_i$ are the maximum values of the relative lateral and vertical velocity of mass m_i.

Letting m_o be total mass of the structure and base mat, the energy required to overturn the structure is equal to

$$E_o = m_o g h \tag{3.7-11}$$

where h is the height to which the center of mass of the structure must be lifted to reach the overturning position. Because the structure may not be a symmetrical one, the value of h is computed with respect to the edge that is nearer to the center of mass. The structure is defined as stable against overturning when the ratio E_o to E_s exceeds 1.5.

These calculations assume the structure rests on the ground surface, hence, are conservative because the structure is actually embedded to a considerable depth. The embedded effect is considered only when the ratio E_o to E_s is less than 1.5.

3.7.2.15 Analysis Procedure for Damping

In a linear dynamic analysis using a modal superposition approach, the procedure to be used to properly account for damping in different elements of a coupled system model is as follows:

(1) The structural percent critical damping of the various structural elements of the model is first specified. Each value is referred to as the damping ratio (C_j) of a particular component which contributes to the complete stiffness of the system.

(2) An eigenvalue analysis of the linear system model is performed. This results in the eigenvector matrices (ϕ_i) which are normalized and satisfy the orthogonality conditions:

$$\phi_i^T K \phi_i = \omega_i^2, \text{ and } \phi_i^T K \phi_j = 0 \text{ for } i \neq j \tag{3.7-12}$$

where

K = stiffness matrix;

ω_i = circular natural frequency associated with mode i; and

ϕ_i^T = transpose of i^{th} mode eigenvector ϕ_i

Matrix ϕ contains all translational and rotational coordinates.

(3) Using the strain energy of the individual components as a weighting function, the following equation is derived to obtain a suitable damping ratio (β_i) for mode i.

$$\beta_i = \frac{1}{\omega_i^2} \sum_{j=1}^{N} \left[C_j \left(\phi_i^T K \phi_i \right)_j \right] \tag{3.7-13}$$

where

β_i = modal damping coefficient for i^{th} mode;

N = total number of structural elements;

ϕi = component of i^{th} mode eigenvector corresponding to j^{th} element;

ϕ_i^T = Transpose of ϕ_i defined above;

C_j = percent critical damping associated with element j;

ATTACHMENT A for page 3.7-14

For vibrating systems and their supports, two general methods are used to obtain the solution of the equations of dynamic equilibrium of a multi-degree-of-freedom model. The first is the Method of Modal Superposition described in subsection 3.7.2.1.1. When the time-history modal superposition method of analysis is used, the time-history peaks are broadened plus and minus 10%. The second method of dynamic analysis is the Direct Integration Method. The solution of the equations of motion is obtained by direct step-by-step numerical integration. The numerical integration time step, Δt, must be sufficiently small to accurately define the dynamic excitation and to render stability and convergency of the solution up to the highest frequency of significance. For most of the 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.

Piping modelling and dynamic analysis are described in subsection 3.7.3.3.1.

Values for $(v_H)_i$ and $(v_V)_i$ are computed as follows:

$$(v_H)_i^2 = (v_x)_i^2 + (v_H)_g^2 \qquad (3.7\text{-}9)$$

$$(v_V)_i^2 = (v_z)_i^2 + (v_V)_g^2 \qquad (3.7\text{-}10)$$

where $(v_H)_g$ and $(v_V)_g$ are the peak horizontal and vertical ground velocity, respectively, and $(v_x)_i$ and $(v_z)_i$ are the maximum values of the relative lateral and vertical velocity of mass m_i.

Letting m_o be total mass of the structure and base mat, the energy required to overturn the structure is equal to

$$E_o = m_o g h \qquad (3.7\text{-}11)$$

where h is the height to which the center of mass of the structure must be lifted to reach the overturning position. Because the structure may not be a symmetrical one, the value of h is computed with respect to the edge that is nearer to the center of mass. The structure is defined as stable against overturning when the ratio E_o to E_s exceeds 1.5.

These calculations assume the structure rests on the ground surface, hence, are conservative because the structure is actually embedded to a considerable depth. The embedded effect is considered only when the ratio E_o to E_s is less than 1.5.

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In a linear dynamic analysis using a modal superposition approach, the procedure to be used to properly account for damping in different elements of a coupled system model is as follows:

(1) The structural percent critical damping of the various structural elements of the model is first specified. Each value is referred to as the damping ratio (C_j) of a particular component which contributes to the complete stiffness of the system.

(2) An eigenvalue analysis of the linear system model is performed. This results in the eigenvector matrices (ϕ_i) which are normalized and satisfy the orthogonality conditions:

$$\phi_i^T K \phi_i = \omega_i^2, \text{ and } \phi_i^T K \phi_j = 0 \text{ for } i \neq j \qquad (3.7\text{-}12)$$

where

K = stiffness matrix;

ω_i = circular natural frequency associated with mode i; and

ϕ_i^T = transpose of i^{th} mode eigenvector ϕ_i

Matrix ϕ contains all translational and rotational coordinates.

(3) Using the strain energy of the individual components as a weighting function, the following equation is derived to obtain a suitable damping ratio (β_i) for mode i.

$$\beta_i = \frac{1}{\omega_i^2} \sum_{j=1}^{N} \left[C_j \left(\phi_i^T K \phi_i \right)_j \right] \qquad (3.7\text{-}13)$$

where

β_i = modal damping coefficient for i^{th} mode;

N = total number of structural elements;

ϕi = component of i^{th} mode eigenvector corresponding to j^{th} element;

ϕ_i^T = Transpose of ϕ_i defined above;

C_j = percent critical damping associated with element j;

K = stiffness matrix of element j; and

ω_i = circular natural frequency of mode i.

3.7.3 Seismic Subsystem Analysis

3.7.3.1 Seismic Analysis Methods

This subsection discusses the methods by which Seismic Category I subsystems and components are qualified to ensure the functional integrity of the specific operating requirements which characterize their Seismic Category I designation.

In general, one of the following five methods of seismically qualifying the equipment is chosen based upon the characteristics and complexities of the subsystem:

(1) dynamic analysis;

(2) testing procedures;

(3) equivalent static load method of analysis;

(4) a combination of (1) and (2); or

(5) a combination of (2) and (3).

replace w/ Att. A

Equivalent static load method of subsystem analysis is described in Subsection 3.7.3.5.

Appropriate design response spectra (OBE and SSE) are furnished to the manufacturer of the equipment for seismic qualification purposes. Additional information such as input time history is also supplied only when necessary.

When analysis is used to qualify Seismic Category I subsystems and components, the analytical techniques must conservatively account for the dynamic nature of the subsystems or components. Both the SSE and OBE, with their difference in damping values, are considered in the dynamic analysis as explained in Subsection 3.7.1.3.

~~The general approach employed is the dynamic analysis of Seismic Category I equipment and component design is based on the response spectrum technique~~. The time-history technique described in Subsection 3.7.2.1.1 generates timehistories at various support elevations for use in the analysis of subsystems and equipment. The structural response spectra curves are subsequently generated from the time history accelerations.

The dynamic analysis of Seismic Category I subsystems and components is accomplished using the response spectrum or time-history approach. Time History analysis is performed using either the direct integration method or the modal superposition method.

At each level of the structure where vital components are located, three orthogonal components of floor response spectra, two horizontal and one vertical, are developed. The floor response spectrum is smoothed and envelopes all calculated response spectra from different site soil conditions. The response spectra are peak broadened plus or minus 10%. When components are supported at two or more elevations, the response spectra of each elevation are superimposed and the resulting spectrum is the upper bound envelope of all the individual spectrum curves considered.

~~For vibrating systems and their supports, multi-degree-of-freedom models are used in accordance with the lumped-parameter modeling techniques and normal mode theory described in Subsection 3.7.2.1.1. Piping analysis is described in Subsection 3.7.3.3.1.~~

When testing is used to qualify Seismic Category I subsystems and components, all the loads normally acting on the equipment are simulated during the test. The actual mounting of the equipment is also simulated or duplicated. Tests are performed by supplying input accelerations to the shake table to such an extent that generated test response spectra (TRS) envelope the required response spectra.

For certain Seismic Category I equipment and components where dynamic testing is necessary to ensure functional integrity, test performance data and results reflect the following:

(1) performance data of equipment which has been subjected to dynamic loads equal to or greater than those experienced under the specified seismic conditions;

(2) test data from previously tested comparable equipment which has been subjected under similar conditions to dynamic loads equal to or greater than those specified; and

ATTACHMENT A for page 3.7-14

For vibrating systems and their supports, two general methods are used to obtain the solution of the equations of dynamic equilibrium of a multi-degree-of-freedom model. The first is the Method of Modal Superposition described in subsection 3.7.2.1.1. When the time-history modal superposition method of analysis is used, the time-history peaks are broadened plus and minus 10%. The second method of dynamic analysis is the Direct Integration Method. The solution of the equations of motion is obtained by direct step-by-step numerical integration. The numerical integration time step, Δt, must be sufficiently small to accurately define the dynamic excitation and to render stability and convergency of the solution up to the highest frequency of significance. For most of the 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.

Piping modelling and dynamic analysis are described in subsection 3.7.3.3.1.

(3) actual testing of equipment in accordance with one of the methods described in Subsection 3.9.2.2 and Section 3.10.

3.7.3.2 Determination of Number of Earthquake Cycles

3.7.3.2.1 Piping

Fifty (50) peak OBE cycles are postulated for fatigue evaluation.

3.7.3.2.2 Other Equipment and Components

Criterion II.2.b of SRP Section 3.7.3 recommends that at least one safe shutdown earthquake (SSE) and five operating basis earthquakes (OBEs) should be assumed during the plant life. It also recommends that a minimum of 10 maximum stress cycles per earthquake should be assumed (i.e., 10 cycles for SSE and 50 cycles for OBE). For equipment and components other than piping, 10 peak OBE stress cycles are postulated for fatigue evaluation based on the following justification.

To evaluate the number of cycles engendered by a given earthquake, a typical Boiling Water Reactor Building reactor dynamic model was excited by three different recorded time histories: May 18, 1940, El Centro NS component, 29.4 sec; 1952, Taft N69° W component, 30 sec; and March 1957, Golden Gates 89°E component, 13.2 sec. The modal response was truncated so that the response of three different frequency bandwidths could be studied, 0^+-to-10 Hz, 10-to-20 Hz, and 20-to-50 Hz. This was done to give a good approximation to the cyclic behavior expected from structures with different frequency content.

Enveloping the results from the three earthquakes and averaging the results from several different points of the dynamic model, the cyclic behavior given in Table 3.7-6 was formed.

Independent of earthquake or component frequency, 99.5% of the stress reversals occur below 75% of the maximum stress level, and 95% of the reversals lie below 50% of the maximum stress level.

In summary, the cyclic behavior number of fatigue cycles of a component during a earthquake is found in the following manner:

(1) the fundamental frequency and peak seismic loads are found by a standard seismic analysis (i.e., from eigen extraction and forced response analysis);

(2) the number of cycles which the component experiences are found from Table 3.7-6 according to the frequency range within which the fundamental frequency lies; and

(3) for fatigue evaluation, one-half percent (0.005) of these cycles is conservatively assumed to be at the peak load, and 4.5% (0.045) at the three-quarter peak. The remainder of the cycles have negligible contribution to fatigue usage.

The SSE has the highest level of response. However, the encounter probability of the SSE is so small that it is not necessary to postulate the possibility of more than one SSE during the 60-year life of a plant. Fatigue evaluation due to the SSE is not necessary since it is a faulted condition and thus not required by ASME Code Section III.

The OBE is an upset condition and is included in fatigue evaluations according to ASME Code Section III. Investigation of seismic histories for many plants show that during a 60-year life it is probable that five earthquakes with intensities one-tenth of the SSE intensity, and one earthquake approximately 20% of the proposed SSE intensity, will occur. The 60-year life corresponds to 40 years of actual plant operation divided by a 67% usage factor. To cover the combined effects of these earthquakes and the cumulative effects of even lesser earthquakes, 10 peak OBE stress cycles are postulated for fatigue evaluation.

3.7.3.3 Procedure Used for Modeling

3.7.3.3.1 Modeling of Piping Systems

3.7.3.3.1.1 Summary

To predict the dynamic response of a piping system to the specified forcing function, the dynamic model must adequately account for all significant modes. Careful selection must be made of the proper response spectrum curves and

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3.7.3.3.1 Modeling and Analysis of Piping Systems

3.7.3.3.1.1 Modeling of Piping Systems

Mathematical models for Seismic Category I piping systems are constructed to reflect the dynamic characteristics of the system. The continuous system is modelled as an assemblage of pipe elements supported by hangers, guides, anchors, struts and snubbers. Pipe and hydrodynamic masses are lumped at the nodes and are connected by weightless elastic beam elements which reflect the physical properties of the corresponding piping segment. The 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 pipe mounted equipment, such as valves, pumps and motors, are modelled with lumped masses connected by elastic beam elements which reflect the physical properties of the pipe mounted equipment. The torsional effects of valve operators and other pipe mounted equipment with offset centers of gravity with respect to the piping center line are included in the mathematical model. On straight runs, mass points are located at spacings no greater than the span which would have a fundamental frequency equal to the cutoff frequency stipulated in Subsection 3.7 when calculated as a simply supported beam with uniformly distributed mass.

Snubbers,struts and frame type supports are modelled with representative stiffness properties. The equivalent stiffness of snubbers is based on dynamic tests performed on prototype snubber assemblies or on data provided by the vendor. The stiffness of supporting structures for snubbers and struts is generally not included in the piping mathematical model. The supporting structure is typically designed to have a maximum deflection of 1/16 inch in the direction of the load. Anchors at equipment such as tanks, pumps or heat exchangers are modelled with representative stiffness properties.

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proper location of anchors in order to separate Seismic Category I from non-Category I piping systems.

3.7.3.3.1.2 ~~Selection of Mass Points~~ Decoupling Criteria

When performing a dynamic analysis, a piping system is idealized either as a mathematical model consisting of lumped masses connected by weightless elastic members or as a consistent mass model. The elastic members are given the properties of the piping system being analyzed. The mass points are carefully located to adequately represent the dynamic properties of the piping system. A mass point is located at the beginning and end of every elbow or valve, at the extended valve operator and at the intersection of every tee. On straight runs, mass points are located at spacings no greater than the span length corresponding to 33 Hz. A mass point is located at every extended mass to account for torsional effects on the piping system. In addition, the increased stiffness and mass of valves are considered in the modeling of a piping system.

3.7.3.3.1.3 Selection of Spectrum Curves

In selecting the spectrum curve to be used for dynamic analysis of a particular piping system, a curve is chosen which most closely describes the accelerations existing at the end points and restraints of the system. ~~The procedure for decoupling small branch lines from the main run of~~ The criteria employed to decouple Seismic Category I piping systems when establishing the analytical models to perform seismic analysis are as follows:

(1) The small branch lines are decoupled from the main runs if they have a diameter less than one-third the diameter of the main run.

(2) The stiffness of all the anchors and its supporting steel is large enough to effectively decouple the piping on either side of the anchor for analytic and code jurisdictional boundary purposes. The RPV is very stiff compared to the piping system and therefore, it is modeled as an anchor. Penetration assemblies (head fittings and penetration sleeve pipe) are very stiff compared to the piping system and are modeled as anchors. The stiffness matrix at the attachment location of the process pipe (i.e., main steam, RHR supply and return, RCIC, etc.) head fitting is sufficiently high to decouple the penetration assembly from the process pipe. Previous analysis indicates that a satisfactory minimum stiffness for this attachment point is equal to the stiffness in bending and torsion of a cantilevered pipe section of the same size as the process pipe and equal in length to three times the process pipe outer diameter.

For a piping system supported at more than two points located at different elevations in the building, the response spectrum analysis is performed using the envelope response spectrum of all attachment points. Alternatively, the ~~multiple support excitation~~ independent support motion (ISM) analysis methods may be used where ~~acceleration time histories or~~ differe. response spectra are applied at all the piping attachment points. ~~Finally, the worst single floor response spectrum selected from a set of floor response spectra obtained at various floors may be applied identically to all floors provided it envelops the other floor response spectra in the set.~~

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3.7.3.3.2 Modeling of Equipment

For dynamic analysis, Seismic Category I equipment is represented by lumped-mass systems which consist of discrete masses connected by weightless springs. The criteria used to lump masses are:

(1) The number of modes of a dynamic system is controlled by the number of masses used; therefore, the number of masses is chosen so that all significant modes are included. The modes are considered as significant if the corresponding natural frequencies are less than 33 Hz and the stresses calculated from these modes are greater than 10% of the total stresses obtained from lower modes. This approach is acceptable provided at least 90% of the loading/inertia is contained in the modes used. Alternately,

When the ISM method of analysis is used, a support group is defined by supports which have the same time-history input. This usually means all supports located on the same floor, or portions of a floor, of a structure. The responses due to [illegible] groups are combined by the SRSS procedur

ATTACHMENT C to page 3.7-16

3.7.3.3.1.4 Modelling of Special Engineered Pipe Supports

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 3.9.3.4.1(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. If these special devices are used, the modeling and analytical methodology will be in accordance with methodology accepted by the regulatory agency at the time of certification or at the time of application, per the discretion of the applicant.

3.7.3.3.1.5 Selection of Input Time-Histories

In selecting the acceleration time-history to be used for dynamic analysis of a piping system, the time-history chosen is one which most closely describes the accelerations existing at the piping support attachment points. For a piping system supported at more than two points located at different elevations in the building, the time-history analysis is performed using the envelope acceleration time-history of all attachment points. Alternatively, the independent support motion method may be used where different acceleration time-histories are input at the piping structural attachment points.

3.7.3.3.1.6 Amplification of Response Spectra at Support Attachment Points

The response spectra provided to the Piping Analyst include any amplification due to the flexibility of building local structures, such as steel platforms used for supporting piping and other equipment. Alternatively, the Civil/Structural group will specify an amplification factor to be applied to the building response spectra.

Decoupled branch piping is analyzed using the appropriate amplified response spectra developed for the system analsis.

the number of degrees of freedom are taken more than twice the number of modes with frequencies less than 33 Hz.

(2) Mass is lumped at any point where a significant concentrated weight is located (e.g., the motor in the analysis of pump motor stand, the impeller in the analysis of pump shaft, etc).

(3) If the equipment has free-end overhang span with flexibility significant compared to the center span, a mass is lumped at the overhang span.

(4) When a mass is lumped between two supports, it is located at a point where the maximum displacement is expected to occur. This tends to lower the natural frequencies of the equipment because the equipment frequencies are in the higher spectral range of the response spectra. Similarly, in the case of live loads (mobile) and a variable support stiffness, the location of the load and the magnitude of support stiffness are chosen to yield the lowest frequency content for the system. This ensures conservative dynamic loads since the equipment frequencies are such that the floor spectra peak is in the lower frequency range. If not, the model is adjusted to give more conservative results.

3.7.3.3.3 Field Location of Supports and Restraints

The field location of seismic supports and restraints for Seismic Category I piping and piping systems components is selected to satisfy the following two conditions:

(1) the location selected must furnish the required response to control strain within allowable limits; and

(2) adequate building strength and stiffness for attachment of the component supports must be available.

The final location of seismic supports and restraints for Seismic Category I piping, piping system components, and equipment, including the placement of snubbers, is checked against the drawings and instructions issued by the engineer. An additional examination of these supports and restraining devices is made to assure that their location and characteristics are consistent with the dynamic and static analyses of the system.

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3.7.3.4 Basis of Selection of Frequencies

Where practical, in order to avoid adverse resonance effects, equipment and components are designed/selected such that their fundamental frequencies are outside the range of 1/2 to twice the dominant frequency of the associated support structures. Moreover, in any case, the equipment is analyzed and/or tested to demonstrate that it is adequately designed for the applicable loads considering both its fundamental frequency and the forcing frequency of the applicable support structure. 210.27

All frequencies in the range of 0.25 to 33 Hz are considered in the analysis and testing of structures, systems, and components. These frequencies are excited under the seismic excitation.

If the fundamental frequency of a component is greater than or equal to 33 Hz, it is treated as seismically rigid and analyzed accordingly. Frequencies less than 0.25 Hz are not considered as they represent very flexible structures and are not encountered in this plant.

The frequency range between 0.25 Hz and 33 Hz covers the range of the broad band response spectrum used in the design.

3.7.3.5 Use of Equivalent Static Load Methods of Analysis

3.7.3.5.1 Subsystems Other Than NSSS

See Subsection 3.7.3.8.1.5 for equivalent static load analysis method.

3.7.3.5.2 NSSS Subsystems

When the natural frequency of a structure or component is unknown, it may be analyzed by applying a static force at the center of mass. In order to conservatively account for the possibility of more than one significant dynamic mode, the static force is calculated as 1.5

times the mass times the maximum spectral acceleration from the floor response spectra of the point of attachments of multispan structures. The factor of 1.5 is adequate for simple beam type structures. For other more complicated structures, the factor used is justified.

3.7.3.6 Three Components of Earthquake Motion

The total seismic response is predicted by combining the response calculated from the two

ATTACHMENT D to page 3.7-17

3.7.3.3.4 Analysis of Frame Type Pipe Supports

The design loads on frame type supports include (a) loads transmitted to the support by the piping response to thermal expansion, dead weight, and the inertia and anchor motion effects of all dynamic loads, (b) internal loads caused by the weight,thermal and inertia effects of loads on the structure itself, and (c) friction loads caused by the pipe sliding on the support. The coefficient of friction used to calculate the friction forces between the pipe and the steel frame is dependent upon the materials used. The pipe support detail drawing documents the coefficient of friction to be used in the analysis. To determine the response of the support structure to applied dynamic loads, the equivalent static load method of analysis described in Subsection 3.7.3.8.1.5 may be used. The loads transmitted to the support by the piping are applied as static loads acting on the support.

The forces the piping places on the frame-type supports are obtained from the piping analysis. In the piping analysis the stiffness of the frame-type supports is included in the piping analysis model, unless the support can be shown to be rigid. The frame-type supports may be modelled as rigid restraints providing they are designed so the maximum deflection in the direction of the applied load is less than 1/16 inch and providing the total gap or clearance between the pipe and frame support is less than 1/8 inch.

horizontal and the vertical analysis.

or time-history modal superposition

When the response spectrum method ~~is~~ are used, the method for combining the responses due to the three orthogonal components of seismic excitation is given as follows:

$$R_i = \left[\sum_{j=1}^{3} R_{ij}^2 \right]^{1/2} \qquad (3.7\text{-}14)$$

where

R_{ij} = maximum, coaxial seismic response of interest (e.g., displacement, moment, shear, stress, strain) in directions i due to earthquake excitation in direction j, (j = 1, 2, 3).

R_i = seismic response of interest in i direction for design (e.g., displacement, moment, shear, stress, strain) obtained by the SRSS rule to account for the nonsimultaneous occurrence of the R_{ij}'s.

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3.7.3.7 Combination of Modal Response

3.7.3.7.1 Subsystems Other Than NSSS

When the response spectrum method of modal analysis is used, contributions from all modes, except the closely spaced modes (i.e., the difference between any two natural frequencies is equal to or less than 10%) are combined by the square-root-of-the-sum-of-the-squares (SRSS) combination of modal responses. This is defined mathematically as:

$$R = \sqrt{\sum_{i=1}^{N} (R_i)^2} \qquad (3.7\text{-}15)$$

where

R = combined response;

R_i = response to the i^{th} mode; and

N = number of modes considered in the analysis.

Closely spaced modes are combined by taking the absolute sum of the such modes.

An alternate to the absolute sum method presented in Regulatory Guide 1.92 is the following:

$$R = \left[\sum_{i=1}^{N} R_i^2 + 2\Sigma \left| R_\ell R_m \right| \right]^{1/2} \qquad (3.7\text{-}16)$$

where the second summation is to be done on all ℓ and m modes whose frequencies are closely spaced to each other.

3.7.3.7.2 NSSS Subsystems

In a response spectrum modal dynamic analysis, if the modes are not closely spaced (i.e., if the frequencies differ from each other by more than 10% of the lower frequency), the modal responses are combined by the square-root-of-the-sum-of- the-squares (SRSS) method as described in Subsection 3.7.3.7.1 and Regulatory Guide 1.92.

If some or all of the modes are closely spaced, a double sum method, as described in Subsection 3.7.3.7.2.2, is used to evaluate the combined response. In a time-history method of dynamic analysis, the vector sum of every step is used to calculate the combined response. The use of the time-history analysis method precludes the need to consider closely spaced modes.

3.7.3.7.2.1 Square-Root-of-the-Sum-of-the-Squares Method

Mathematically, this SRSS method is expressed as follows:

$$R = \left(\sum_{i=i}^{N} (R_i)^2 \right)^{1/2} \qquad (3.7\text{-}17)$$

When the time-history responses from each of the three components of the earthquake motion are calculated by the direct integration method and combined algebraically at each time step, the maximum responses can be obtained from the combined time solution. When this method is used, the earthquake motions specified in the three different where

R = combined response;

R_i = response to the i^{th} mode; and

N = number of modes considered in the analysis.

3.7.3.7.2.2 Double Sum Method

This method, as defined in Regulatory Guide 1.92, is mathematically:

$$R = \left(\sum_{k=1}^{N} \sum_{s=1}^{N} | R_k R_s | \epsilon_{ks} \right)^{1/2} \qquad (3.7\text{-}18)$$

where

R = representative maximum value of a particular response of a given element to a given component of excitation;

R_k = peak value of the response of the element due to the k^{th} mode;

N = number of significant modes considered in the modal response combination; and

R_s = peak value of the response of the element attributed to s^{th} mode

where

$$\epsilon_{ks} = \left[1 + \left\{ \frac{(\omega'_k - \omega'_s)}{(\beta'_k \omega_k + \beta'_s \omega_s)} \right\}^2 \right]^{-1} \qquad (3.7\text{-}19)$$

in which

$$\omega'_k = \omega_k \left[1 - \beta_k^2 \right]^{1/2}$$

$$\beta'_k = \beta_k + \frac{2}{t_d \omega_k}$$

where ω_k and β_k are the modal frequency and the damping ratio in the kth mode, respectively, and t_d is the duration of the earthquake.

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3.7.3.8 Analytical Procedure for Piping

3.7.3.8.1 Piping Subsystems Other Than NSSS

3.7.3.8.1.1 Qualification by Analysis

The methods used in seismic analysis vary according to the type of subsystems and supporting structure involved. The following possible cases are defined along with the associated analytical methods used.

3.7.3.8.1.2 Rigid Subsystems with Rigid Supports

If all natural frequencies of the subsystem are greater than 33 Hz, the subsystem is considered rigid and analyzed statically as such. In the static analysis, the seismic forces on each component of the subsystem are obtained by concentrating the mass at the center of gravity and multiplying the mass by the appropriate maximum floor acceleration.

3.7.3.8.1.3 Rigid Subsystems with Flexible Supports

If it can be shown that the subsystem itself is a rigid body (e.g., piping supported at only two points) while its supports are flexible, the overall subsystem is modeled as a single-degree-of-freedom subsystem consisting of an effective mass and spring.

The natural frequency of the subsystem is computed and the acceleration determined from the floor response spectrum curve using the appropriate damping value. A static analysis is performed using 1.5 times the acceleration value. In lieu of calculating the natural frequency, the peak acceleration from the spectrum curve may be used.

If the subsystem has no definite orientation, the excitation along each of three mutually perpendicular axes is aligned with respect to the system to produce maximum loading. The

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3.7.3.7.3 Methodologies Used to Account for High-Frequency Modes

Sufficient modes are to be included in the dynamic analysis to ensure that the inclusion of additional modes does not result in more than a 10% increase in responses. To satisfy this requirement, the responses associated with high-frequency modes are combined with the low-frequency modal responses. High-frequency modes are those modes with frequencies greater than the dynamic analysis cutoff frequency specified in Subsection 3.7.

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 (33 Hz for seismic). Combine such modes in accordance with the methods described ~~above~~ in Subsections 3.7.3.7.1 and 2.

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 DOF i is given by:

$$d_i = \sum_{n=1}^{N} \Gamma_n \times \phi_{n,i} \qquad (3.7\text{-}\overset{20}{\cancel{11}})$$

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 DOF i

Γ_n = participation factor for mode n (see Eq. 3.7-3 for expression)

Next, determine the fraction of DOF mass not included in the summation of these modes:

$$e_i = |d_i - \delta_{ij}| \qquad (3.7\text{-}\overset{21}{\cancel{12}})$$

where δ_{ij} is the Kronecker delta, which is one if DOF i is in the direction of the input motion and zero if DOF i is a rotation or not in the direction of the input motion. If, for any DOF i, 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 DOF i are given by:

$$P_i = ZPA \times M_i \times e_i \qquad (3.7\text{-}\overset{22}{\cancel{13}})$$

where P_i is the force or moment to be applied at DOF i, and M_i is the mass or mass moment of inertia associated with DOF i. 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) are 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 percent. Modes that have natural frequencies less than that at which the spectral acceleration approximately returns to the ZPA are combined in accordance with RG 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.

~~3.7.2.8 Interaction of Non-Category I Structures with Seismic Category I Structures~~

~~The interfaces between Seismic Category I and non-Category I structures and plant equipment are designed for the dynamic loads and displacements produced by both the Seismic Category I and non-Category I structures and plant equipment. All non-Category I structures meet any one of the following requirements:~~

- ~~The collapse of any non-Category I structure will not cause the non-Category I structure to strike a Seismic Category I structure or component.~~
- ~~The collapse of any non-Category I structure will not impair the integrity of Seismic Category I structures or components.~~
- ~~The non-Category I structures will be analyzed and designed to prevent their failure under SSE conditions in a manner such that the margin of safety of these structures is equivalent to that of Seismic Category I structures.~~

~~3.7.2.9 Effects of Parameter Variations on Floor Response Spectra~~

~~Floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak broadened 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. When the seismic analysis is performed for a wide range of site conditions with sufficient variation in soil properties for the purpose of standardized design, the site-envelope floor response spectra are peak broadened by ±10. In lieu of peak broadening, the peak shifting method of Appendix N of ASME Section III, as permitted by RG 1.84, can be used.~~

excitation in each of the three axes is considered to act simultaneously. The excitations are combined by the SRSS method.

3.7.3.8.1.4 Flexible Subsystems

If the piping subsystem has more than two supports, it cannot be considered a rigid body and must be modeled as a multi-degree-of-freedom subsystem.

The subsystem is modeled as discussed in Subsection 3.7.3.3.1 in sufficient detail (i.e., number of mass points) to ensure that the lowest natural frequency between mass points is greater than 33 Hz. The mathematical model is analyzed using a time-history analysis technique or a response spectrum analysis approach. After the natural frequencies of the subsystem are obtained, a stress analysis is performed using the inertia forces and equivalent static loads obtained from the dynamic analysis for each mode.

~~For a response spectrum analysis based on a modal superposition method, the modal response accelerations are taken directly from the spectrum. The total seismic stress is normally obtained by combining the modal stress using the SRSS method. The seismic stress of closely spaced modes (i.e., within 10% of the adjacent mode) are combined by absolute summation. The resulting total is treated as a pseudomode and is then combined with the remaining modal stresses by the SRSS method.~~

~~The approach is simple and straightforward in all cases where the group of modes with closely spaced frequencies is tightly bundled (i.e., the lowest and the highest modes of the group are within 10% of each other). However, when the group of closely spaced modes is spaced widely over the frequency range of interest while the frequencies of the adjacent modes are closely spaced, the absolute sum method of combining response tends to yield over-conservative results. To prevent this problem, a general approach applicable to all modes is considered appropriate. The following equation is merely a mathematical representation of this approach.~~

~~The most probable system response, R, is given by:~~

$$\cancel{R = \left(\sum_{i=1}^{N} R_i^2 + 2\Sigma \left| R_\ell R_m \right| \right)^{1/2} \qquad (3.7\text{-}20)}$$

~~where the second summation is to be done on all ℓ and m modes whose frequencies are closely spaced to each other,~~

and where

R_i = response to the i^{th} mode

N = number of significant modes considered in the modal response combinations.

The excitation in each of the three major orthogonal directions is considered to act simultaneously with their effect combined by the SRSS method.

3.7.3.8.1.5 Static Analysis

A static analysis is performed in lieu of a dynamic analysis by applying the following forces at the concentrated mass locations (nodes) of the analytical model of the piping system:

(1) horizontal static load, $F_h = C_h W$, in one of the horizontal principal directions;

(2) equal static load, F_h, in the other horizontal principal direction; and

(3) vertical static load, $F_v = C_v W$;

where

C_h, C_v = multipliers of the gravity acceleration, g, determined from the horizontal and vertical floor response spectrum curves, respectively. (They are functions of the period and the appropriate damping of the piping system); and

W = weight at node points of the analytical model.

In a response spectrum dynamic analysis, modal responses are combined as described in Subsection 3.7.3.7.
In a response spectrum or time-history dynamic analysis, responses due to the three orthogonal components of seismic excitation are combined as described in Subsection 3.7.3.6.

For special case analyses, C_h and C_v may be taken as:

(1) 1.0 times the zero-period acceleration of the response spectrum of subsystems described in Subsection 3.7.3.8.1.2;

(2) 1.5 times the value of the response spectrum at the determined frequency for subsystems described in Subsection 3.7.3.8.1.3 and 3.7.3.8.1.4; and

(3) 1.5 times the peak of the response spectrum for subsystems described in Subsections 3.7.3.8.1.3 and 3.7.3.8.1.4.

An alternate method of static analysis which allows for simpler technique with added conservatism is acceptable . No determination of natural frequencies is made, but rather the response of the subsystem is assumed to be the peak of the appropriate response spectrum at a conservative and justifiable value of damping. The response is then multiplied by a static coefficient of 1.5 to take into account the effects of both multifrequency excitation and multimodal response.

3.7.3.8.1.6 Dynamic Analysis

The dynamic analysis procedure using the response spectrum method is provided as follows:

(1) The number of node points and members is indicated. If a computer program is utilized, use the same order of number in the computer program input. The mass at each node point, the length of each member, elastic constants, and geometric properties are determined.

(2) The dynamic degrees of freedom according to the boundary conditions are determined.

(3) The dynamic properties of the subsystem (i.e., natural frequencies and mode shapes) are computed.

(4) Using a given direction of earthquake motion, the modal participation factors, s_j, for each mode are calculated:

$$s_j = \frac{\sum_{i=1}^{N} M_i \phi_{ij}}{\sum_{i=1}^{N} M_i \phi_{ij}^{2}} \qquad (3.7\text{-}21)$$

where

M_i = i^{th} mass

ϕ_{ij} = component of ϕ_{ij} in the earthquake direction

ϕ'_{ij} = i^{th} characteristic displacement in the j^{th} mode

s_j = modal participation factor for the j^{th} mode

N = number of masses.

(5) Using the appropriate response spectrum curve, the spectral acceleration, r_a, for the j^{th} mode as a function of the j^{th} mode natural frequency and the damping of the system is determined.

(6) The maximum modal acceleration at each mass point, i, in the model is computed as follows:

$$a_{ij} = s_j \, r_{aj} \phi_{ij} \qquad (3.7\text{-}22)$$

where

a_{ij} = acceleration of the i^{th} mass point in the j^{th} mode.

(7) The maximum modal inertia force at the i^{th} mass point for the j^{th} mode is calculated from the equation:

$$F_{ij} = M_i \, a_{ij} \qquad (3.7\text{-}23)$$

(8) For each mode, the maximum inertia forces

are applied to the subsystem model, and the modal forces, shears, moments, stresses, and deflections are determined.

(9) The modal forces, shears, moments, stresses, and deflections for a given direction are combined in accordance with Subsection 3.7.3.8.1.4.

(10) Steps (5) through (9) are performed for each of the three earthquake directions.

(11) The seismic force, shear, moment, and stress resulting from the simultaneous application of the three components of earthquake loading are obtained in the following manner:

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2} \qquad (3.7\text{-}24)$$

R = equivalent seismic response quantity (force, shear, moment, stress, etc.)

R_x R_y R_z = colinear response quantities due to earthquake motion in the x, y, and z directions, respectively.

3.7.3.8.1.7 Damping Ratio

The damping ratio percentage of critical damping of piping subsystems corresponds to Regulatory Guide 1.61 or 1.84 (ASME Code Case N-411-1). The damping ratio is specified in Table 3.7-1.

INSERT G

Add new para

3.7.3.8.1.8 Effect of Differential Building Movements

In most cases, piping subsystems are anchored and restrained to floors and walls of buildings that may have differential movements during a seismic event. The movements may range from insignificant differential displacements between rigid walls of a common building at low elevations to relatively large displacements between separate buildings at a high seismicity site.

Differential endpoint or restraint deflections cause forces and moments to be induced into the piping system. The stress thus produced is a secondary stress. It is justifiable to place this stress, which results from restraint of free-end displacement of the piping system, in the secondary stress category because the stresses are self-limiting and, when the stresses exceed yield strength, minor distortions or deformations within the piping system satisfy the condition which caused the stress to occur.

The earthquake thus produces a stress-exhibiting property much like a thermal expansion stress and a static analysis can be used to obtain actual stresses. The differential displacements are obtained from the dynamic analysis of the building. The displacements are applied to the piping anchors and restraints corresponding to the maximum differential displacements which could occur. The static analysis is made three times: once for one of the horizontal differential displacements, once for the other horizontal differential displacements, and once for the vertical.

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3.7.3.8.2 NSSS Piping Subsystems

3.7.3.8.2.1 Dynamic Analysis

As described in Subsection 3.7.3.2.1, pipe line is idealized as a mathematical model consisting of lumped masses connected by elastic members. The stiffness matrix for the piping subsystem is determined using the elastic properties of the pipe. This includes the effects of torsional, bending, shear, and axial deformations as well as changes in stiffness due to curved members.

Next, the mode shapes and the undamped natural frequencies are obtained. The dynamic response of the subsystem is usually calculated by using the response spectrum method of analysis. When the connected equipment is supported at more than two points located at different elevations in the building, the response spectrum analysis is performed using the envelope response spectrum of all attachment points. Alternatively, the multiple excitation analysis methods may be used where acceleration time histories or response spectra are applied at all the equipment and piping attachment points.

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INSERT F page 3.7-22

The inertia (primary) and displacement (secondary) loads are dynamic in nature and their peak values are not expected to occur at the same time. Hence combination of the peak values of inertia load and anchor displacement load is quite conservative. In addition, anchor movement effects are computed from static analyses in which the displacements are applied to produce the most conservative loads on the components. Therefore, the primary and secondary loads are combined by the SRSS method.

INSERT G page 3.7-22

Strain energy weighted modal damping can also be used in the dynamic analysis. Strain energy weighting is used to obtain the modal damping coefficient due to the contributions of damping in the different elements of the piping system. The element damping values are specified in Table 3.7-1. Strain energy weighted modal damping is calculated as specified in Subsection 3.7.2.15.

INSERT I page 3.7-22

In a response spectrum dynamic analysis, modal responses are combined as described in subsection 3.7.3.7. In a response spectrum or time-history dynamic analysis, responses due to the three orthogonal components of seismic excitation are combined as described in subsection 3.7.3.6.

New section

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3.7.3.8.1.9 Use of Small Bore Pipe Handbooks

As an alternative to a static and dynamic flexibility analysis, for small bore piping(defined as piping 2 inches and less in nominal pipe size), it is acceptable to use small bore piping handbooks to design the piping whenever the following criteria are met:

(1) The small bore piping handbook at the time of application is currently accepted by regulatory agencies for use on equivalent piping at other nuclear power plants.

(2) When the small bore piping handbook is serving the purpose of the Design Report it meets all of the ASME requirements for a piping design report. This includes the piping and its supports.

(3) Formal documentation exists showing piping designed and installed to the small bore piping handbook is (a)conservative in comparison to results from a detail stress analysis for all applied loads and load combinations defined in the design specification, (b)does not result in piping that is less reliable because of an excessive number of supports, (c)does not result in violations of required clearances around sensitive components.

The small bore piping handbook methodology will not be applied when specific information is needed on (a)magnitude of pipe and fitting stresses,(b)pipe and fitting cumulative usage factors,(c)accelerations of pipe mounted equipment, or locations of postulated pipe breaks and leaks.

The small bore piping handbook methodology will not be applied to piping systems that are fully engineered and installed in accordance with engineereing drawings.

3.7.3.8.2.2 Effect of Differential Building Movements

The relative displacement between anchors is determined from the dynamic analysis of the structures. The results of the relative anchor-point displacement are used in a static analysis to determine the additional stresses due to relative anchor-point displacements. Further details are given in Subsection 3.7.3.8.1.8.

3.7.3.9 Multiple Supported Equipment Components With Distinct Inputs

The procedure and criteria for analysis are described in Subsections 3.7.2.1.3 and 3.7.3.3.1.3.

3.7.3.10 Use of Constant Vertical Static Factors

210.28 All Seismic Category I subsystems and components are subjected to a vertical dynamic analysis with the vertical floor spectra or time histories defining the input. A static analysis is performed in lieu of dynamic analysis if the peak value of the applicable floor spectra times a factor of 1.5 is used in the analysis. A factor of 1.0 instead of 1.5 can be used if the equipment is simple enough such that it behaves essentially as a single degree of freedom system. If the fundamental frequency of a component in the vertical direction is greater than or equal to 33 Hz, it is treated as seismically rigid and analyzed statically using the zero-period-response spectrum.

3.7.3.11 Torsional Effects of Eccentric Masses

Torsional effects of eccentric masses are included for Seismic Category I subsystems similar to that for the piping systems discussed in Subsection 3.7.3.3.1.2.

3.7.3.12 Buried Seismic Category I Piping and Tunnels

For buried Category I buried piping systems and tunnels the following items are considered in the analysis:

(1) The i~~nertial~~ effects due to an earthquake upon buried systems and tunnels will be adequately accounted for in the analysis. In case of buried systems sufficiently flexible relative to the surrounding or underlying soil, it is assumed that the systems will follow essentially the displacements and deformations that the soil would have if the systems were absent. When applicable, procedures, which take into account the phenomena of wave travel and wave reflection in compacting soil displacements from the ground displacements, are employed.

(2) The effects of static resistance of the surrounding soil on piping deformations or displacements, differential movements of piping anchors, bent geometry and curvature changes, etc., are considered. When applicable, procedures utilizing the principles of the theory of structures on elastic foundations are used.

(3) When applicable, the effects due to local soil settlements, soil arching, etc., are also considered in the analysis.

Add items (4) & (5) See Att J

3.7.3.13 Interaction of Other Piping with Seismic Category I Piping

In certain instances, non-Seismic Category I piping may be connected to Seismic Category I piping at locations other than a piece of equipment which, for purposes of analysis, could be represented as an anchor. The transition points typically occur at Seismic Category I valves which may or may not be physically anchored. Since a dynamic analysis must be modeled from pipe anchor point to anchor point, two options exist:

(1) specify and design a structural anchor at the Seismic Category I valve and analyze the Seismic Category I subsystem; or, if impractical to design an anchor,

(2) analyze the subsystem from the anchor point in the Seismic Category I subsystem through the valve to either the first anchor point in the non-Seismic Category I subsystem; or to sufficient distance in the non-Seismic Category I Subsystem so as not to significantly degrade the accuracy of analysis of the Seismic Category I piping.

Where small, non-Seismic Category piping is directly attached to Seismic Category I piping, its effect on the Seismic Category I piping is accounted for by lumping a portion of its mass with the Seismic Category I piping at the point of attachment.

Furthermore, non-Seismic Category I piping (particularly high energy piping as defined in Section 3.6) is designed to withstand the SSE to avoid jeopardizing adjacent Seismic Category I piping if it is not feasible or practical to isolate these two piping systems.

3.7.3.14 Seismic Analysis for Reactor Internals

The modeling of RPV internals is discussed in Subsection 3.7.2.3.2. The damping values are given in Table 3.7-1. The seismic model of the RPV and internal in shown in Figure 3.7-32.

3.7.3.15 Analysis Procedures for Damping

The modeling of RPV internals is discussed in Subsection 3.7.2.3.2. The damping values are given in Table 3.7-1. The seismic model of the RPV and internals is shown in Figure 3.7-32.

3.7.3.16 Analysis Procedure for NonSeismic Structures in Lieu of Dynamic Analysis

The method described here can be used for non-seismic structures in lieu of a dynamic analysis.

Structures designed to this method should be able to do the following:

(1) Resist minor levels of earthquake ground motion without damage.

(2) Resist moderate levels of earthquake ground motion without structural damage, but possibly experience some nonstructural damage.

(3) Resist major levels of earthquake ground motion having an intensity equal to the strongest either experienced or forecast at the building site, without collapse, but possibly with some structural as well as nonstructural damage.

3.7.3.16.1 Lateral Forces

Seismic loads are characterized as a force profile that varies with the height of the structure. These forces are applied at each floor of the structure and the resulting forces and moments are calculated from static equilibrium.

The buildings total base shear is characterized by the following equation:

$V = Z*I*C*W/R_w$; where

V = Total lateral force or shear at the base.

$F_x F_i F_n$ = Lateral force applied to level i, n, or x respectively.

F_t = That portion of V considered to be concentrated at the top of the structure in addition to F_n

Z = Seismic zone factor

I = Importance factor

C = Numerical Coefficient

R_w = Numerical Coefficient

S = Coefficient for site soil characteristics

T = Fundamental period of vibration of the structure in the direction under consideration, as determined by using the properties and deformation characteristics of the resisting elements in a properly substantiated analysis.

W = Total dead load of building including the partition load where applicable.

$w_i w_x$ = That portion of W which is located at or is assigned to level i or x, respectively

$h_i h_x$ = Height in feet above the base to level i or x, respectively

Att. J pg. 3.7-23

Add item (4) to Paragraph 3.7.3.12:

(4) All analyses will be based on soil characteristics that will give conservative results when compared with actual characteristics at the plant site. ~~This includes~~ These characteristics include soil density, relative density, static strength, type of backfill, coefficient of friction between pipe and backfill, and modulus of subgrade reaction.

Add item (5) to Paragraph 3.7.3.12:

(5) Most ~~(maybe all)~~ underground Category 1 piping is installed in pipe tunnels. For piping installed in pipe tunnels the categorization of seismic stresses and allowable stress limits will be the the same as above ground piping. Any underground Category 1 piping not installed in pipe tunnels may categorize stresses as follows: (a) All seismic bending stresses may be considered as secondary stress and, when combined with bending stresses induced by other loads such as thermal expansion, building settlement, soil settlement and relative anchor motions, shall satisfy appropriate code requirements for secondary stresses. (b) Axial stresses induced by axial friction forces under thermal expansion and seismic loads will be evaluated as primary stresses using the primary stress limits for the appropriate code pipe class.

analyzed for the faulted loading conditions. The ECCS and SLC pumps are active ASME Class 2 components. The allowable stresses for active pumps are provided in a footnote to Table 3.9-2.

The reactor coolant pressure boundary components of the reactor recirculation system (RRS) pump motor assembly, and recirculation motor cooling (RMC) subsystem heat exchanger are ASME Class 1 and Class 3, respectively, and are analyzed for the faulted loading conditions. All equipment stresses are within the elastic limits.

3.9.1.4.7 Fuel Storage and Refueling Equipment

Storage, refueling, and servicing equipment which is important to safety is classified as essential components per the requirements of 10CFR50 Appendix A. This equipment and other equipment which in case of a failure would degrade an essential component is defined in Section 9.1 and is classified as Seismic Category I. 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 in three directions. Imposed stresses are generated and combined for normal, upset, and faulted conditions. Stresses are compared, depending on the specific safety class of the equipment, to Industrial Codes, ASME, ANSI or Industrial Standards, AISC, allowables.

3.9.1.4.8 Fuel Assembly (Including Channel)

GE BWR fuel assembly (including channel) design bases, and analytical and evaluation methods including those applicable to the faulted conditions are the same as those contained in References 1 and 2.

3.9.1.4.9 ASME Class 2 and 3 Vessels

Elastic analysis methods are used for evaluating faulted loading conditions for Class 2 and 3 vessels. The equivalent allowable stresses using elastic techniques are obtained from NC/ND-3300 and NC-3200 of the ASME Code Section III. These allowables are above elastic limits.

3.9.1.4.10 ASME Class 2 and 3 Pumps

Elastic analysis methods are used for evaluating faulted loading conditions for Class 2 and 3 pumps. The equivalent allowable stresses for nonactive pumps using elastic techniques are obtained from NC/ND-3400 of the ASME Code Section III. These allowables are above elastic limits. The allowables for active pumps are provided in a footnote to Table 3.9-2.

3.9.1.4.11 ASME Class 2 and 3 Valves

Elastic analysis methods and standard design rules are used for evaluating faulted loading conditions for Class 2, and 3 valves. The equivalent allowable stresses for nonactive valves using elastic techniques are obtained from NC/ND-3500 of ASME Code, Section III. These allowables are above elastic limits. ~~The allowables for active valves are provided in a footnote to Table 3.9-2.~~

3.9.1.4.12 ASME Class 1, 2 and 3 Piping

Elastic analysis methods are used for evaluating faulted loading conditions for Class 1, 2, and 3 piping. The equivalent allowable stresses using elastic techniques are obtained from ~~Appendix F (for Class 1), and~~ NC/ND-3600 (for Class ~~2~~ 1, 2 and 3 piping) of the ASME Code Section III. ~~These allowables are above elastic limits. The allowables for functional capability of the essential piping are provided in a footnote to Table 3.9-2.~~

NB!

3.9.1.5 Inelastic Analysis Methods

Inelastic analysis is only applied to ABWR components to demonstrate the acceptability of three types of postulated events. Each event is an extermly low-probability occurence and the equipment affected by these events would not be reused. These three events are:

(1) Postulated gross piping failure.

(2) Postulated blowout of a reactor internal recirculation (RIP) motor casing due to a weld failure.

(3) Postulated blowout of a control rod drive (CRD) housing due to 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 3.6.2.3.3.

In the case of the RIP motor casing failure event, there are specific restraints applied to mitigate the effects of the failure. The mitigation arrangement consists of lugs on the RPV bottom head to which are attached two long rods for each RIP. The lower end of each rod engages two lugs on the RIP motor/cover. The use of inelastic analysis methods is limited to the middle slender body of the rod itself. The attachment lugs, bolts and clevises are shown to be adequate by elastic analysis. The selection of stainless steel for the rod is based on its high ductility assumed for energy absorption during inelastic deformation.

The mitigation for the CRD housing attachment weld failure is by somewhat different means than are those of the RIP in that the components with regular functions also function to mitigate the weld failure effect. The components are specifically:

(1) Core support plate

(2) Control rod guide tube

(3) Control rod drive housing

(4) Control rod drive outer tube

(5) Bayonet fingers

Only the cylindrical 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 analysis for there latter two events together with the criteria used for evaluation are consistent with the procedures described in Subsection 3.6.2.3.3 for the different components of a pipe whip restraint. Figure 3.9-6 shows the stress-strain curve used for the blowout restraints.

3.9.2 Dynamic Testing and Analysis

3.9.2.1 Piping Vibration, Thermal Expansion, and Dynamic Effects

The overall test program is divided into two phases; the preoperational test phase and the initial startup test phase. Piping vibration, thermal expansion and dynamic effects testing will be performed during both of these phases as described in Chapter 14. Subsections 14.2.12.1.51, 14.2.12.2.10 and 14.2.12.2.11 relate the specific role of this testing to the overall test program. Discussed below are the general requirements for this testing. It 230.31

internals to the RBV is also determined with dynamic model and dynamic analysis method described below for seismic analysis.

(4) **LOCA Loads**-The Assumed LOCA also results in RBV due to suppression pool dynamics as described in Appendix 3B and the response of the reactor internals are again determined with the dynamic model and dynamic analysis method used for seismic analysis. Various types of LOCA loads are identified on Table 3.9-2.

(5) **Seismic Loads**-The theory, methods, and computer codes used for dynamic analysis of the reactor vessel, internals, attached piping and adjoining structures are described in Section 3.7 and Subsection 3.9.1.2. Dynamic analysis is performed by coupling the lumped-mass model of the reactor vessel and internals with the building model to determine the system natural frequencies and mode shapes. The relative displacement, acceleration, and load response is then determined by either the time-history method or the resonse-spectrum method. The load on the reactor internals due to faulted event SSE are obtained from this analysis.

The above loads are considered in combination as defined in Table 3.9-2. The SRV, LOCA (SBL, IBL or LBL) and SSE loads as defined in Table 3.9-2 are all assumed to act in the same direction. The peak colinear responses of the reactor internals to each of these loads are added by the square root of the sum of the squares (SRSS) method. The resultant stresses in the reactor internal structures are directly added with stress resulting from the static and steady state loads in the faulted load combination, including the stress due to peak reactor internal pressure differential during the LOCA. The reactor internals satisfy the stress deformation and fatigue limits as defined in Subsection 3.9.5.3.

3.9.2.6 Correlations of Reactor Internals Vibration Tests With the Analytical Results

Prior to initiation of the instrumented vibration measurement program for the prototype plant, extensive dynamic analyses of the reactor and internals are performed. The results of these analyses are used to generate the allowable vibration levels during the vibration test. The vibration data obtained during the test will be analyzed in detail.

INSERT K for page 3.9-18

In the event any non-Class 1 components are subjected to cyclic loadings of a magnitude and/or duration so severe that the 60 year design life can not be assured by required Code calculations, applicants referencing the ABWR design will 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."

The results of the data analyses, vibration amplitudes, natural frequencies, and mode shapes are then compared to those obtained from the theoretical analysis.

Such comparisons provide the analysts with added insight into the dynamic behavior of the reactor internals. The additional knowledge gained from previous vibration tests has been utilized in the generation of the dynamic models for seismic and loss of coolant accident (LOCA) analyses for this plant. The models used for this plant are similar to those used for the vibration analysis of earlier prototype BWR plants.

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

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 3.9-2 presents the combinations of dynamic events to be considered for the design and analysis of all ABWR 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 3.9.7.4 for COL license information)

Table 3.9-2 also presents the evaluation models and criteria. The predicted loads or stresses and the design or allowable values for the most critical areas of each component are compared in accordance with the applicable code criteria or other limiting criteria. The calculated results meet the limits.

The design life for the ABWR Standard Plant is 60 years. A 60 year design life is a requirement for all major plant components with reasonable expection 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 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. ~~Applicants referencing the ABWR design will identify these ASME Class 2, 3 and Quality Group D components and provide the analyses required by the ASME Code, Subsection NB. These analyses will include the appropriate operating vibration loads and for the effects of mixing hot and cold fluids.~~

Replace w/ INSERT K on pg. 3.7-17.1

3.9.3.1.1 Plant Conditions

All events that the plant will or 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 in Subsection 3.9.3.1.1.5) and correlated to service levels for design limits defined in the ASME Boiler and Pressure Vessel Code Section III as shown in Tables 3.9-1 and 3.9-2.

to accomplish its safety functions as required by any subsequent design condition event.

~~Specific stress criteria to meet the functional requirements are identified in a footnote to Table 3.9-2.~~

3.9.3.1.2 Reactor Pressure Vessel Assembly

The reactor vessel assembly consists of the reactor pressure vessel, vessel support skirt, and shroud support.

The reactor pressure vessel, vessel support skirt, and shroud support are constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III. The shroud support consists of the shroud support plate and the shroud support cylinder and its legs. The reactor pressure vessel assembly components are classified as an ASME Class 1. Complete stress reports on these components are prepared in accordance with ASME Code requirements. NUREG-0619 (Reference 5) is also considered for feedwater nozzle and other such RPV inlet nozzle design.

The stress analysis is performed on the reactor pressure vessel, vessel support skirt, and shroud support for various plant operating conditions (including faulted conditions) by using the elastic methods except as noted in Subsection 3.9.1.4.2. 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.

3.9.3.1.3 Main Steam (MS) System Piping

210.6 The piping systems extending from the reactor pressure vessel to and including the outboard main steam isolation valve are constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 1 criteria. ~~The rules contained in Appendix F of ASME Code Section III are used in evaluating faulted loading conditions independently of other design and operating conditions. Stresses calculated on an elastic basis are evaluated in accordance with F-1360.~~ 210.6 210.36

The MS system piping extending from the outboard main steam isolation valve to the turbine stop valve is constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 2 Criteria. 210.36

INSERT ATT. K

3.9.3.1.4 Recirculation Motor Cooling (RMC) Subsystem

The RMC system piping loop between the recirculation motor casing and the heat exchanger is constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Subsection NB-3600. ~~The rules contained in Appendix F of ASME Code Section III are used in evaluating faulted loading conditions independently of all other design and operating conditions. Stresses calculated on an elastic basis are evaluated in accordance with F-1360.~~ 210.36

3.9.3.1.5 Recirculation Pump Motor Pressure Boundary

The motor casing of the recirculation internal pump is a part of and welded into an RPV nozzle and is constructed in accordance with the requirements of an ASME Boiler and Pressure Vessel Code Section III, Class 1 component. The motor cover is a part of the pump/motor assembly and is constructed as an ASME Class 1 component. These pumps are not required to operate during the safe shutdown earthquake or after an accident. 210.36

3.9.3.1.6 Standby Liquid Control (SLC) Tank

The standby liquid control tank is constructed in accordance with the requirements of an ASME Boiler and Pressure Vessel Code Section III, Class 2 component. 210.36

3.9.3.1.7 RRS and RHR Heat Exchangers

The primary and secondary sides of the RRS (reactor recirculation system) are constructed in accordance with the requirements of an ASME Boiler and Pressure Vessel Code Section III, Class 1 and Class 2 component, respectively. The primary and secondary side of the RHR system heat exchanger is constructed as an ASME Class 2 and Class 3 component respectively. 210.36

Stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the ASME Code Section III.

ATTACHMENT K to page 3.9-20

Turbine stop valve (TSV) closure in the main steam (MS) piping system results in a transient that produces momentary unbalanced forces acting on the MS piping system. Upon closure of the TSV, a pressure wave is created and it travels at sonic velocity toward the reactor vessel through each MS line. Flow of steam into each MS line from the reactor vessel continues until the steam compression wave reaches the reactor vessel. Repeated reflection of the pressure wave at the reactor vessel and the TSV produce time varying pressures and velocities, throughout the MS lines.

The analysis of the MS piping TSV closure transient consists of a stepwise time-history solution of the steam flow equation to generate a time-history of the steam properties at numerous locations along the pipe. Reaction loads on the pipe are determined at each elbow. These loads are composed of pressure-times-area, momentum change and fluid-friction terms.

The time-history direct integration method of analysis is used to determine the response of the MS piping system to TSV closure. The forces are applied at locations on the piping system where steam flow changes direction thus causing momentary reactions. The resulting loads on the MS piping are combined with loads due to other effects as specified in Subsection 3.9.3.1.

For Class 1 piping, stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the ASME Code Section III.

ance with the ASME Boiler and Pressure Vessel Code Section III. ~~For Class 1 piping, for the faulted plant condition, stresses are calculated on an elastic basis and evaluated in accordance with Appendix F 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.

3.9.3.2 Pump and Valve Operability Assurance

Active mechanical (with or without electrical operation) equipment are Seismic Category I and each is designed to perform a mechanical motion for its safety-related function during the life of the plant under postulated plant conditions. Equipment with faulted condition functional requirements include active pumps and valves in fluid systems such as the residual heat removal system, emergency core cooling system, and main steam system.

This Subsection discusses operability assurance of active ASME Code Section III pumps and valves, including motor, turbine or operator that is a part of the pump or valve (See Subsection 3.9.2.2).

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

Section 4.4 of GE's Environmental Qualification Program (Reference 6) applies to this subsection, and the seismic qualification methodology presented therein is applicable to mechanical as well as electrical equipment.

3.9.3.2.1 ECCS Pumps, Motors and Turbine

Dynamic qualification of the ECCS (RHR, RCIC and HPCF) pumps with motor or turbine assembly is also described in Subsections 3.9.2.2.2.6 and 3.9.2.2.2.7.

3.9.3.2.1.1 Consideration of Loading, Stress, and Acceleration Conditions in the Analysis

In order to avoid damage to the ECCS pumps during the faulted plant condition, the stresses caused by the combination of normal operating loads, SSE, other RBV loads, and dynamic system loads are limited to the material elastic limit. A three dimensional finite-element model of the pump and associated motor (see Subsections 3.9.3.2.2 and 3.9.3.2.1.5 for RCIC pump and turbine, respectively) and its support is developed and analyzed using the response spectrum and the dynamic analysis method. The same is analyzed due to static nozzle loads, pump thrust loads, and dead weight. Critical location stresses are compared with the allowable stresses and the critical location deflections with the allowables; and accelerations are checked to evaluate operability. The average membrane stress σm for the faulted condition loads is limited to 1.2S or approximately 0.75 σ_y (σ_y = yield stress), and the maximum stress in local fibers (σm + bending stress σb) is limited to 1.8S or approximately 1.1 σ_y. The max- imum faulted event nozzle loads are also con- sidered in an analysis of the pump supports to assure that a system misalignment cannot occur.

Performing these analyses with the conservative loads stated and with the restrictive stress limits as allowables assures that critical parts of the pump and associated motor or turbine will not be damaged during the faulted condition and that the operability of the pump for post-faulted condition operation will not be impaired.

3.9.3.2.1.2 Pump/Motor Operation During and Following Dynamic Loading

Active ECCS pump/motor rotor combinations are designed to rotate at a constant speed under all conditions. Motors are designed to withstand short periods of severe overload. The high rotary inertia in the operating pump quirements 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 (See Subsection 3.9.3.4.1). The dynamic qualification for operability is unique for each valve type; therefore, each method of qualification is detailed individually below.

3.9.3.2.4.1 Main Steam Isolation Valve

The typical Y-pattern 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 and safe shutdown earthquake.

The valve body is designed, analyzed and tested in accordance with the ASME Code Section III, Class 1 requirements. The MSIVs are modeled mathematically in the main steam line 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.

3.9.3.2.4.2 Main Steam Safety/Relief Valve

The typical SRV design described in Subsection 5.2.2.4.1 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 Code (ASME Class 1) analysis and test.

(1) 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.

(2) 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 main steam line system analysis, as with the MSIVs. This analysis assures the equipment design limits are not exceeded.

3.9.3.2.4.3 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 ASME Code, Section III, 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.

3.9.3.2.4.4 High Pressure Core Flooder Valve (Motor-Operated)

The typical HPCF valve body design, analysis and testing is in accordance with the requirements of the ASME Code, Section III, Class 1 or 2 components. The Class 1E electrical motor actuator is qualified by type test in accordance with IEEE 382, as discussed in Subsection 3.11.2. A mathematical model of this valve is included in the HPCF piping system analysis. The analysis results are assured not to exceed the horizontal and vertical dynamic acceleration limits acting simultaneously for a dynamic (SSE and other RBV) event, which is treated as an emergency condition.

3.9.3.2.5 Other Active Valves

Other safety-related active valves are ASME Class 1, 2 or 3 and are designed to perform their mechanical motion during dynamic loading conditions. The operability assurance program ensures that these valves will operate during a dynamic seismic and other RBV event.

3.9.3.2.5.1 Procedures

Qualification tests accompanied by analyses are conducted for all active valves. Procedures for qualifying electrical and instrumentation components which are depended upon to cause the valve to accomplish its intended function are described in Subsection 3.9.3.2.5.1.3.

3.9.3.2.5.1.1 Tests

Prior to installation of the safety-related valves, the following tests are performed: (1) shell hydrostatic test to ASME Code Section III requirements; (2) back seat and main seat leakage tests; (3) disc hydrostatic test; (4) functional tests to verify that the valve will open and close within the specified time limits when subject to the design differential pressure; and (5) operability qualification of valve actuators for the environmental conditions over the installed life. Environmental qualification procedures for operation follow those specified in Section 3.11. The results of all required tests are properly documented and included as a part of the operability acceptance documentation package.

3.9.3.2.5.1.2 Dynamic Load Qualification

The functionality of an active valve during and after a seismic and other RBV event may be demonstrated by an analysis or by a combination of analysis and test. The qualification of electrical and instrumentation components controlling valve actuation is discussed in Subsection 3.9.3.2.5.1.3. The valves are designed using either stress analyses or the pressure temperature rating requirements based upon design conditions. An analysis of the extended structure is performed for static equivalent dynamic loads applied at the center of gravity of the extended structure. See Subsection 3.9.2.2 for further details.

The maximum stress limits allowed in these analyses confirm structural integrity and are the limits developed and accepted by the ASME for the particular ASME Class of valve analyzed. ~~Additional detail on stress limits for operability is provided in a footnote to Table 3.9-2.~~

Dynamic load qualification is accomplished in the following way:

(1) All the active valves are designed to have a fundamental frequency which is greater than the high frequency asymptote (ZPA) of the dynamic event. This is shown by suitable test or analysis.

(2) The actuator and yoke of the valve system is statically loaded to an amount greater than that due to a dynamic event. The load is applied at the center to gravity of the actuator alone in the direction of the weakest axis of the yoke. The simulated operational differential pressure is simultaneously applied to the valve during the static deflection tests.

(3) The valve is then operated while in the deflected position (i.e., from the normal operating position to the safe position). The valve is verified to perform its safety-related function within the specified operating time limits.

(4) Motor operators and other electrical appurtenances necessary for operation are qualified as operable during a dynamic event by appropriate qualification tests prior to installation on the valve. These motor operators then have individual Seismic Category I supports attached to decouple the dynamic loads between the operators and valves themselves.

The piping, stress analysis, and pipe support design maintain the motor operator accelerations below the qualification levels with adequate margin of safety.

If the fundamental frequency of the valve, by test or analysis, is less than that for the ZPA, a dynamic analysis of the valve performed to determine the equivalent acceleration to be applied during the static test. The analysis provides the amplification of the input

3.9.3.4 Component Supports

The design of bolts for component supports is specified in the ASME Code Section III, 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 10,000 psi on the nominal bolt area in shear or tension.

Concrete anchor bolts which are used for pipe support base plates will be designed to the applicable factors of safety which are defined in I&E Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Revision 1 dated June 21,1979.

3.9.3.4.1 Piping

Supports and their attachments for essential ASME Code Section III, Class 1,2, and 3 piping are designed in accordance with Subsection NF* up to the interface of the building structure. 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 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 stress limits are per ASME III, Subsection NF and Appendix F. Supports are generally designed either by load rating method per paragraph NF-3260 or by the stress limits for linear supports per paragraph NF-3231. 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.

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The design of all supports for non-nuclear piping satisfies the requirements of ANSI B31.1, Paragraphs 120 and 121.

For the major active valves identified in Subsection 3.9.3.2.4, the valve operators are not used as attachment points for piping supports.

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 ~~of~~ or equipment after they have been installed. All piping supports are designed in accordance with the rules of Subsection NF of the ASME Code up to the building structure interface as defined in the project design specifications.

(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.

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*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 will be performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual", Publication T114-2/83.

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.

(3) Snubbers - The operating loads on snubbers are the loads caused by dynamic events (e.g., seismic, RBV due to LOCA and SRV discharge, discharge through a relief valve line or valve closure) during various operating conditions. Snubbers restrain piping against response to the vibratory 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 entire piping system including valves and support system between anchor points is mathematically modeled for complete piping structural analysis. In the dynamic analysis, the snubbers are modeled as a spring with a given spring stiffness depending on the snubber size. The analysis determines the forces and moments acting on each piping components and the forces acting on the snubbers due to all dynamic loading and operating conditions defined in the piping design specification. The forces on snubbers are operating loads for various operating conditions. The calculated loads cannot exceed the snubber design load capacity for various operating conditions, i.e., design, normal, upset, emergency and faulted.~~

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 will 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 all of the rules and regulations of the ASME Code Section III, 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 insure 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:

o Snubbers are subjected to force or displacement versus time loading at frequencies within the range of

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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 ASME Code Section III, Subsection NF-3000.

Struts are passive supports, requiring little maintenance and in-service inspection, and will normally be 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 will not be used at locations where restraint of pipe movement to thermal expansion will significantly increase the secondary piping stress ranges or equipment nozzle loads. Increases of thermal expansion loads in the pipe and nozzles will normally be restricted to less than 20%.

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, which are assured not to exceed the design loads for various operating conditions.

o Dynamic cyclic load tests are conducted for hydraulic snubbers to determine the operational characteristics of the snubber control value.

significant modes of the piping system;

- o Displacements are measured to determine the performance characteristics specified;

- o Tests are conducted at various temperatures to ensure operability over the specified range;

- o Peak test loads in both tension and compression are required to be equal to or higher than the rated load requirements; and

- o 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 which 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 Chapter 16 technical specifications will be prepared. This examination will be made after snubber installation but not more than 6 months prior to initial system pre-operational testing. The pre-service examination will verify 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 be recommended level and not 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 because of unexpected situations, reexamination of Items 1, 4, and 5 will be performed. Snubbers which are installed incorrectly or otherwise fail to meet the above requirements will be repaired or replaced and re-examined in accordance with the above criteria.

(4) Struts - ~~The design load on struts includes those loads caused by dead weight, thermal expansion, seismic forces (i.e., OBE and SSE), other RBV loads,~~

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~~system anchor displacements, and reaction forces caused by relief valve discharge or valve closure, etc.~~

~~Struts are designed in accordance with ASME Code Section III, Subsection NF-3000 to be capable of carrying the design loads for various operating conditions. As in case of snubbers, the forces on struts are obtained from an analysis, which are assured not to exceed the design loads for various operating conditions.~~

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3.9.3.4.2 Reactor Pressure Vessel Support Skirt

The ABWR RPV support skirt is designed as an ASME Code Class 1 component per the requirements of ASME Code Section III 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 in the critical support areas for various plant operating conditions. The stress level margins assure the adequacy of the RPV support skirt. An analysis for buckling shows that the support skirt complies with Subparagraph F-1332.5 of ASME III, Appendix F, and the loads do not exceed two thirds of the critical buckling strength of the skirt. The permissible skirt loads at any elevation, when simultaneously applied, are limited by the following interaction equation:

$$(P/P_{crit}) + (q/q_{crit}) + (\tau/\tau_{crit}) < (1/S.F.)$$

where:

q = longitudinal load
P = external pressure
τ = transverse shear stress
S.F. = safety factor
= 3.0 for design, testing, service levels A & B
= 2.0 for Service Level C
= 1.5 for Service Level D.

3.9.3.4.3 Reactor Pressure Vessel Stabilizer

The RPV stabilizer is designed as a Safety Class 1 linear type component support in accordance with the requirements of ASME Boiler and Pressure Vessel Code Section III, Subsection NF. The stabilizer provides a reaction point near the upper end of the RPV to resist horizontal loads due to effects such as earthquake, pipe rupture and RBV. The design 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 in the critical support areas for various plant operating conditions.

3.9.3.4.4 Floor-Mounted Major Equipment (Pumps, Heat Exchangers, and RCIC Turbine)

Since the major active valves are supported by piping and not tied to building structures, valve "supports" do not exist (See Subsection 3.9.3.4.1).

The HPCF, RHR, RCIC, SLC, FPCCU, SPCU, and CUW pumps; RMC, RHR, RWCU, and FPCCU heat exchangers; and RCIC turbine are all 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.

Seismic Category I active pump supports are qualified for dynamic (seismic and other RBV) loads by testing when the pump supports

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*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 will be performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual", Publication T114-2/83.

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Add new Paragraph 3.9.3.4.1 (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 ~~restricts~~ restraints to lateral movement in either one or two directions. Frame type pipe supports are designed in accordance with ASME Code Section III, Subsection NF-3000.

"Frame type pipe supports are passive supports, requiring little maintenance and in-service inspection, and will normally be 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 will not be used at locations where restraint of pipe movement to thermal expansion will significantly increase the secondary piping stress ranges or equipment nozzle loads. Increases of thermal expansion loads in the pipe and nozzles will normally be restricted to less than 20%.

"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 ~~struts~~ Frame type supports are obtained from an analysis, which are assured not to exceed the design loads for various operating conditions."

Add new Paragraph 3.9.3.4.1 (6):

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

Energy Absorbers - are linear energy absorbing support parts designed to dissipate energy associated with dynamic pipe movements by yielding. When energy absorbers are used they will be 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 since energy absorbers allow thermal movement of the pipe only in its design directions.

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 ASME Code Section III, 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.

3.9.7 COL License Information

3.9.7.1 Reactor Internals Vibration Analysis, Measurement and Inspection Program

The first COL applicant will provide, at the time of application, the results of the vibration assessment program for the ABWR prototype internals. These results will include the following information specified in Regulatory Guide 1.20.

R. G. 1.20	Subject
C.2.1	Vibration Analysis Program
C.2.2	Vibration Measurement Program
C.2.3	Inspection Program
C.2.4	Documentation of Results

NRC review and approval of the above information on the first COL applicants docket will complete the vibration assessment program requirements for prototype reactor internals.

In addition to the information tabulated above, the first COL applicant will provide the information on the schedules in accordance with the applicable portions of position C.3 of Regulatory Guide 1.20 for non-prototype internals.

Subsequent COL applicants need only provide the information on the schedules in accordance with the applicable portions of position C.3 of Regulatory Guide 1.20 for non-prototype internals. (See Subsection 3.9.2.4 for interface requirements).

3.9.7.2 ASME Class 2 or 3 or Quality Group Components with 60 Year Design Life

~~COL applicants will identify ASME Class 2 or 3 or Quality Group D components that are subjected to loadings which could result in thermal or dynamic fatigue and provide the analyses required by the ASME Code, Subsection NB. These analyses will include the appropriate operating vibration loads and for the effects of mixing hot and cold fluids. (See Subsection 3.9.3.1.~~

COL applicants will identify ASME Class 2 or 3 or Quality Group D components that are subjected to cyclic loadings of a magnitude and/or duration so severe the 60 year design life can not be assured by required Code calculations 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. (See Subsection 3.9.3.1.)

3.9.7.3 Pump and Valve Inservice Testing Program

COL applicants will provide a plan for the detailed pump and valve inservice testing and inspection program. This plan will

(1) Include baseline pre-service testing to support the periodic in-service testing of the components required by technical specifications. Provisions are included to disassemble and inspect the pump, check valves, and MOVs within the Code and safety-related classification as necessary, depending on test results. (See Subsections 3.9.6, 3.9.6.1, 3.9.6.2.1 and 3.9.6.2.2)

(2) Provide a study to determine the optimal frequency for valve stroking during inservice testing. (See Subsection 3.9.6.2.2)

(3) Address the concerns and issues identified in Generic Letter 89-10; specifically the method of assessment of the loads, the method of sizing the actuators, and the setting of the torque and limit switches. (See Subsection 3.9.6.2.2)

3.9.7.4 Audit of Design Specification and Design Reports

COL applicants will make available to the NRC staff design specification and design reports required by ASME Code for vessels, pumps, valves and piping systems for the purpose of audit. (See Subsection 3.9.3.1)

3.9.8 References

1. *BWR Fuel Channel Mechanical Design and Deflection*, NEDE-21354-P, September 1976.

2. *BWR/6 Fuel Assembly Evaluation of Combined Safe Shutdown Earthquake (SSE) and Loss-of-Coolant Accident (LOCA) Loadings*, NEDE-21175-P, November 1976.

3. NEDE-24057-P (Class III) and NEDE-24057 (Class I) Assessment of Reactor Internals Vibration in BWR/4 and BWR/5 Plants,

Table 3.9-2

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA FOR SAFETY-RELATED, ASME CODE CLASS 1, 2 AND 3 COMPONENTS, COMPONENT SUPPORTS, AND CLASS CC STRUCTURES

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

NOTES:

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

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

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

(3) For vessels and pumps, 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.

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

~~(5) For active Class 1, 2 or 3 valves, the design pressure is specified equal to or greater than the pressure for which the valve must operate (open or close).~~

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 (Continued)

NOTES:

~~(6) All ASME Code Class 1, 2 and 3 Piping Systems which are essential for safe shutdown under the postulated events are designed to meet the requirements of NEDO-21985 (Reference 7) and NRC's "Evaluation of Topical Report - Piping Functional Capability Criteria," by MEB dated July 17, 1980.~~

(7) For active Class 2 and 3 ~~valves and~~ pumps, the stresses are limited by criteria: $\sigma m \leq 1.2S$, and $(\sigma m \text{ or } \sigma L) + \sigma b \leq 1.8S$, where the notations are as defined in the ASME Code, Section III, subsections NC or ND, respectively.

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

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

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

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

(12) This applies only to the main steam lines and components mounted on it. The low probability that the TSVC and SRV loads can exist at the same time results in this combination being considered under service level D. 210.34

LOAD DEFINITION LEGEND:

Normal (N) -	Normal and/or abnormal loads associated with the system operating conditions, including thermal loads, depending on acceptance criteria.
SOT	System Operational Transient (see Subsection 3.9.3.1).
IOT	Infrequent Operational Transient (see Subsection 3.9.3.1).
ATWS -	Anticipated Transient Without Scram.
TSVC -	Turbine stop valve closure induced loads in the main steam piping and components integral to or mounted thereon.
RBV Loads -	Dynamic loads in structures, systems and components because of reactor building vibration (RBV) induced by a dynamic event.
OBE -	RBV loads induced by operational basis earthquake.
NLF -	Non LOCA Fault 210.34

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

(Continued)

LOAD DEFINITION LEGEND:

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 associated with automatic depressurization system which actuate within milliseconds of each other during the postulated small or intermediate break LOCA, or SSE.

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 $LOCA_1$ through $LOCA_7$. LOCA events are grouped in three categories, SBL, IBL or LBL, as defined here.

$LOCA_1$ - Pool swell (PS) drag/fallback loads on essential piping and components located between the main vent discharge outlet and the suppression pool water upper surface.

$LOCA_2$ - Pool swell (PS) impact loads acting on essential piping and components located above the suppression pool water upper surface.

$LOCA_3$ - (a) Oscillating pressure induced loads on submerged essential piping and components during main vent clearing (VLC), condensation oscillations (CO), or chugging (CHUG), or

(b) Jet impingement (JI) load on essential piping and components as a result of a postulated IBL or LBL event.

Piping and components are defined essential, if they are required for shutdown of the reactor or to mitigate consequences of the postulated pipe failure without offsite power (see introduction to Subsection 3.6).

$LOCA_4$ - RBV load from main vent clearing (VLC).

$LOCA_5$ - RBV loads from condensation oscillations (CO).

$LOCA_6$ - RBV loads from chugging (CHUG).

response spectra with nonconstant mod~~e~~al damping. The nonconstant mod~~e~~al damping analysis option can calculate spectral acceleration at the discrete eigenvalues of a dynamic system using either the strain energy weighted modal damping or the ASME Code ~~Class~~ Case N-411-1 damping values.

3D.4.6 Piping Dynamic Analysis Program--PDA

The pipe whip dynamic analysis is performed using the PDA computer program, as described in Subsection 3.6.2.2.2. PDA is a computer program used to determine the response of a pipe subjected to the thrust force occurring after a pipe break. It also is used to determine the pipe whip restraint design and capacity.

The program treats the situation in terms of generic pipe break configuration, which involves a straight, uniform pipe fixed at one end and subjected to a time-dependent thrust force at the other end. A typical restraint used to reduce the resulting deformation is also included at a location between the two ends. Nonlinear and time-independent stress-strain relations are used to model the pipe and the restraint. Using a plastic hinge concept, bending of the pipe is assumed to occur only at the fixed end and at the location supported by the restraint.

Effects of pipe shear deflection are considered negligible. The pipe-bending moment-deflection (or rotation) relation used for these locations is obtained from a static nonlinear cantilever beam analysis. Using moment-angular rotation relations, nonlinear equations of motion are formulated using energy considerations and the equations are numerically integrated in small time steps to yield the time-history of the pipe motion.

3D.4.7 Deleted

3D.4.8 Thermal Transient Program--LION

The LION program is used to compute radial and axial thermal gradients in piping. The program calculates a time-history of ΔT_1, ΔT_2, Ta, and Tb (defined in the ASME Code, Section III, Subsection NB) for uniform and tapered pipe wall thickness.

3D.4.9 Deleted

3D.4.10 Engineering Analysis System--ANSYS

linear and non-linear static and dynamic

The ANSYS computer program is a large scale general purpose program for the solution of ~~[illegible]~~ Engineerin Analysis problems. ~~Analysis capabilities include static and dynamic; plastic, creep and swelling; small and large deflections; and other applications.~~

This program it has ~~will~~ accommodate a complete model and ~~an~~ enhanced capacities in input, output and graphic interface. Locations of interest for stresses and displacements can be obtained by this nonlinear analysis. ~~It is served as a verification work for the PDA program.~~

Other program of the same capacities with periodical improvement is also applicable to this analysis.

This program is used to perform the non-linear analysis of a piping system for loading due to postulated pipe breaks. The program calculates the piping forces, moments, deflections and stresses caused by the transient, piping displacement and piping segment loads due to postulated pipe breaks.

Compliance with Code requirements shall be in accordance with the following

(1) The ferritic materials used for piping, pumps, and valves of the reactor coolant pressure boundary are usually 63.5 mm or less in thickness. Impact testing is performed in accordance with NB-2332 for thicknesses of 63.5 mm or less. ~~The materials comply with Appendix G, Section G-3100 of ASME Code Section III.~~

(Impact testing is performed in accordance with NB-2331 for thicknesses greater than 63.5 mm.)

(2) Materials for bolting with nominal diameters exceeding 25.4 mm are required to meet both the 0.64 mm lateral expansion specified in NB-2333 and the 6.2 kg-m Charpy V value specified in 10CFR50, Appendix G. The 6.2 kg-m requirement stems from the ASME Code where it applies to bolts over 100 mm in diameter, starting Summer 1973 Addenda. Prior to this, the Code referred to only 2 sizes of bolts ($\leq$ 25.4 mm and > 25.4 mm). GE continued the two-size categories, and added the 6.2 kg-m as a more conservative requirement. 252.9

(3) The reactor vessel complies with the requirements of NB-2331. The reference temperature (RT_{NDT}) is established for all required pressure-retaining materials used in the construction of Class 1 vessels. This includes plates, forgings, weld material, and heat-affected zone. The RT_{NDT} differs from the nil-ductility temperature (NDT) in that in addition to passing the drop test, three Charpy V-Notch specimens (traverse) must exhibit 6.9 kg-m absorbed energy and 0.89 mm lateral expansion at 33°C above the RT_{NDT}. The core beltline material must meet 10.4 kg-m absorbed upper shelf energy.

252.9 (4) Calibration of instrument and equipment shall meet the requirements of the ASME Code, Section III, paragraph NB-2360.

5.2.3.3.2 Control of Welding

5.2.3.3.2.1 Regulatory Guide 1.50: Control of Preheat Temperature Employed for Welding of Low-Alloy Steel

Regulatory Guide 1.50 delineates preheat temperature control requirements and welding procedure qualifications supplementing those in ASME Sections III and IX.

The use of low-alloy steel is restricted to the reactor pressure vessel. Other ferritic components in the reactor coolant-pressure boundary are fabricated from carbon steel materials.

Preheat temperature employed for welding of low alloy steel meet or exceed the recommendations of ASME Code Section III, Subsection NA. Components are either held for an extended time at preheat temperature to assure removal of hydrogen, or preheat is maintained until post-weld heat treatment. The minimum preheat and maximum interpass temperatures are specified and monitored.

All welds were nondestructively examined by radiographic methods. In addition, a supplemental ultrasonic examination was performed.

5.2.3.3.2.2 Regulatory Guide 1.34: Control of Electroslag Weld Properties

For electroslag welding applied to structural joints, the welding process variable specified in the procedure qualification shall be monitored during the welding process.

5.2.3.3.2.3 Regulatory Guide 1.71: Welder Qualification for Areas of Limited Accessibility

Welder qualification for areas of limited accessibility is discussed in Subsection 5.2.3.4.2.3.

5.2.3.3.3 Regulatory Guide 1.66: Nondestructive Examination of Tubular Products

Regulatory Guide 1.66 describes a method of implementing requirements acceptable to NRC regarding nondestructive examination requirements of tubular products used in RCPB. This Regulatory Guide was withdrawn on September 28, 1977, by the NRC because the additional requirements isolatable portions of the following systems: SLC, RHR, HPCF, and RCIC. The relief valves will be selected in accordance with the rules set forth in the ASME Code Section III, Class 1, 2, and 3 components. Other applicable sections of the ASME Code, as well as ANSI, API, and ASTM Codes, will be followed.

5.4.13.2 Description

Pressure relief valves have been designed and constructed in accordance with the same code class as that of the line valves in the system.

Table 3.2-1 lists the applicable code classes for valves. The design criteria, design loading, and design procedure are described in Subsection 3.9.3.

5.4.13.3 Safety Evaluation

The use of pressure-relieving devices will assure that over-pressure will not exceed 10% above the design pressure of the system. The number of pressure-relieving devices on a system or portion of a system has been determined on this basis.

5.4.13.4 (Deleted)

5.4.14 Component Supports

Support elements are provided for those components included in the RCPB and the connected systems.

5.4.14.1 Safety Design Bases

Design loading combinations, design procedures, and acceptability criteria are as described in Subsection 3.9.3. Flexibility calculations and seismic analysis for Class 1, 2, and 3 components are to be confirmed with the appropriate requirements of ASME Code Section III.

Support types and materials used for fabricated support elements are to conform with Sections NF-2000 and NF-3000 of ASME Code Section III. Pipe support spacing guidelines of Table ~~121.1.4 of ANSI B31.1, Power Piping Code,~~ NF-3611 in ASME Code Section III are to be followed.

5.4.14.2 Description

The use and the location of rigid-type supports, variable or constant spring-type supports, snubbers, and anchors or guides are to be determined by flexibility and seismic/dynamic stress analyses. ~~Component support elements are manufacturer standard items.~~ Direct weldment to thin wall pipe is to be avoided where possible.

5.4.14.3 Safety Evaluation

The flexibility and seismic/dynamic analyses are to be performed for the design of adequate component support systems including all temporary and transient loading conditions expected by each component. For example, Provisions are to be made to provide spring-type supports for the initial dead weight loading due to hydrostatic testing of steam systems to prevent damage to this type support.

5.4.14.4 Inspection and Testing

After completion of the installation of a support system, all hangers and snubbers ~~elements~~ are to be visually examined to assure that they are in correct adjustment to their cold setting position. Upon hot start-up operations, thermal growth will be observed to confirm that spring-type hangers and snubbers will function properly between their hot and cold setting positions. Final adjustment capability is provided on all hangers ~~or support types~~. Weld inspections and standards are to be in accordance with ASME Code Section III. Welder qualifications and welding procedures are in accordance with ASME Code Section IX and NF-4300 of ASME Code Section III.

5.4.15 References

1. *Design and Performance of General Electric Boiling Water Reactor Main Steam Line Isolation Valves*, General Electric Co., Atomic Power Equipment Department, March 1969 (APED-5750).