3.9 MECHANICAL SYSTEMS AND COMPONENTS

This section is divided as follows: Section 3.9A applies to systems and components within SWEC scope of supply and Section 3.9B applies to systems and components within GE scope of supply.

3.9A MECHANICAL SYSTEMS AND COMPONENTS (SWEC SCOPE OF SUPPLY)

3.9A.1 Special Topics for Mechanical Components

3.9A.1.1 Design Transients

Table 3.9A-1 lists the plant events that were used for the design and analysis of ASME Section III Safety Class 1 components and supports. The table also shows the number of cycles per event and event classification. Application of these transients is discussed under load combinations in Section 3.9A.3.1.

3.9A.1.2 Computer Programs Used in Analyses

The computer programs used in analyses are described, and their applicability and validity are demonstrated in Appendix 3A.

3.9A.1.3 Experimental Stress Analysis

Experimental stress analysis for the design of balance-of-plant (BOP) equipment was not used.

3.9A.1.4 Consideration for the Evaluation of the Faulted Condition

3.9A.1.4.1 Equipment and Components

The elastic analysis techniques described in Section 3.7A.3 are utilized in the qualification of Category I ASME Code and non-Code equipment. Stress limits utilized for the faulted plant condition are outlined in Section 3.9A.3.1. Design conditions and stress limits defined are applicable for an elastic system (and equipment) analysis. Stress limits for inelastic system (and/or component) analysis are in accordance with ASME Section III, Appendix F.

3.9A.1.4.1.1 ASME III Compliance

Category I ASME Safety Class 1, 2, and 3 components are designed, analyzed, and certified in accordance with the appropriate ASME III Code edition and addenda as defined in their design specifications. However, if Code nameplates are removed from installed equipment, traceability is provided in accordance with ASME III 1980 Edition, Winter 1981 Addendum, Subsection NCA, Subarticle 8240(b).

3.9A.1.4.2 Piping Systems

Category I ASME Safety Class 1, 2, and 3 piping and pipe supports are analyzed and designed in accordance with requirements of ASME Section III, Subsections NB, NC, ND, and NF, respectively. The analyses also comply with Appendix F of ASME Section III. The 1974 Edition is used with the following exceptions:

1. Building settlements, not applicable to the faulted condition, are analyzed according to the 1977 Edition.

2. The number of OBE load cycles is based on Appendix N of the 1977 Edition, Winter 1978 Addenda.

3. For pipe supports, the 1974 Edition is used with the additional requirements described in Section 3.9A.3.4.1.

4. The boundary of jurisdiction of ASME Code Section III, Class 1, 2, or 3 process piping extends to and includes the seat of the root valve to the instrument. The appropriate quality group extends from the root valve to the instrument and shall be designed to ASME Section III. Seismic Category I supports shall be installed with a 10CFR50 Appendix B program described in Section 3.9A.3.4.1.

5. Material upgraded by material manufacturer will meet the provisions of ASME III, 1977 Edition, Summer 1977 Addenda, Subsection NCA.

6. Installation of attachments to Category I ASME Safety Class 1, 2, and 3 piping systems after testing is to be accomplished in accordance with ASME Section III, 1980 Edition, Winter 1981 Addenda, Subarticle 4436, Subsections NB, NC, and ND.

7. The selection of the type and certification of penetrometers required for nondestructive examination is governed by ASME Section V as invoked by ASME Section III. The 1974 Edition, including Summer 1974 Addenda, is used.

8. The inside corner radius in Note 6d of Figures NC and ND 3673.2(b)-1 is as defined in ASME III, 1980 Edition, Winter 1980 Addendum. This radius is required on the inside wall of the run pipe at welded branch connections greater than 4 in. The radius is not required for nominal branch pipe size smaller than 4 in.

9. The requirements for the stamping of N-type nameplates are as defined in the subparagraphs NCA-8220 and NCA-8320 of the 1980 Edition of ASME III. The arrangement shall be substantially as shown on Figure NCA-8321-1 of the 1980 ASME III Code.

10. Nondestructive examination is governed by ASME Section V as invoked by ASME Section III, 1980 Edition of ASME Section V including Summer 1980 Addenda, is used for evaluation criteria of scattered radiation.

11. To establish acceptable criteria for venting during system fill operation, ASME Section III, 1981 Summer Addenda, Subarticles NB-6211, NC-6211, and ND-6211 are used.

12. The requirements for examination of socket weld components during in-process repair prior to reuse are defined in ASME III, 1980 Edition, NB-4121.3.

13. The requirements for the elimination of surface defects are as defined in Subparagraph NC-4452 of ASME Section III, 1983 Edition, Summer 1984 Addenda.

14. ASME III, Subsections NB-6211, NC-6211, and ND-6211, Summer 1980 Addenda, may be used for hydrostatic testing.

15. ASME III, paragraph NCA-1273, Summer 1980 Addenda, is used when defining fluid conditioner and flow control devices other than valves.

16. ASME III Appendices Figure I-9.2 of the 1983 Edition is used for determination of acceptable stress limits for stainless steel piping during the preoperation and power ascension phases of the piping vibration test program.

17. Use of ASME Subparagraph NB-3630(d)(2) of ASME Section III, Division 1, Summer 1975 Addenda, is permitted for stress analysis of Class 1 piping in accordance with requirements of Subsection NC.

18. Residual heat removal (RHS) supply and discharge lines connected to the recirculation piping in primary containment are analyzed in accordance with the applicable ASME III Code governing the recirculation piping.

The stress limits and techniques specified in ASME Section III, Appendix F, Summer 1983 Addenda, may be used in evaluating faulted loaded conditions for Class 1, 2 and 3 valves.

Loadings considered in the faulted condition include the following:

1. Loading associated with normal plant conditions, including hydrodynamic loads associated with suppression pool phenomena.

2. Loading associated with the postulated SSE.

3. Dynamic system loading associated with faulted plant conditions, i.e., DBA, break of a MSL, or recirculation line.

4. Dynamic system loading associated with the intermediate break accident (IBA) and small break accident (SBA).

Procedures for developing the loading functions in Items 1 and 2 above are described in Sections 3.9A.1.5 and 3.7A.3.8. Loading functions in Items 3 and 4 are described in Section 3.6A.2. Loads associated with the suppression pool phenomena are described in the DAR (Appendix 6A).

3.9A.1.5 Analysis of Piping Systems

Category I piping systems (ASME Safety Class 1, 2, 3) are analyzed in accordance with ASME Section III, 1974 Edition, Subarticles NB-3600, NC-3600, and ND-3600 unless otherwise noted as an exception in Section 3.9A.1.4.2. ANSI B31.1 seismically supported and nonseismic piping systems are analyzed in accordance with ANSI B31.1 Code, 1973 Edition, including Addendum C, dated December 18, 1973. In addition, high-energy piping systems are analyzed for pipe rupture criteria.

All seismically supported and nonseismically supported ANSI B31.1 systems may be hydrostatically tested in accordance with a later Code edition than previously specified.

Later editions of ANSI B31.1 are considered when defining minimum welding dimensions required for socket welding components other than flanges.

Analytical modeling and seismic analysis are described in Section 3.7A.3.8. Static analysis and other dynamic analyses that contribute the remaining stresses in the Code stress criteria are described in the following sections.

Piping engineering and design specifications for Unit 2 allow the use of various types of branch connections, including pipe-to-pipe. Unless a specific branch connection is indicated in the specification or on the piping drawings, an unreinforced pipe-to-pipe connection is used in the pipe stress analysis. No further action is required if the allowable stresses are met. If the allowable stresses are not met, then the piping stress calculation identifies the reinforcement of the branch connection that is required.

For cases where the branch line is decoupled from the run piping, the proper stress intensification factor is used in the analysis of both the branch line and the main run piping. If reinforcement for mechanical loads is required, it is so identified in the piping stress calculation and drawings. Reinforcement requirements for mechanical loads, identified by the pipe stress calculations, are incorporated on the piping drawings. Pressure reinforcement calculations required by ASME

III, paragraph NB-3643, and ANSI B31.1, paragraph 104.3, are performed by the piping fabricator, and additional reinforcement, if required, is identified and added to the fabricated pipe.

3.9A.1.5.1 Static Analysis

The static equation of equilibrium for the idealized system may be written in matrix form, as follows:

$$KU = P - Q \qquad (3.9A\text{-}1)$$

Where:

K = Stiffness matrix for assembled system

U = Nodal displacement vector

P = External forces, weights, etc.

Q = Equivalent thermal forces = $\int_O^L AE \propto \overline{T} d\ell$

A = Cross-section area

E = Young's Modulus

$\propto$ = Thermal expansion coefficient

$\overline{T}$ = Average wall temperature less 70°F installation temperature

ℓ = Coordinate along pipe axis

L = Length of pipe

The unknown nodal displacements are obtained from one of the piping analysis computer programs (Appendix 3A) by solving this equation using the Gaussian method. The nodal displacements are then applied to the individual members, and member stiffnesses are used to find internal forces. The nodal displacements at support locations can be used along with the support stiffness to determine support reactions.

<u>Dead Loads (Weight, Pressure) and Live Loads</u>

The effect of pressure, and the combined effects of weight, contents, and insulation, are calculated using one of the piping analysis computer programs (Appendix 3A). The analysis for deadweight assumes all flexible restraints, such as spring hangers, to be rigid. If a pipe has different contents (medium) and therefore different weights in various flow modes, this is taken into consideration. Other details are discussed in Section 3.7A.3.8.3. Live loads are considered if they are expected to constitute a significant component of the total mechanical load.

The filling of MSLs with water during vessel flooding and alternate shutdown events is indicated on the main steam thermal transients and considered in pipe stress analysis in accordance with NB-3600. Spring hangers are designed to carry the full water-filled piping load during hydrotest. Additional deadweight stress as a result of filling the piping with water is considered in the NB-3600 analysis of the system.

The main steam SRV discharge piping has been designed and qualified for the steam hammer load due to steam blowdown. The results of the BWR Owners' Group (BWROG) Safety Relief Valve Test Program, in which Unit 2 has been a participant, show that the measured spring and support response was significantly less for water than steam. The test report, as documented in NEDE-24988-P, stated that "the maximum pipe response due to liquid discharge was generally less than 30 percent of that due to steam discharge." The test program was established to measure the SRV discharge line (SRVDL) response for alternate shutdown cooling conditions and to compare these loads with steam loads.

Additional deadweight stress resulting from water-filled main steam safety relief is considered in the ND-3600 analysis of the main steam relief valve lines.

Initial Displacements (Anchor Movements)

The piping analysis computer programs (Appendix 3A) permit calculation of the thermal initial support displacements combined with the thermal response due to the average pipe wall temperature change.

Earthquake anchor movements are considered (Section 3.7A.3.8.3). In ASME Safety Class I analysis the loads due to OBE anchor movements are combined with the OBE inertia loads via absolute summation. In ASME Safety Class 2 and 3 analysis the Code permits their exclusion from occasional loads if they are included with the thermal expansion loads.

Thermal Loads

A piping system may experience various operating modes. All operating modes are modeled as follows: Portions of piping with flowing medium have the temperature of the medium, while inactive branches have ambient temperature. Nonuniform temperature distributions along the pipe near branch connections of active and inactive legs are considered.

In Safety Class I analysis, stresses due to temperature distribution across the thickness of the pipe wall and geometric and material discontinuities during thermal transients must be considered. These are represented in ASME Section III, Subarticle NB-3600, by:

$$E \propto \Delta T_1, E \propto \Delta T_2, and\ E_{ab}\ (\alpha_a T_a - \alpha_b T_b) \qquad (3.9A\text{-}2)$$

Based on geometry, fluid type, insulation, thermal transients, environmental data:

$$\propto \Delta T_1, \propto \Delta T_2, and\ E_{ab}\ (\alpha_a T_a - \alpha_b T_b) \qquad (3.9A\text{-}3)$$

are obtained from the HTLOAD program (Appendix 3A), or hand calculations.

3.9A.1.5.2 Occasional Dynamic Loads Excluding Seismic and Hydrodynamic Inertia Loads

Occasional loads are also analyzed using one of the piping analysis computer programs (Appendix 3A). In the matrix equation of motion:

$$M\ddot{U} + C\dot{U} + KU = F(t) \qquad (3.9A\text{-}4)$$

Where:

M = Mass matrix

C = Damping matrix

K = Stiffness matrix

U = Displacement vector

the forcing function F(t) is applied as a set of force time histories, one for each mass degree-of-freedom that experiences a dynamic load.

<u>Fluid Transients</u>

Fluid transients are considered in the following systems:

1. Main steam and main steam bypass systems.
2. Main steam SRV discharge system.
3. Moisture separator/reheater safety relief system.
4. Feedwater system.
5. ECCS, including ECCS pressure relief valve discharge piping.
6. SWP system.
7. RHR system.
8. RCIC system.

9. RWCU system.

10. SLCS system.

11. CRD system.

The computer programs (Appendix 3A) used to calculate these force time histories due to water hammer, steam hammer, and pipe with air trapped in water lines, are WATHAM, STEHAM, and WATAIR, respectively.

Jet Impingement

The effects of direct jet impingement on piping are evaluated after all other piping analyses are completed and targets from all postulated breaks have been identified.

Relief Valve Reactions (Other Than Main Steam SRVs)

Valves that are subjected to jet reaction forces are either supported by static restraints adjacent to the valve body, in such a manner that the effects on the piping outside these restraints can be neglected, or the piping system is analyzed for relief valve discharge load case.

Suppression Pool Induced Dynamic Loads in the Reactor Building

These loads are described and assessed in the DAR (Appendix 6A).

3.9A.1.5.3 Field-Run Piping

There is no field-run ASME safety class piping in Unit 2.

3.9A.1.5.4 Load Combinations and Stress Criteria

In detailed analyses of ASME safety class piping systems, the individual load cases are combined as shown in Table 3.9A-2.

In the simplified analysis for small bore piping (Section 3.7A.3.8) the same principle is followed; however, the resulting seismic spans, thermal offsets, and support loads are bounding values determined from several fundamental configurations. The classification for ASME Safety Class 1, 2, and 3 piping systems according to type of analysis is given in Table 3.9A-3.

3.9A.1.6 Safety-Related HVAC Ductwork and Supports

Safety-related duct systems are designed for internal pressure, deadweight, and dynamic loads which result from seismic events and plant operating conditions. Dynamic loads are applied statically as 'g' forces taken from building ARS curves. The 'g' values are taken as either maximum or the 'g' corresponding to the system natural frequency. Ductwork is qualified to the SMACNA Duct Construction Standards and the AISI Code; duct supports are qualified to the AISC Code.

3.9A.2 Dynamic Testing and Analysis

3.9A.2.1 Piping Vibration, Thermal Expansion, and Dynamic Effects

A detailed preoperational test program was submitted 60 days before the start of the tests, as required by RG 1.68.

3.9A.2.1.1 Flow Modes

Tabulated flow modes for various systems are provided as part of the above test program.

3.9A.2.1.2 Preoperational Vibration Testing

Safety-related piping systems designated as Safety Class 1, 2, or 3 are designed in accordance with ASME Section III. Each system is designed to withstand dynamic loadings from operational transient conditions that are encountered during expected service as required by Paragraphs NB-3622, NC-3622, and ND-3622 of the ASME Code.

To verify that piping systems would withstand operational vibration conditions, a vibration monitoring program was implemented which included both safety-related and nonsafety-related process piping and instrument lines. A vibration monitoring test specification was prepared to categorize the requirements for the test program. Safety-related systems are categorized as follows:

a. Systems With Flow - Accessible lines (including attached instrument lines) were monitored visually or with hand-held instruments, and inaccessible lines and lines with transient vibrations were monitored by remote instrumentation.

b. Other Systems - No testing was required.

Instrument lines connected to inaccessible process lines were not individually monitored. Instrument lines were considered acceptable from a steady-state vibration point of view if the vibration of the process pipe to which the instrument lines are connected was within the acceptance test limits. If the vibration levels in the process pipe were above the acceptable test limits, consideration was given to the connected instrument lines.

During the vibration monitoring program, vibration testing was performed either during the preoperation or power ascension testing phases on the systems identified below.

	Preoperation	Power Ascension

System	Phase	Phase*
Low-Pressure Core Spray (CSL)	X	
High-Pressure Core Spray (CSH)	X	
Reactor Water Cleanup (WCS)	X	
Feedwater (FWS)	X	X
Spent Fuel Pool Cooling (SFC)	X	
Service Water (SWP)	X	
Residual Heat Removal (RHS)	X	X
Main Steam (MSS)		X
Main Steam Safety Relief (SVV)		X
Air Startup Standby Diesel Generator (EGA)	X	
Service Air (SAS)	X	
Reactor Core Isolation Cooling (ICS)		X
Condensate (CNM)		X
Standby Liquid Control (SLS)	X	
Control Building Chilled Water (HVK)	X	
Instrument Air (IAS)	X	
Reactor Building Closed Loop Cooling Water (CCP)	X	
Nitrogen System (GSN)	X	
Standby Gas Treatment (GTS)	X	
Containment Purge System (CPS)	X	
Reactor Coolant Recirculation (RCS)		X
Control Rod Drive (RDS)	X	
Nuclear Boiler Instrumentation (ISC)		X

See Section 3.9B.2.1 for vibration testing of GE-supplied systems.

Vibration measurements were conducted for steady-state and transient conditions such as pump starts and valve operation. Also, visual inspections to determine vibration response were performed, with emphasis placed on vents, drains, and branch piping.

* Testing on these systems is accomplished during the startup test phase as described in Table 14.2-303.

3.9A.2.1.3 Preoperational Thermal Expansion Testing

Preoperational tests for BWRs are conducted at near ambient conditions; therefore, thermal expansion testing during the preoperational test phase is very limited. For the systems delineated in Section 3.9A.2.1.2 that are operated at other than ambient conditions during the preoperational test phase, pipe deflections are observed or measured at selected locations. The startup expansion testing program is discussed in further detail in Section 3.9B.2.1.2.

3.9A.2.1.4 Measurement Locations

The exact locations of measuring devices and identification of visual inspection points are supplied in the test program. Measurements taken at points with dynamic instrumentation show whether the stress and fatigue limits are within acceptable levels, and measurements taken at points with expansion instrumentation in an expansion test, excluding dynamic effects, are checked against displacement criteria.

3.9A.2.1.5 Acceptance Criteria

Acceptance criteria for vibrations were dependent upon whether steady-state or transient vibration was measured.

For steady-state vibrations, acceptance criteria were based on ANSI/ASME OM3-1982 rules. The majority of the piping was tested by a two-phase process. Phase 1 consisted of visually observing the pipe to determine if a vibration was perceived. If vibration was not observed, that portion of the pipe was acceptable. If vibration was observed, Phase 2 was implemented. This consisted of taking local measurements using hand-held instruments at points where steady-state vibration was observed. Vibration velocity was measured and, if it was less than 0.5 in/sec, the piping was acceptable. At velocities equal to or greater than 0.5 in/sec, displacement measurements were taken and forwarded to engineering for resolution.

For the remaining piping, where significant steady-state vibration was anticipated, or where inaccessible for normal viewing, vibration was monitored by fixed displacement transducers (lanyard potentiometers) with remote readouts. The recorded displacements were compared to the acceptance criteria as determined by ANSI/ASME OM3-1982. If the acceptance criteria were exceeded, the recorded displacements were evaluated by engineering to determine a resolution.

For all steady-state vibration, OM3-1982 guidelines were used; however, displacements for carbon steel were based on 80 percent of stress endurance limits divided by a factor of 1.3. Displacements for stainless steel piping were based on stress allowables for 10E11 cycles, as shown on Figure I-9-2 of ASME III of the 1983 Code. Curve C of the figure was used for initial screening. If detailed analysis was required, Curve B was used in accordance with Code requirements.

For transient vibration testing, vibration also was measured by fixed displacement transducers (lanyard potentiometers) with remote readouts, and two levels of acceptance criteria were used.

1. Level 1 criteria establish the maximum limits for the level of pipe motion which, if exceeded, mandates a test hold or termination. Level 1 criteria ensure that the pipe stress level will not exceed $1.2S_h$, the applicable Code allowable.

The displacement limits for Level 1 criteria were determined from those predicted for loading conditions that were used to evaluate the applicable Code equation for an occasional load. If any Level 1 criteria were exceeded, an engineering evaluation was performed to develop corrective action or show that the measured results were acceptable.

2. Level 2 criteria are based on pipe stresses as analyzed and predicted for the fluid transient for the particular event. If any Level 2 limits were exceeded, a detailed engineering evaluation was performed to develop corrective action or show that the measured results were acceptable.

Acceptance criteria for vibration on systems listed in Section 3.9A.2.1.2 are specified in the vibration test program. The stress calculated based on measured displacements represents the combined stress of pressure, deadweight, and fluid transient loads, and was combined with the analytical stress of the load cases not simulated, such as the OBE, and then compared with the combined analytical result. The allowable stresses are listed in Table 3.9A-2.

The limits for thermal displacements depend on the equipment design parameters. Under all plant conditions the piping is not permitted to touch another object that may interfere with the operation of the piping system or equipment.

3.9A.2.1.6 Corrective Actions

If during the vibration test it should be noted that the vibrations are beyond the acceptable design level, additional supports and restraints may be provided. The possibility of piping rerouting would also be considered, and a reanalysis or retest would be performed to assure that the design meets the acceptance criteria.

Similarly, if the design tolerances for thermal displacements are not satisfied at a point along the piping, the equipment affected can usually be realigned. Otherwise, supports and restraints would be rearranged, and pipe rerouting would also be considered.

3.9A.2.2 Seismic Qualification of Safety-Related Mechanical Equipment

This section provides the qualification criteria and methods for equipment affected by seismic loads. The methods for the qualification of equipment affected by hydrodynamic loads associated with SRV discharge and the postulated LOCA are provided in the DAR, Appendix 6A, Subsection 6A.9.

3.9A.2.2.1 Seismic Qualification Criteria

The purpose of qualifying Category I mechanical equipment is to demonstrate its ability to perform a safety-related function during and after a postulated seismic occurrence of a magnitude up to and including the SSE. Equipment that does not perform any safety-related function, but whose failure could jeopardize the function of Category I equipment, is required only to maintain its structural integrity.

Seismic qualification of equipment is accomplished by one of the four methods discussed in Section 3.7A.3.1. Analysis is used to demonstrate structural integrity of the equipment. When mechanical equipment is qualified by analysis, the calculated stresses are maintained within the specified allowables that contain the required margins of safety described in Section 3.9A.2.2.2. Where the equipment is classified as active, additional deflection analysis and/or testing is performed. Details of qualification methods for specific equipment are contained in Table 3.9A-4.

These methods are applied to mechanical equipment as follows.

<u>Analysis</u>

The listing below is for equipment where the maintenance of structural integrity only is required to assure performance of the design-intended function. This equipment is qualified by analysis:

1. Piping.

2. Ductwork.

3. Tanks and vessels.

4. Heat exchangers.

5. HVAC - passive components.

6. Pump and valve pressure boundary parts that are not required to operate and perform a safety function.

Analysis is also used to qualify rotating machinery items where verification must be obtained to demonstrate that deformations resulting from seismic loadings do not cause binding of the rotating element, to the extent that the component cannot perform its design-intended function. Components in this category include:

1. Active pumps and valves.

2. Fans and dampers.

The large size and weight of some of these components, together with the difficulties encountered in applying operating loads during dynamic testing, serve to make analysis the most viable qualification method for the rotating machine elements.

Dynamic Testing

The following equipment whose functional capability cannot be adequately demonstrated by analysis is qualified by dynamic testing:

1. Standby diesel generator components.

2. Hydrogen recombiner control panels.

3. Electric motor valve actuators, including limit switches.

4. Pneumatic and hydraulic valve limit switches and solenoid valves.

5. Electrical control panels, relay boards, switchgear and MCCs, and radiation monitoring equipment.

6. Control instrumentation such as flow switches, thermocouples, and transmitters.

7. Batteries, battery chargers, and inverters.

8. Electrical penetrations.

Combination of Analysis with Testing

A combination of analysis with static or dynamic testing is used for seismic qualification of active valves as follows:

1. The natural frequencies of the valve assembly are determined by analysis or test.

2. A static deflection test is performed to verify that deformation due to seismic loadings does not cause binding of internal valve parts, which prevents valve operations within specified time limits.
3. The electric motor-driven, pneumatic, and hydraulic valve actuator and other electrical appurtenances are qualified by dynamic testing.

For those active valves that are simple in design or do not have significant extended structures or electrical appurtenances, seismic qualification is achieved by analysis alone to ensure that the valve can perform its design-intended function.

Equipment that is qualified by testing is mounted and operated in a manner similar to that of the actual system. For testing procedures refer to Section 3.7A.3.

3.9A.2.2.2 Acceptance Criteria

The acceptance criteria used are as follows:

1. Tests, when used, demonstrate that the component performs its required safety function during and after the test. The TRS envelop the applicable frequency range of the RRS with the required 10-percent margin in accordance with IEEE-323-1974. Where the TRS does not envelop the RRS with the suggested margins of IEEE-323-1974, a justification is provided.

2. Analysis, when used, verifies that stresses do not exceed the specified allowable stress limits for the loading conditions shown in Tables 3.9A-5 and 3.9A-6 and that deformations do not exceed those which will not permit the component to perform its design-intended function.

For ASME components, the specified allowable stress limits are those shown in Tables 3.9A-7 and 3.9A-8.

For non-ASME components, the Design Condition I loading has allowable stresses limited to 75 percent of the minimum yield strength at the design temperature of the material, in accordance with applicable ASTM specification. For the Design Condition II loading the stresses do not exceed the smaller of:

1. 100 percent of the minimum yield strength, or

2. 70 percent of the minimum ultimate tensile strength of the material (at temperature), in accordance with the ASTM or equivalent specification for the material.

For definitions of Design Conditions I and II, see Section 3.9A.3.1.2.

3.9A.2.2.3 Seismic Qualification of Specific Non-NSSS Mechanical Equipment

<u>Piping</u>

All safety-related piping, including piping in pipe tunnels, is seismically analyzed in accordance with Section 3.7A.3.8.

<u>Tanks</u>

The safety-related tanks have been seismically qualified as follows.

The seismic analysis on the buried standby diesel generator fuel oil storage tank consisted of the following:

1. Selection of the applicable seismic acceleration factors at the elevation in the diesel generator building at which the tank is installed.

2. Calculation of the lowest natural frequency of the filled tank in its buried environment taking into account both the mass and spring rate of this environment. This frequency occurs in the rigid range.

3. Choice of the correct seismic factors by combining analysis parameters 1 and 2.

4. Determination of loads on both the tank and support rings by static analysis with seismic g-factors applied to all tank and sand masses.

5. ASME Code methods for the design of the tank shell, heads, stiffening, and support rings were used. Local stress analysis, by BIJLAARD or other methods, as appropriate, was used in determining stresses at nozzles and support rings.

6. Analyses were performed for both normal and upset conditions (including live and dead loads, thermal and pressure stresses, and OBE seismic factors) and faulted conditions composed of live and dead loads plus full SSE inertial loads.

7. Adequacy of the tank at design pressure was determined. The tank was hydrotested at 1.5 times design pressure in compliance with ASME Code.

The seismic analysis for the air damper/accumulators, the chilled water expansion tanks, the skimmer surge tanks, and the standby diesel generator fuel oil day tanks, consisted of the following:

1. An analysis of the vessel was performed to prove that it has rigid characteristics, i.e., the natural frequency of vibration of the predominant mode of the supported vessel is in the flat portion of the applicable response spectrum curves. The applicable seismic acceleration coefficients were chosen according to the location of each vessel.

2. The seismic acceleration coefficients were applied statically, and a static analysis was performed on the equipment and supports. The vertical and horizontal seismic effects were applied simultaneously to the subject vessel at its gravitational center for the seismic load calculation and design.

3. Determination of loads for both the tanks and supports by static analysis with seismic coefficients applied to all tank masses.

4. The remainder of the analysis was performed according to preceding steps 5 through 7 for safety-related tanks.

Since the ADS and main steam SRV accumulators are located inside the reactor building, seismic as well as hydrodynamic effects were considered in their analysis. The preceding Steps 1 and 2 were therefore performed with the applicable acceleration coefficients.

Pumps

Qualification of pumps is shown in Table 3.9A-9 and further discussed in Section 3.9A.3.2. The results of tests and analyses are described in Table 3.9A-4 for pumps listed in Table 3.9A-9.

Valves

The qualification of active valves is discussed in Section 3.9A.3.2. The results of tests and analyses are described in Table 3.9A-4 for the valves listed in Table 3.9A-12.

There are no manually-operated valves which must change position for any safety system to perform its function in the short term following any event. The operation of certain manual valves may be required in the long term. These valves include those necessary to replenish fuel oil to the diesel generator fuel oil storage tanks and nitrogen to the ADS valve accumulator receiving tanks, and to accomplish boron replenishment in the SLCS following an anticipated transient without scram (ATWS) event. The only other valves which may be required to change position to accomplish a safety function are those RHR valves located in the SFC/RHR interties. As discussed in Section 9.1.3.3, these interties may be used to provide additional fuel pool cooling following a full core offload.

Other Mechanical Equipment

The qualification method for mechanical equipment other than the above is discussed in Section 3.7A.3. The qualification results are described in Table 3.9A-4.

Electrical Equipment and Instrumentation

The seismic qualification criteria and methods of qualification of Category I electrical equipment and instrumentation, other than those items discussed in this section, are described in Section 3.10.

Cranes

Cranes are seismically qualified in accordance with the following criteria:

1. The possibility of the crane being dislodged by a seismic disturbance is precluded.

2. No part of the crane becomes detached and falls during an earthquake.

3. The crane load will not lower in an uncontrolled manner during, or as the result of, an earthquake.

3.9A.3 ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures

3.9A.3.1 Loading Combinations, Design Transients, and Stress Limits

The design basis for all safety-related piping, components, equipment, and supports considers all applied loads such as pressure temperature, deadweight, external mechanical, thermal, fluid transient, seismic, and hydrodynamic loads. Operability requirements are described in Technical Requirements Manual (TRM) Section 3.4.2.

Hydrodynamic loads are unique to the Mark II containment of Unit 2 and other similar suppression pool-type containments. The design basis for all safety-related piping, components, and equipment subjected to hydrodynamic loads meets the requirements of the following NRC documents:

1. NUREG-0487, Supplements 1 and 2, Mark II Containment Lead Plant Program Load Evaluation and Acceptance Criteria.

2. NUREG-0808, Mark II Containment Program Load Evaluation and Acceptance Criteria.

3. NUREG-0802, Safety/Relief Valve - Quencher Loads Evaluation Reports - BWR Mark II and III Containments.

4. NUREG-0783, Suppression Pool Temperature Limits for BWR Containments.

5. NUREG-0763, Guidelines for Confirmatory Inplant Tests of Safety-Relief Valve Discharges for BWR Plants.

All safety-related equipment, piping, and components and their supports located in the reactor building are evaluated using hydrodynamic loads. All other structures are not affected by hydrodynamic loads.

See Appendix 6A, Design Assessment Report, for further details.

3.9A.3.1.1 ASME Section III, Class 1 Components

<u>Equipment</u>

ASME III, Class 1 mechanical equipment, i.e., valves, pumps, and cooling coils, is designed in accordance with ASME Section III, Subsection NB. Loading combinations and service conditions are outlined in Table 3.9A-5. Corresponding stress limits in accordance with Article NB-3000 are listed in Table 3.9A-7. This equipment is listed in Table 3.9A-4.

These load descriptions include Dynamic Load 1, Dynamic Load 2, and Dynamic Load 3 notations, which are load combinations for equipment in the reactor building only, resulting from consideration of hydrodynamic loading conditions; for equipment outside the reactor building, these reduce to OBE, SSE, and OBE, respectively.

For the conditions specified, the allowable stress limits defined in Table 3.9A-7 are applicable to stress results obtained by elastic analysis techniques. The analysis methods described in Section 3.7A.3 are used in implementing this criterion. Computer programs used in these analyses are discussed in Appendix 3A.

<u>Piping</u>

The pipe stress analysis load combinations and stress limits for ASME Class 1 piping are given in Table 3.9A-2. The design transients and number of associated stress cycles for the various plant conditions are given in Table 3.9A-1, which includes the dynamic load events OBE, SSE, LOCA-related load cases, and SRV discharge cases. The suppression pool events are discussed in Appendix 6A. There are several SRV cases. In Table 3.9A-2 SRV refers to the envelope of the response of all SRV cases applicable to a particular load combination. The number of load cycles used for different SRV cases is given in Table 3.9A-1. Under emergency and faulted conditions no fatigue analysis need be performed.

Figures 3.9A-6 through 3.9A-67 are typical examples of response spectra for the load conditions of:

1. Seismic OBE
2. Seismic SSE
3. SRV loads
4. LOCA-related loads
    a. Chugging
    b. Basic CO
    c. ADS CO
5. Seismic OBE 2-5 percent damping in accordance with Code Case N-411
6. Seismic SSE 2-5 percent damping in accordance with Code Case N-411

These response spectras are provided at the following locations:

1. Top of RPV

2. Top of BSW

3. Primary containment at the suppression pool water level

4. Reactor building mat (only hydrodynamic loads are provided)

The provided response spectra have been broadened in accordance with RG 1.122. Both vertical and horizontal spectra are provided for each location.

In order to ensure their continued operation during emergency and faulted events, ECCS and other essential systems are required to meet the functional capability criteria of NEDO-21985, Functional Capability Criteria of Essential Mark II Piping, September 1978.

ASME Class 1 piping meets the criteria of ASME Section III, 1974 Edition, and 10CFR50.55a, Section (d).

Analysis of the individual load cases is described or referred to in Section 3.9A.1.5.

ASME Code Class 1 piping fatigue evaluation was performed for the SRV piping in the suppression pool area. All of the thermal and dynamic loads and respective operating cycle data were used for evaluation of the SRV line. The CUF obtained from the analysis is less than 1.0; hence, no fatigue crack is anticipated due to all of the prescribed loads.

ASME Code Class 1 piping fatigue evaluation was performed for the downcomers. The CUF obtained from the analysis is less than 1.0;hence, no fatigue crack is anticipated due to all of the prescribed loads.

3.9A.3.1.2 ASME Class 2 and 3 Components

<u>Equipment</u>

Tables 3.9A-6 and 3.9A-8 list loading conditions and stress limits for ASME Section III, Class 2 and 3 components of the Category I fluid systems constructed in accordance with ASME Section III, Subsections NC and ND. These conditions are:

1. <u>Design Condition I</u> Includes the specified design loads (temperature, pressure, etc.), plus Dynamic Load 1 loads.

2. <u>Design Condition II</u> Includes the specified design loads (as above), plus Dynamic Load 2 loads, plus pipe rupture loads (if applicable).

The design load combinations are analogous to either the Code Class 1 normal or upset conditions for Design Condition I and to the faulted condition for Design Condition II. See Table 3.9A-5 for the definitions of Dynamic Load 1 and Dynamic Load 2.

These requirements, which supplement the present scope of ASME Section III, Subsections NC and ND, are consistent with the present Code format and philosophy. Further extension of terminology (normal, upset, etc.) is not required, since Code Class 2 and 3 systems are not generally evaluated for such varieties of operating conditions and transients, but rather to design conditions which conservatively envelop all operating conditions.

Generally, only design conditions of pressure and temperature are necessary to satisfy ASME Code requirements. These conditions envelop all service level conditions for the component such as normal, upset, emergency, and faulted plant conditions. Use of design conditions plus seismic loading is therefore a conservative criterion.

The stress limits and design conditions presented in Table 3.9A-8 are intended to ensure that no gross deformation of the component occurs. These limits are applicable for an elastic system (and component) analysis. Stress limits for inelastic system (and/or component) analysis are in accordance with ASME Section III, Appendix F.

Piping Systems

The load combinations and stress limits for ASME Class 2 and 3 piping are given in Table 3.9A-2. They conform to the criteria of ASME Section III, which imply elastic analysis. Under faulted condition, with primary stress limit 2.4 S_H, gross inelastic deformations that may occur are permitted by the Code.

Analysis of the individual load cases is described or referred to in Section 3.9A.1.5. The application of detailed or simplified analysis depends on criteria stated in Table 3.9A-3.

Typical examples of ARS used in the design of piping systems are described in Section 3.9A.3.1.1.

3.9A.3.1.3 Compliance with Regulatory Guide 1.48

Unit 2 compliance to the regulatory guide is documented in Table 1.8-1.

3.9A.3.2 Pump and Valve Operability Assurance

This section provides the operability assurance programs for pumps and valves affected by seismic loads. The operability assurance programs for pumps and valves affected by hydrodynamic loads associated with SRV discharge and the postulated LOCA are provided in the DAR, Appendix 6A, Subsection 6A.9.

Active pumps and valves are those whose operability is relied upon to perform a safety function such as safe shutdown of the reactor, or mitigation of the consequences of a postulated accident. Pumps and valves installed in seismic Category I piping systems are designed in accordance with the requirement of ASME Section III, Subsections NB, NC, and ND. Active pumps and valves are listed in Tables 3.9A-9 and 3.9A-12, respectively.

Active valves are qualified by testing and analysis, and active pumps by testing and analysis with appropriate stress limits and nozzle loads. The content of these programs is detailed in the following sections.

3.9A.3.2.1 Pump Operability Program

All active pumps are qualified for operability by being subjected to tests both prior to installation in the plant and after installation in the plant. The in-shop tests include:

1. Hydrostatic tests to ASME Section III requirements.

2. Performance tests while the pump is operated with flow to determine total developed head, minimum and maximum head, net positive suction head (NPSH) requirements, and other pump/motor parameters. As a result of these tests, a certified pump curve is developed for each pump that may be used to verify continued satisfactory operation subsequent to pump installation. Proper seal function is verified during the performance test.

Also monitored during these operational tests are bearing temperatures and vibration levels that are shown to be below appropriate limits specified to the manufacturer for design of each active pump.

After the pump is installed in the plant, it undergoes cold hydro tests, preoperational tests, and the required periodic inservice inspections and inservice tests as applicable.

These tests demonstrate reliability of the pump for the design life of the plant.

In addition to these tests, active pumps are qualified for operability during a SSE condition to assure that 1) the pump is not damaged during the seismic event, and 2) the pump continues operating when subjected to the SSE loads.

The pump manufacturer is required to show that the pump operates normally when subjected to the maximum applicable amplified seismic (floor) accelerations, attached piping nozzle loads, and dynamic system loads associated with the faulted plant operating condition. Analysis procedures are utilized in accordance with those outlined in Section 3.7A.3. Natural frequencies are determined in order to obtain maximum seismic accelerations based on applicable amplified (floor) response spectra.

In order to avoid damage during the faulted plant condition, the stresses caused by the combination of normal operating loads, SSE, and dynamic system loads are limited to the values indicated in Table 3.9A-8. The maximum seismic nozzle loads are also considered in an analysis of the pump supports to assure that a system misalignment cannot occur. A static shaft deflection analysis of the rotor is performed with horizontal and vertical accelerations based on floor response levels. The deflections determined from the static shaft analysis are compared to allowable rotor clearances. The results of the pump stress/deflection analyses are summarized in Table 3.9A-10.

Performing these analyses with the conservative loads stated, and with the restrictive stress limits of Table 3.9A-8 as allowables, assures that critical parts of the pump are not damaged during the short duration of the faulted condition; therefore, the reliability of the pump for post-faulted condition operation is not impaired by the seismic event.

In addition to the post-faulted condition operation, it is necessary to assure that the pump functions throughout the SSE. The pump/motor combination is designed to rotate at a constant speed under all conditions unless the rotor becomes completely seized, i.e., no rotation. Typically, the rotor can be seized 5 full seconds before a circuit breaker trip shuts down the pump to prevent damage to the motor. However, the high rotary inertia in the operating pump rotor, and the random nature and short duration loading characteristics of the seismic event prevent the rotor from becoming seized. In actuality, the seismic loadings cause only a slight increase, if any, in the torque (i.e., motor current) necessary to drive the pump at the constant design speed. Therefore, the pump does not shut down during the SSE and operates at the design speed despite the SSE loads.

When seismic testing of the pump assembly is impractical, a seismic analysis is performed on the pump assembly to ensure operability. The analysis considers the pump, motor, and supporting structures together. In addition, the pump motor is independently qualified for operation during the maximum seismic event. Any auxiliary equipment that is identified to be vital to the operation of the pump or pump motor, and that is not qualified for operation during the pump analysis or motor qualifications, is separately qualified for operation at the accelerations that it would experience at its mounting. The pump motor and vital auxiliary equipment are qualified by meeting the requirements of IEEE-344-1975.

The functional ability of active pumps after a faulted condition is assured since only normal operating loads and steady-state nozzle loads exist. Since it is demonstrated that the pumps would not be damaged during the faulted condition, the postfaulted condition operating loads are identical to the normal plant operating loads. This is assured by requiring that the imposed nozzle loads (steady-state loads) for normal conditions and postfaulted conditions are limited by the magnitudes of the normal condition nozzle loads. The postfaulted condition ability of the pumps to function under these applied loads is proven during the normal operating plant conditions for active pumps. The active pump motors are qualified to operate satisfactorily when subjected to their surrounding environmental conditions for both normal operation and post-accident operation by meeting the requirements of IEEE-323-1974 (Section 3.11).

3.9A.3.2.2 Valve Operability Program

Safety-related active valves are required to perform their mechanical function during and/or after the course of a postulated accident. Assurance must be supplied that these valves can operate during and/or after a seismic event. Qualification tests accompanied by analyses are conducted for all active valves.

Valves without significant extended structures are considered seismically adequate as a result of piping seismic adequacy.

For valves with operators having significantly extended structures, an analysis is performed for static equivalent seismic SSE loads applied at the center of gravity of the extended structure. The maximum stress limits allowed in these analyses ensure the maintenance of structural integrity. The limits used for valves are shown in Tables 3.9A-7 and 3.9A-8, depending upon the class.

The safety-related valves are also subjected to a series of tests prior to service and during the plant life. Prior to installation, the following tests are performed: shell hydrostatic test to ASME Section III requirements; back seat and main seat leakage tests; disc hydrostatic test; and functional tests to verify that the valve opens and closes within the specified time limits, when subjected to the design differential pressure and operability qualification of motor operators for the environmental conditions over the installed life (i.e., aging, radiation, accident environment simulation, etc.) according to IEEE-323-1974. The pre-4.3 percent stretch power uprate (SPU) design differential pressure is applied to those valves whose design differential pressure increased slightly as a result of the 4.3 percent SPU. Cold hydro qualification tests, preoperational tests, periodic inservice inspections and inservice tests are performed to verify and assure the functional ability of the valve.

In addition to these tests and analyses, representative active valves of each design type, pressure, and size group are tested for verification of operability during a simulated seismic event, by demonstrating operational capabilities within the specified limits. The basic criteria used in selecting the representative value for qualification testing is based on an evaluation of the following parameters:

1. Assembly weight

2. Size, type, and pressure ratings

3. Actuator type and performance characteristics

4. Mounting arrangement and appurtenances

The methodology utilized in assessing the degree of similarity of evaluating the differences follows generally the guidelines of ANSI Standard B16.41-1983, Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants.

The proposed testing procedures are as follows. The valve is mounted in a manner that conservatively represents the actual valve installation. The valve assembly includes the operator and all appurtenances normally attached to the valve in service. The operability of the valve during a SSE is demonstrated by satisfying the following criteria:

1. All the active valves are required to have a fundamental natural frequency that is generally greater than 33 Hz. This is shown by suitable test or analysis.

2. The valve is operated in the normal unloaded position for baseline data. The actuator and yoke of the valve system are then statically loaded by an amount equal to that determined from an analysis as representing SSE accelerations applied at the center of gravity of the operator about the weaker axis of the yoke. The design differential pressure of the valve is simultaneously applied to the valve during the static deflection tests. The pre-4.3 percent SPU design differential pressure is applied to those valves whose design differential pressure increased slightly as a result of the 4.3 percent SPU.

3. The valve is then operated while in the deflected position, i.e., from the normal operating mode to the faulted operating mode. The valve is again operated in the normal position after the static load is removed. The valve is required to perform its safety-related function within the specified operating time limits in both the deflected and the normal position.

4. Electric motor operators and other electrical appurtenances necessary for operation are qualified in accordance with IEEE-323-1974 and IEEE-344-1975.

5. Environmental qualification of nonmetallic components in accordance with the Environmental Qualification Program.

The accelerations used for the valve qualification are generally 3.0 g horizontal and 3.0 g vertical. The piping design maintains the motor operator accelerations to these levels with an adequate margin of safety.

Selection of parent valve operators for testing generally follows the methodology outlined in Appendix A of IEEE-382-1980, IEEE Standard for Qualification of Safety-Related Valve Actuators. This standard provides a comprehensive method of analyzing all the relevant parameters of valve operators such as: type, size, weight, electrical characteristics (ac/dc, voltage, current), performance characteristics (speed, motor torque), and materials for the selection of a valve operator for qualification testing.

Consideration is also given to the effects of thermal and vibration aging, in conjunction with applicable margins, by utilizing the worst-case parameters in qualification.

Testing is conducted on a representative number of valves from each of the primary safety-related design types. Selected valve sizes are qualified by the tests and the results used to qualify that group of valves which the tested valve represents. Stress and deformation analyses are used to support the interpolation.

An assessment of the stresses at the pipe/valve interface generally indicates that distortion, if any, due to seismic loads will not cause binding of internal components. Therefore, additions of piping and loads during the operability tests is unnecessary.

For valves where stresses in the valve body could be significant, the piping and loads were imposed during the operability tests. Examples include solenoid valves and air-operated control valves.

For selected "active" valve categories, specific qualification programs are conducted to demonstrate operability. The method of qualification for these valves is detailed as follows:

1. <u>Butterfly Valves</u>

   The containment and drywell vent/pipe isolation valves are evaluated for operability during and after a postulated accident by both analyses and testing methods.

   a. The valve assembly is analytically evaluated and shown to perform its safety-related function (i.e., to close within the required response time). Valve analysis considers seismic, hydrodynamic, operating, air flow, and LOCA loads.

   b. The valve assembly is statically loaded by an amount equal in magnitude to the dynamic force and applied at the actuator C.G. The design pressure of the valve is simultaneously applied and the valve is operated while in the deflected position.

c. Electrical appurtenances (limit switches and solenoid-operated valves [SOV]) are qualified according to the requirements of IEEE-323-1974 and IEEE-344-1975.

d. In addition, assurance of operability is demonstrated by the following tests:

(1) In-shop shell hydrostatic tests

(2) Cold cyclic tests

(3) Seat leakage tests

(4) Pre/postinstallation functional tests

2. <u>Check Valves</u>

Check valves are characteristically simple in design, and their operation is not affected by seismic accelerations or the applied piping end loads. Check valve design is compact, and there are no extended structures or masses whose motion could cause distortions or restrict operation of the valve. The piping end loads due to maximum seismic excitation do not affect the functional ability of the valve since clearance is provided between the valve disc and the casing wall. This clearance around the disc prevents the disc from becoming bound or restricted due to any casing distortions caused by piping end loads. Therefore, the design of these valves is such that when the structural integrity of the valve is assured, using standard design or analysis methods, the ability of the valve to operate is assured by the design features. In addition to these design considerations, the valves are also subjected to the following tests and analysis:

a. Stress analysis, including the SSE loads.

b. In-shop hydrostatic test.

c. In-shop seat leakage test.

d. Periodic in situ valve exercising and inspection to assure the functional ability of the valve.

For the feedwater check valve, the operability following a postulated feedwater line break is also demonstrated. The maximum disc impact velocity and the pressure differential across the disc are determined. A stress analysis of the valve, which considers the impact and the seismic inertia loads, demonstrates valve design adequacy.

3. Safety Relief Valves

SRVs are evaluated for operability during and after a postulated accident of both analyses and testing methods.

a. The valve is analytically evaluated for seismic/hydrodynamic and operating loads and shown to perform its safety-related functions.

b. The valve is statically loaded by an amount equal in magnitude to the dynamic force. A pressure, representative of the design pressure, is simultaneously applied and the valve is operated while in the deflected positions.

c. In addition, assurance of operability is demonstrated by the following tests:

(1) In-shop hydrostatic seat leakage tests.

(2) In-shop hydrostatic body leakage tests.

(3) Performance tests.

(4) Periodic in situ valve inspections and an applicable periodic valve removal, refurbishment, and performance testing.

Using the methods described, all the safety-related valves in the system are qualified for operability during a seismic event. These methods conservatively simulate the seismic event and ensure that the active valves can perform their safety-related function when necessary.

3.9A.3.3 Design and Installation Details for Mounting of Pressure-Relief Devices

Pressure-relieving devices for ASME Safety Class 1 and 2 system components are:

1. Main steam SRVs.

2. SRVs for protecting RHR system heat exchangers.

The design and installation of main steam SRVs is described in Section 3.9B.3.3.

The design and installation of SRVs for protecting the RHR system heat exchangers (Section 5.4.7.2.3) is in accordance with ASME Section III, Article NC-7000, and RG 1.67.

Piping to and from SRVs is designed in accordance with ASME Section III, Paragraph NC-3677.

The STEHAM computer program (Appendix 3A) is used to calculate fluid transient forces in each piping segment (straight pipe piece between two elbows, an elbow and a tee, or an elbow and a terminal end) downstream of the SRVs. A conservatively low value of valve opening time is used in this calculation. Water slugs in pipe segments ending in the suppression pool are taken into account.

Dynamic stresses in the piping are computed by time-history integration or the equivalent static methods using one of the piping analysis computer programs described in Appendix 3A. These stresses are combined with those due to other mechanical loads, in accordance with load combinations described in Section 3.9A.3.1. Both SRVs protecting a heat exchanger are assumed to discharge concurrently. These loads meet design allowables provided by the vendor.

3.9A.3.4 Component Supports

Expansion anchor bolts, used in supporting the mechanical components from concrete structures, are drilled-in wedge-type uniform hole anchors. Drilled-in, bearing-type, flared hole anchors are also used in supporting the mechanical components from concrete structures.

Drilled-in, wedge-type, uniform hole expansion anchors are designed for a minimum safety factor of four, as determined by the ultimate load tests performed by the manufacturer. The setting torque has been determined by in situ tests. Most recently, the setting torque is as prescribed by the manufacturer.

Drilled-in, bearing-type, flared hole anchors are designed for a minimum safety factor of three, as determined by field testing. The loads are transferred into concrete by direct bearing against concrete. The bolt material is capable of reaching full ductility prior to failure. Due to these reasons, the anchors afford greater reliability, and a lower safety factor is justified.

The design, procurement, and installation of building steel comply with requirements of the AISC specification for the design, fabrication, and erection of structural steel for buildings, as described in Sections 3.8.4.2 and 3.8.4.6.3. The examination and inspection of building steel comply with the requirements of NRC RG 1.94, as described in Table 1.8-1.

3.9A.3.4.1 Pipe Supports

The pipe support designs, using base plates and concrete expansion anchor bolts, are performed using the flexibility criteria of NRC IE Bulletin 79-02 before they are released for fabrication. Verification of as-built conditions, in accordance with NRC IE Bulletin 79-14, is described in Section 3.7A.3.8.1.

The bases for design and construction of ASME and non-ASME piping supports are given in Table 3.9A-16.

Nonnuclear Piping

Nonnuclear piping supports satisfy the requirements of the American National Standard Code for Pressure Piping, ANSI B31.1-1973, up to and including the Winter 1973 Addenda, paragraph 120 and 121. An exception is taken to paragraph 120.2.4 of this edition by invoking the same paragraph of ANSI B31.1-1980, permitting the use of the 8th Edition - 1980 Edition of the AISC Manual for Steel Construction for the design of partial penetration groove welds in accordance with Table 1.17.5.

Nuclear Piping

Pipe supports for nuclear piping are designed and fabricated in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, 1974 Edition, no Addenda dated July 1, 1974, subject to the exceptions and additions listed below. Code stamping of pipe supports is not a requirement of the 1974 Edition. All pipe supports applicable to the RCPB piping or other piping are considered either linear or component standard, with portions of component standard supports designed to plate and shell rules.

The pipe support jurisdictional boundaries are in accordance with NF-1000 (see examples on Figure 3.9A-5). Portions of supports that are integrally attached to piping are designed, including local pipe stresses, in accordance with ASME III, Subsection NB, NC, or ND as applicable. The applicable dimensional standards of Table NB-3691-1 apply.

See Appendix 3E for a discussion of the criteria in the 1974 Edition of ASME Subsection NF regarding stresses in supports due to thermal growth in piping and seismic anchor motion as it compares to similar criteria in the 1983 Edition.

As permitted by NA-1140, the portions of the 1974 Edition of the ASME Code for which specific provisions of later ASME Code addenda or editions are substituted are listed below.

NA-3256 Filing of Design Specifications

> The Summer 1978 Addenda dated June 30, 1978, is invoked for the new subparagraph NCA-3256(b) to permit design specifications for component standard supports to be provided by the manufacturer and to permit/facilitate the implementation of ASME III Code Case N-247. See Table 5.2-1.

NA-3352 Stress Reports

The Summer 1978 Addenda dated June 30, 1978, is invoked for paragraph NCA-3351 to permit the use of the term design report in lieu of stress report and to permit/facilitate the implementation of ASME III Code Case N-247. See Table 5.2-1.

NF-1214 Component Standard Supports

The Summer 1976 Addenda dated June 20, 1976, is invoked to delete the specific reference to hydraulic snubbers.

NF-2121 Permitted Material Specifications

The Summer 1974 Addenda dated June 30, 1974, is invoked to permit the use of SA672 material.

NF-2121 Permitted Material Specifications

The Winter 1974 Addenda dated December 31, 1974, is invoked to permit the use of increased allowable stress for SA515 G65.

NF-2121 Permitted Material Specifications

The Summer 1976 Addenda dated June 30, 1976, is invoked to include the new subparagraph NF-2121(c) to permit the exclusion of certain shim stock from the requirements of Article NF-2120.

NF-2121 Permitted Material Specifications

The 1977 Edition dated July 1, 1977, is invoked to permit the use of SA36 material.

NF-2121 Permitted Material Specifications

The 1980 Edition dated July 1, 1980, is invoked to permit the use of SA564, Type 630 material.

NF-2121 Permitted Material Specifications

The Winter 1981 Addenda dated December 31, 1981, is invoked to permit the use of SA-194-2H nuts.

NF-2130 Certification by Material Manufacturer

The Summer 1982 Addenda dated June 30, 1982, is invoked for material certification.

NF-2610 Documentation and Maintenance of Quality Systems Programs

The 1977 Edition dated July 1, 1977, is invoked to revise the material manufacturers and material suppliers responsibilities for materials defined as small products or materials permitted to be supplied with Certificates of Compliance.

NF-3274 Snubbers

The Summer 1976 Addenda dated June 30, 1976, is invoked for NF-3134.6 to permit the use of mechanical snubbers.

NF-3226.5 Special Stress Limits
NF-3321.1 Design Conditions
XVII-2211 Stress in Tension

The Winter 1978 Addenda dated December 31, 1978, is invoked for these paragraph sections which in effect delete the code methods for consideration of through thickness stresses in plates and elements of rolled shapes.

NF-3391.1 Allowable Stress Limits
NF-3392.1 Allowable Stress Limits

The Winter 1979 Addenda dated December 31, 1979, is invoked for these paragraph sections which in effect delete the code methods for consideration of through thickness stresses in plates and elements of rolled shapes.

XVII-2454 Butt and Groove Welds

The 1980 Edition dated July 1, 1980, is invoked to redefine the throat thickness of partial penetration groove welds in accordance with Table XVII-2452.1-1.

In the case that material cannot be purchased to meet the specified ASME III Code, then material that meets subsequent ASME III Code Editions/Addenda up to and including the 1980 Edition/Summer 1982 Addenda may be substituted after a review and reconciliation of related requirements of the ASME III Code are performed and documented.

Table 3.9A-14 lists the load conditions, load combinations, and allowable stresses. Loads are applied in whatever manner is necessary to attain the worst possible stress levels for all support elements. Component standard supports are qualified either by analysis or by a combination of analysis and load rating. All other supports are qualified by analysis.

No specific deformation limits are required; however, pipe support deformations are consistent with pipe stress analysis.

The pipe support buckling criteria are consistent with the requirements of ASME III, Appendix XVII.

The design criteria and dynamic testing requirements for component and pipe supports listed in the following paragraphs are applicable under all plant operating conditions.

<u>Instrument Lines</u> The requirements for instrument lines are listed in Table 3.9A-15.

<u>Component Supports</u> All component supports are designed, fabricated, and assembled so they cannot become disengaged by the movement of the supported pipe or equipment during operation. All component supports are designed in accordance with the rules of ASME Section III, Subsection NF.

<u>Spring Hangers (Variable and Constant Support)</u> The design load on spring hangers is the load caused by deadweight alone. Variable spring hangers are calibrated to ensure that they support the deadweight at both their hot and cold load settings. For constant support spring hangers, the deadweight is always supported as a constant load, not subject to separate hot and cold loads. Spring hangers also allow for a down-travel and up-travel in excess of the specified thermal movement to account for dynamic movement.

<u>Rod Hangers</u> Rod hangers are only used as a rigid restraint when there is no possibility of compression.

<u>Struts</u> The design loads on struts include those loads caused by deadweight, thermal expansion, primary seismic (OBE and SSE), system anchor displacements, and reaction forces caused by relief valve discharge and turbine stop valve closure, etc. Struts are designed in accordance with Article NF-3000.

<u>Snubbers</u> The design loads on snubbers include all dynamic loads such as seismic forces (OBE and SSE), system dynamic anchor movements, and reaction forces caused by short duration relief valve discharge and turbine stop valve closure, produced by suppression pool phenomena. The snubbers are designed and load-rated in accordance with Article NF-3000 to be capable of carrying the design load for all dynamic operating conditions. Faulted condition design uses the criteria outlined in Appendix F of the ASME Code. The prototype snubbers have been tested dynamically to ensure that they can perform as required in the following manner:

1. The snubber was subjected to a force that varied approximately as the sine wave.

2. The frequency (Hz) of the input force was varied by small increments within the specified range.

3. The resulting relative displacements and corresponding loads across the working components, including end attachments, were recorded.

4. The test was conducted with the snubber at various temperatures.

5. The peak load in both static tension and compression tests was higher than the rated load.

6. The duration of the tests at each frequency was specified.

7. Snubbers were tested for applicable abnormal environmental conditions, followed by operational tests. The environmental test results are filed at the snubber manufacturer's location. The other test results are forwarded with the shipment of each snubber and are incorporated into the permanent plant file.

Anchors Anchors are designed to restrain all rotations and translations of piping. Terminal anchors are those which are common to two independently analyzed piping subsystems, one on each side of the anchor. For each load type, loads from both sides of the anchor are combined to form a total anchor load. For vibratory loads the total anchor load is ± (the SRSS of two loads from both sides of the anchor). For static loads the total anchor load is the algebraic sum of loads from both sides of the anchor. Design transient cyclic data are not applicable to piping supports, since no fatigue evaluation is necessary to meet the code requirements, unless the design specification identifies more than 20,000 load cycles. Design of anchors separating seismically designed and nonseismic piping is discussed in Section 3.7A.3.1.3.1.

3.9A.3.4.2 Pump Supports

The pump pedestal and pedestal bolt analysis includes consideration of loads from operating and seismic events, connecting pipes, temperature, and deadweight. The stress limits of ASME Section III, Subsection NF are met. The analysis includes deflection of the pedestal.

3.9A.3.4.3 Other Components Supports

Equipment supports and their connections to building structures that are governed by ASME are in accordance with ASME Section III, Subsection NF. ASME classifies these supports as either plate and shell- or linear-type supports.

Plate and Shell-Type Supports

These supports, e.g., vessel skirts and saddles, are fabricated from plate and shell elements and have the same ASME Code classification as the vessel.

Jurisdictional Boundaries

Figures 3.9A-2 and 3.9A-3 show the boundaries for different subsections of the ASME Code and building structures. As shown, the NF jurisdiction typically includes the connection between the component support and the building, with the exception of concrete anchorages.

Basis for Design and Construction

These supports are designed, fabricated, and installed in accordance with ASME Section III, Subsection NF.

Loads, Load Combinations, and Stress Limits

The combination of design loadings for these supports is categorized with respect to plant operating conditions. These conditions are identified as service levels A through D (Table 3.9A-13). Stress limits for the corresponding service levels also are given in Table 3.9A-13.

Deformation Limits

Deformations are considered so there is no interference with adjacent equipment, piping, or structures. If support deformations are determined to be critical, they become an integral part of the design and are held within the required limits; otherwise, deformations are consistent with support stress analysis.

Buckling Criteria

Analysis is performed to determine critical buckling strength, including local instabilities. Actual loads are compared to critical buckling loads in accordance with ASME Section III, Appendix F.

<u>Linear-Type Supports</u>

These supports, e.g., structural elements such as beams, columns, and frames, have the same ASME Code classification as the component.

Jurisdictional Boundaries

A typical linear equipment support for a HVR unit cooler is illustrated on Figure 3.9A-4. The jurisdictional boundary on the typical support is the connection between the supporting beams and the framing structure. The bolted or welded connection is NF-designed.

Basics for Design and Construction

These supports are designed, fabricated, and installed in accordance with ASME Section III, Subsection NF.

Loads, Load Combinations, and Stress Limits

The combination of design loading for these supports is categorized with respect to plant operating conditions. These conditions are identified as service levels A through D (Table

3.9A-13). Stress limits are also in accordance with ASME Section III, Subsection NF.

Deformation Limits

Deformations are considered so there are no interferences with adjacent equipment, piping, or structures. If support deformations are determined to be critical, they become an integral part of the design and are held within the required limits; otherwise, deformations are consistent with support stress analysis.

Buckling Criteria

Support buckling criteria is consistent with the requirements of ASME Section III, Appendix XVII.

<u>Bolting</u>

The allowable stress limits used for bolts in equipment anchorage, component supports, and flanged connections are given by the following:

1. Anchor Bolts Used in Equipment Anchorage - Appendix B of ACI 349, Code Requirements for Nuclear Safety-Related Concrete Structures.

2. Bolts Used in Component Supports - ASME Section III, Division I, Subsection NF, and Appendix XVII, paragraph 2460. For service levels C and D,

   XVII-2460 with factors indicated under XVII-2110 is applicable to the design requirements of bolting. The calculated stresses under these categories do not exceed the specified minimum yield stresses at temperature.

3. Bolts Used in Flanged Connections - ASME III.

Equipment mounted with high-strength bolts include vessels, unit coolers, and heat exchangers. The material for high-strength bolts used for the mounting of component supports to building structures conforms to the assigned jurisdictional boundary. Concrete high-strength anchor bolts used at component supports include A193, A325, and A490 steel. ASME Section III, NF high-strength bolts include SA-193 and SA-325 material.

High-strength bolts and low-strength bolts are used in pipe and duct support designs.

3.9A.4 Control Rod Drive Systems

See Section 3.9B.4.

3.9A.5 Reactor Pressure Vessel Internals

See Section 3.9B.5.

3.9A.6 Inservice Testing of Pumps and Valves

An IST program was prepared in conformance with the applicable portions of GDC 37, 40, 43, and 46. This program, submitted in November 1985, included baseline preservice testing and a periodic IST program for pumps and valves and is based on the ASME Boiler and Pressure Vessel Code, Section XI, 1980 Edition, through the Winter 1980 Addenda. Revision 0 of the First Ten-Year Interval IST Program was submitted to the NRC on March 31, 1988. Additional information was provided by letter dated September 30, 1988, and February 8, 1989. The NRC approved the IST program by letter dated October 29, 1990 (TAC No. 63429). The First Ten-Year Interval Program became effective on April 5, 1988, and was based on the ASME Boiler and Pressure Vessel Code, Section XI, 1983 Edition through the Summer 1983 Addenda. The purpose of the IST program is to ensure that certain ASME Class 1, 2, and 3 pumps provided with an emergency power source, and ASME Class 1, 2, and 3 valves required to perform a specific function in bringing the reactor to a cold shutdown condition or in mitigating the consequences of an accident, are in a state of operational readiness throughout the life of the plant. This inservice pump and valve test program is based on the Code of record in accordance with 10CFR50.55a. The IST program plan will be periodically updated in accordance with 10CFR50.55a.

3.9A.6.1 Inservice Testing of Pumps

The IST program for certain ASME Class 1, 2, and 3 pumps that have an emergency power source is in accordance with the requirements of 10CFR50.55a and the Code of record for the IST program plan. The basis of the test program is to detect changes in the hydraulic and mechanical condition of the pump relative to a reference set of parameters. Reference values will be established in accordance with the IST program plan and its implementing documents.

Pumps are tested periodically during plant operation and during shutdown periods, in accordance with the IST program plan.

3.9A.6.2 Inservice Testing of Valves

The IST program for all ASME Class 1, 2, and 3 valves that are required to perform a safety function will be in accordance with the requirements of 10CFR50.55a. All valves requiring inservice testing will be listed in the valve testing section of the Unit 2 IST program plan. Each valve in the plan is categorized in accordance with the requirements of the approved Code Edition (i.e., the Edition and Addenda that are incorporated by reference in 10CFR50.55a, or that may be specifically approved for use at

Unit 2 by the NRC). Test methods for each valve tested under the IST program plan will be described in the valve test procedures.

The valves which separate the RCPB, identified in Table 3.4.6-1 of the Technical Requirements Manual, Section 3.4.6, from interfacing low-pressure systems shall be leak tested in accordance with Technical Specifications.

These pressure isolation valves (PIV) are included in the Unit 2 IST program. The Unit 2 leak testing requirements for these valves are specified in the IST program plan and described by valve testing procedures.

1. For those check and globe valves which require a 10CFR50 Appendix J Type C test, the air leak rate data may be converted to a water leakage rate at 1,020 ± 20 psig and compared to the acceptance criteria for compliance with the Technical Specification requirement.

2. The periodic leak test will be performed during refueling outages.

3. After maintenance which can affect leak-tightness of the valve, leak testing will be performed in accordance with the IST program plan and the Technical Specification, prior to returning the valve to service.

P&IDs were supplied with the FSAR and Preservice and Inservice Inspection Plans which described inservice testing of the RCS pressure isolation valves. Procedures to support Technical Specification testing were generated in accordance with the startup schedule. During the Second Ten-Year Interval and successive intervals, the P&IDs are incorporated by reference into the IST program plan. The pump and valve testing procedures required to implement the IST program plan are part of the overall IST program and, like the P&IDs, they are separately controlled and maintained.

3.9A.6.3 Relief Requests

Proposed alternatives and requests for relief from the requirements of the ASME Code for IST of pumps and valves will be processed and submitted to the NRC, as required by 10CFR50.55a and the Unit 2 Technical Specifications. Implementation of relief requests and NRC-approved alternatives will be in accordance with Technical Specifications and 10CFR50.55a.

3.9A.6.4 Pipe Welds Within Break Exclusion Area

During each inspection interval, as defined in IWA-2400, an ISI is performed on all nonexempt ASME Code Section XI circumferential and longitudinal welds within the break exclusion region for high-energy fluid system piping. These inspections consist of augmented volumetric examinations (nominal pipe size greater than or equal to 4 in) and augmented surface examinations (nominal pipe size less than 4 in) such that 100 percent of the previously defined welds are inspected at each interval, or as required per the risk-informed process for piping outlined in EPRI Topical Report TR-1006937 and Nuclear Engineering Report NER-2A-025, NMP2 RI-ISI BER Evaluation. The break exclusion zone consists of those portions of high-energy fluid system piping between the moment limiting restraint(s) outside the outboard containment isolation valve and the moment limiting restraint(s) beyond the inboard containment isolation valve. The choice of the restraint(s) that define the limits of the break exclusion zone is based upon those restraint(s) which are necessary to ensure the operability of the primary containment isolation valves.

TABLE 3.9A-1
(Sheet 1 of 3)

TRANSIENTS AND THE NUMBER OF ASSOCIATED CYCLES
CONSIDERED IN THE DESIGN AND FATIGUE ANALYSES
OF CLASS 1 PIPING

	Transients	No. of Cycles
Normal, Upset, and Testing Conditions		
	Dynamic loads caused by SRV discharge events[(3)]	
	a. Piping	5,200
	b. Equipment	6,000
	OBE at rated operating conditions[(4)]	50
1.	Boltup	123
2.	Design hydrotest	130
3.	Startup (100°F/hr heatup rate)[(1)]	120
4.	Turbine roll and increase to rated power	120
5.	Daily power reduction to 75%	10,000
6.	Weekly power reduction to 50%	2,000
7.	Rod pattern change	400
8,10.	Scram - turbine generator trip, feedwater on, isolation valves stay open	50
9.	Partial feedwater heater bypass	70
11.	Other scrams	140
12.	Rated power normal operation - inadvertent actuation	10
13.	Reduction to 0% power	111
14.	Hot standby	111
15.	Shutdown prior to vessel flooding	111
16.	Vessel flooding	111
17.	Shutdown	111
18.	Vessel unbolt	123
19.	Refueling	0
20.	Loss of feedwater pumps - isolation valves closed	10
21.	Single relief or safety valve blowdown	8
29.	Inadvertent/accidental vessel overfilling[(7)]	4
Emergency		
22.	Reactor overpressure with delayed scram[(2)]	1
23.	Automatic blowdown[(2)]	1
24.	Improper start of cold recirc loop[(2)]	1
25.	Sudden start of pump in cold recirc loop[(2)]	1
26.	Hot standby-drain shutoff pump restart[(2)]	1
27.	Dynamic loads caused by suppression pool events during SBA, IBA[(2)]	[(6)]

TABLE 3.9A-1
(Sheet 2 of 3)

TRANSIENTS AND THE NUMBER OF ASSOCIATED CYCLES
CONSIDERED IN THE DESIGN AND FATIGUE ANALYSES
OF CLASS 1 PIPING

Transients		No. of Cycles
Faulted		
28.	Pipe rupture and blowdown[2]	1
	SSE at rated operating conditions[2,5]	10
	Dynamic loads caused by suppression pool events during DBA[2]	1,500

(1) Bulk average vessel coolant temperature change in any 1-hr period.

(2) The probability of event to occur in 40-yr plant life, P_{40}, is:

Emergency conditions: $10^{-1} > P_{40} \geqq 10^{-3}$

Faulted conditions: $10^{-3} > P_{40} \geqq 10^{-6}$

(3) The SRV discharge events used for analysis are given in Table 3.9A-2.

(4) In some cases, considered as an emergency event.

(5) Includes 10 maximum load cycles per event.

(6) Fatigue analysis is not required for emergency and faulted conditions.

(7) Number of cycles is based on maximum temperature differential (ΔT) of 141°F between the main steam pipe wall temperature and the incoming fluid temperature, and it includes one cycle for vessel overfilling which occurred in January 1988 during power ascension testing.

TABLE 3.9A-2
(Sheet 1 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

PART I

ASME Code Class 1 Systems [1,2]

ASME III (1974) NB-3600 Equations (Class 1)	P	DW	OBEI [3]	OBEA [3]	SSEI [3]	Fluid Trans [3]	SRV [3-5]	SBA IBA Max of Chug or CO_a [3,4]	DBA Max of Bubble Form or Chug or CO_b [3,4]	CO_b	DBA AP [3]	Jet Imp [3,6]	Th	ΔT_1	ΔT_2	T_a-T_b	RHRB [3,4]	RHR Chug [3,4,14]	RHR CO [3,4,14]	Plant Conditions	ASME III Allow-ables [7,8]
Eq. 9 NB-3652	X [8]	X [8]	X			X	X													Normal & upset	1.5 S_m
[5]	X	X	X			X	X	X				X								Emergency (SBA, IBA)	2.25 S_m
	X	X	X			X	X			X		X								Emergency (SBA, IBA)	2.25 S_m
	X	X	X			X											X			Emergency	2.25 S_m
	X	X	X			X														Emergency	2.25 S_m
	X	X	X			X														Emergency	2.25 S_m
	X	X			X	X	X	X				X								Faulted (SBA, IBA)	3.0 S_m
	X	X			X	X				X		X								Faulted (SBA, IBA)	3.0 S_m
	X	X			X	X					X	X								Faulted (AP)	3.0 S_m
	X	X			X	X			X			X								Faulted (DBA)	3.0 S_m
Eq. 10 NB-3653.1	X	X	X [10]	X [10]		X [10]	X [10]						X	X		X				Normal & upset	3.0 S_m
Eq. 11 NB-3653.2	X	X	X [10]	X [10]		X [10]	X [10]						X	X	X	X				Normal & upset	

TABLE 3.9A-2
(Sheet 2 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

PART I (Cont'd)

ASME Code Class 1 Systems [1,2]

ASME III (1974) NB-3600 Equations (Class 1)	P	DW	OBEI (3)	OBEA (3)	SSEI (3)	Fluid Trans (3)	Max SRV (3-5)	SBA IBA Max of Chug or CO_a (3,4)	DBA Max of Bubble Form or Chug or CO_b (3,4)	CO_b	DBA AP (3)	Jet Imp (3,6)	Th	ΔT_1	ΔT_2	T_a-T_b	RHRB (3,4)	RHR Chug (3,4)	RHR CO (3,4)	Plant Conditions	ASME III Allow-ables (7)
Eq. 12 NB-3653.6 (a)													X							Normal & upset	3.0 S_m
Eq. 13 NB-3653.6 (b)	X	X	X			X	X									X				Normal & upset	3.0 S_m
Eq. 14 NB-3653.6 (c)	X	X	X(10)	X(10)		X(10)	X(10)						X	X	X	X				Normal & upset	CUF $\leq$ 1
Eq. 10a NC-3652.3 (11)	Any single nonrepeated anchor movement																			All	3.0 S_c

TABLE 3.9A-2
(Sheet 3 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

PART II

ASME Code Class 2 and 3 Systems[1,2]

ASME III (1974) NC-3600 ND-3600 Equations (Class 2 & Class 3)	P	DW	OBEI (3)	OBEA (3)	SSEI (3)	Fluid Trans (3)	SRV (3-5)	SBA IBA Max of Chug or CO_a (3,4)	DBA Max of Bubble Form or Chug or CO_b (3,4)	CO_b	DBA AP (3)	Jet Imp (3,6)	Th	Anch Move Non-repeated	RHRB (3,4)	RHR Chug (3,4, 14)	RHR CO (3,4, 14)	Plant Conditions	ASME III Allow-ables (7,12,15)
Eq. 8 NC-3652.1 ND-3652.1	X[12]	X[12]																Normal	1.0 S_h
Eq. 9 XNC-3652.2 ND-3652.2 (5,9)	X	X	X			X	X											Upset	1.2 S_h
	X	X	X			X	X	X				X						Emergency (SBA, IBA)	1.8 S_h
	X	X	X			X				X		X						Emergency (SBA, IBA)	1.8 S_h
	X	X	X			X									X			Emergency	1.8 S_h
	X	X	X			X												Emergency	1.8 S_h
	X	X	X			X												Emergency	1.8 S_h
	X	X			X	X	X	X				X						Faulted (SBA, IBA)	2.4 S_h
	X	X			X	X				X		X						Faulted (SBA, IBA)	2.4 S_h
	X	X			X	X					X	X						Faulted (AP)	2.4 S_h
	X	X			X	X			X			X						Faulted (DBA)	2.4 S_h
Eq. 10 NC-3652.3 ND-3652.3				X									X					Normal & upset	S_A

TABLE 3.9A-2
(Sheet 4 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

PART II (Cont'd)

ASME Code Class 2 and 3 Systems[1,2]

ASME III (1974) NC-3600 ND-3600 Equations (Class 2 & Class 3)	P	DW	OBEI [3]	OBEA [3]	SSE I [3]	Fluid Trans [3]	SRV [3-5]	SBA IBA Max of Chug or CO_a [3,4]	DBA Max of Bubble Form or Chug or CO_b [3,4]	CO_b	DBA AP [3]	Jet Imp [3,6]	Th	Anch Move Non-repeated	RHRB [3,4]	RHR Chug [3,4,14]	RHR CO [3,4,14]	Plant Conditions	ASME III Allow-ables [7,15]
Eq. 10a NC-3652.3 ND-3652.3 [11]														X				Normal, upset, emergency, faulted	3.0 S_c
Eq. 11 NC-3652.3 ND-3652.3	X	X		X									X					Normal & upset	$S_h + S_A$

TABLE 3.9A-2
(Sheet 5 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

PART III

ANSI B31.1 Code Class[13]

ANSI B31.1 Code Equations	P	DW	Fluid Trans[3]	Th	Anch Move Nonrepeated	Plant Conditions	ANSI B31.1 Code Allowables[12]
Eq. 11	X[12]	X[12]				Normal	1.0 S_h
Eq. 12[5]	X	X	X			Normal & upset	1.2 S_h
Eq. 13				X		Normal & upset	S_A
Eq. 13a[11]					X	Normal upset, emergency, faulted	3.0 S_c
Eq. 14	X	X		X		Normal & upset	S_A+S_h

TABLE 3.9A-2
(Sheet 6 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

KEY:

P	=	Longitudinal pressure stress. For ASME Section III Class 1 piping, the design pressure is used for Equation 9 and operating pressure for Equations 10, 11, and 13. For ASME Section III Class 2 and 3 piping and ANSI B31.1, design pressure is used in all equations containing a pressure term.
DW	=	Load due to the weight of pipe, contents, insulation, and in-line components.
OBEI	=	Inertia load due to operating basis earthquake (OBE).
OBEA	=	Operating basis earthquake anchor and support differential displacement load.
SSEI	=	Inertia load due to safe shutdown earthquake (SSE).
Fluid transient	=	Internal piping loads due to fluid transient effects such as water hammer, steam hammer, SRV blowdown, or pump startup loads.
Th	=	Thermal expansion, thermal stratification (experienced by feedwater piping) and thermal anchor and support differential displacement load.
ΔT_1	=	Local thermal transient stress across pipe wall due to linear temperature distribution.
ΔT_2	=	Local thermal transient stress across pipe wall due to nonlinear component of temperature distribution.
T_a-T_b	=	Local thermal transient stress due to average temperature difference of geometric and/or material discontinuity.
Anchor movement nonrepeated	=	Load due to any single nonrepeated anchor movement.
SRV	=	All applicable SRV inertia load cases. These cases single (1-valve actuation), asymmetric (simultaneous actuation of 3 valves), symmetric (simultaneous actuation of all valves), and ADS (simultaneous actuation of 7 ADS valves). SRV inertia load cases applicable to a particular load combination depend upon their postulated occurrence with other dynamic loads in the combination.
CO_a	=	Condensation oscillation structural vibrations with ADS.
CO_b	=	Basic condensation oscillation structural vibrations.
SBA, IBA max of chug or Co_a	=	Maximum inertia load of either chugging or condensation oscillation structural vibrations that occur during a small or intermediate break accident.
DBA max of bubble form or chug or CO_a	=	Maximum inertia load of either bubble formation or chugging or condensation oscillation structural vibrations that occur during a DBA.
RHRB	=	RHR bubble drag load.
RHR CO	=	RHR CO drag load.
RHR Chug	=	RHR chugging drag load.
DBA AP	=	Inertia load due to annulus pressurization structural vibration effects occurring during a DBA. Annulus refers to the space between the RPV and the biological shield wall.

TABLE 3.9A-2
(Sheet 7 of 7)

LOAD COMBINATIONS AND STRESS LIMITS FOR PIPE STRESS ANALYSIS

NOTES:

(1) The SRV, SBA, IBA, and DBA load cases (the columns between Fluid Trans and Jet Imp) occur in the reactor building only. Except for AP, they are suppression pool-related dynamic events. Piping inside or attached to the reactor building is affected by the reactor building vibrations up to the first anchor outside the building.

(2) References used to develop table:
a. ASME III issued 1974 dated July 1, 1974, and Code Case 1606-1.
b. Mark II Containment Dynamic Forcing Functions Information Report (DFFR) Rev. 4, November 1981.

(3) The amplitudes of events characterized by random vibration are determined with conservatism in such a way that the load combinations are in accordance with NRC NUREG-0484, Rev. 1.

Only OBEI and OBEA are combined by absolute summation. All other combinations of dynamic loads are by the SRSS method. Both OBEI and (OBEI + OBEA) are considered dynamic loads.

(4) In addition to inertia loads, piping submerged in the suppression pool experiences: Water drag loads during SRV and RHR relief valve discharge, CO, bubble formation, DBA pool swell and fallback, and acoustic pressure loads during chugging. Piping above the water level of the suppression pool experiences pool swell impact loads or froth loads, and fallback loads, in the DBA case.

(5) The damping values used for dynamic analysis are based on Regulatory Guide 1.61 (Table 3.7A-1), with OBE values applicable to normal and upset loads and SSE values applicable to emergency and faulted loads. Alternate damping values for seismic analysis will be those described in ASME Code Case N-411.

(6) Jet impingement from water or steam jets emanating from postulated breaks of piping of other systems applies only to areas identified as targets.

(7) Allowables given are based on the ASME Section III, 1974 edition. In addition, all ASME III Safety Class 1, 2, and 3 piping systems that are required to function for safe shutdown under the postulated events are designed to meet the functional capability criteria of NEDO-21985.

(8) For systems that require hydrotesting, repeat Equation 9 without occasional loads, using test pressure and deadweight for water-filled pipe. The allowables for the hydrotest case are given in NB-3226.

(9) OBEA load can be included in Equation 9 instead of Equation 10 in Class 2 and 3 systems (in accordance with ASME III, Paragraphs NC-3652 and ND-3652, respectively) and in Equation 12 instead of Equation 13 in Class 4 systems (in accordance with ANSI B31.1). Option is used in a few cases only.

(10) Due to the nature of dynamic cyclic loads, the inertia effects of dynamic loads including OBE displacements are considered in fatigue evaluation of ASME Code Class 1 piping. The cycles are consumed in a manner consistent with the example given in ASME Section III, Subsection NB, Subparagraph NB-3653.1.

(11) Equation 10a is adapted from the 1977 edition of ASME Section III, Subsections NC and ND.

(12) For systems that require hydrotesting, repeat Equation 8, using test pressure and deadweight for water-filled pipe. The allowable for the hydrotest case is 90 percent of the yield stress at temperature.

(13) Reference used to develop table: ANSI B31.1 dated 1973 and all addenda thereto up to and including Addendum C (issued December 31, 1973).

(14) A T-quencher of the same design as the main steam SRVDL has been installed to the RHR relief valve discharge piping to mitigate the relief valve actuation loads. As a result, the RHR Chugging and RHR CO loads are negligible.

(15) The faulted stress limits and analysis techniques specified in ASME Section III, Appendix F, can be applied. Inelastic methods can be used as allowed by the Code.

TABLE 3.9A-3
(Sheet 1 of 1)

PIPE STRESS ANALYSIS CLASSIFICATIONS
FOR ASME CODE CLASSES 1, 2, 3

Piping Class	Analysis Classification		
Class 1	Nominal pipe size	D>1"	D≤1"
	Type of analysis	Class 1	Class 2[1]
Class 2,3	Nominal pipe size or tubing OD	D>6"	D≤6"
	Type of analysis	Computer analysis	Noncomputer analysis[2]

[1] Section 3.7A.3.8.2 for acceptance criteria.
[2] Piping or instrumentation tubing is qualified by placing the supports in accordance with a generic procedure or by hand calculations of stress and support loads.

TABLE 3.9A-4
(Sheet 1 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
Motor-operated rotary gates	A static analysis and test were performed. The applicable standards and guidelines are IEEE-323-1974 and IEEE-344-1975 and RG 1.61, 1.89, 1.92, and 1.100.	The motor-operated rotary gates are affected by seismic loads only. The analysis indicated that the stress levels are within the allowable limits of 3.9A.2.2.2. Refer to Table 3.10A-1 for the qualification of the Limitorque actuators.
Special air filter assemblies	A static analysis and test were performed. The applicable standards, codes, and guidelines are IEEE-344-1975, ASME Section III, and RG 1.61, 1.92, 1.84, 1.85, 1.89, and 1.100.	The filter assemblies are affected by seismic loads only. The results of the analysis of structural and functional elements of the equipment indicate that the stresses are within the allowable limits of 3.9A.2.2.2. Refer to Table 3.10A-1 for the qualification of the heater/flow switches.
Spent fuel pool cooling water heat exchangers	A static analysis was performed. The applicable standards, codes, and guidelines are IEEE-344-1975, ASME Section III, and RG 1.61, 1.92, 1.89, and 1.100.	The heat exchangers are affected by seismic loads. The analysis indicates that the stress levels are within the allowable limits of 3.9A.2.2.2.
Self-cleaning strainers	The strainers are qualified by static analysis and test. The applicable standards, codes, and guidelines are IEEE-323-1974, IEEE-334-1974, IEEE-344-1975, ASME Section III, and RG 1.61, 1.84, 1.85, 1.89, 1.92, and 1.100.	The strainers are subjected to seismic loads. The analysis indicates that the stress intensity for the strainer components is within the allowable stress limits of 3.9A.2.2.2. The deflections do not affect the operability of the strainer. Refer to Table 3.10A-1 for the qualification of the motors.
Simplex strainers	The strainers are qualified by static analysis. The applicable standards are ASME Code Section III and RG 1.61 and 1.92.	The strainers are subjected to seismic loads. The structural integrity of the strainers is demonstrated since the analysis indicates the stress levels are within the allowable limits of 3.9A.2.2.2.
ECCS suppression pool strainers	The strainers are qualified by static analysis. The applicable standards are ASME Code Section III and RG 1.61 and 1.92.	The strainers are subjected to seismic, hydrodynamic, and suppression pool drag loads. The analysis indicates that the stress intensity for the strainer components is within the allowable stress limits of 3.9A.2.2.2.
RCIC suppression pool strainer	The strainer is qualified by static analysis. The applicable standards are ASME Code Section III and RG 1.61 and 1.92.	The strainer is subjected to seismic, hydrodynamic, and suppression pool drag loads. The analysis indicates that the stress intensity for the strainer components is within the allowable stress limits of 3.9A.2.2.2.
Active pumps horizontal centrifugal Diesel generator fuel oil transfer	Pumps are qualified by dynamic and static analysis and operability tests. The applicable standards and guidelines are IEEE-344-1975, IEEE-334-1974, RG 1.48,	The pumps are affected by seismic loads only. The structural integrity and functional capability of the pumps have been demonstrated by static and dynamic analysis. The centrifugal pumps have been determined to be rigid. The fundamental frequency of the fuel oil transfer pumps was 6 Hz.

TABLE 3.9A-4
(Sheet 2 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
	1.61, 1.89, 1.92, and 1.100, and ASME Code Section III.	Stresses are maintained within the allowable limits of Table 3.9A-8. All of the deflections are within the normal clearances. The lowest margin of safety with respect to both the stresses and deflections is approximately 1 percent. In addition to the seismic analysis, the operability of the pumps is ensured through the program described in Paragraph 3.9A.3.2.1. The qualification of the motors conforms to IEEE-334-1974. See Table 3.10A-1 for the qualification results of the pump motors and for the qualification summary of the electric motors.
Local instrument racks	The instrument racks are qualified by analysis. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.61 and 1.100.	The racks are affected by seismic loads only. The analysis was performed using a finite element model. The equipment was determined to be rigid and, therefore, static analysis was utilized. Results of the analysis indicate that the stresses are within the allowable stresses of 3.9A.2.2.2.
Flexible metal hoses	Flexible metal hoses are qualified by analysis. Applicable standards and guidelines are EJMA, ASME Code Section III, ASME Code Case N-192-2, IEEE-344-1975, and RG 1.61, 1.84, 1.85, 1.92, and 1.100.	Flexible hoses are affected by both seismic and hydrodynamic loads. Design adequacy was verified by analysis in accordance with the EJMA Standard. This analysis takes into account design temperature, pressure, dynamic loads, differential displacements, and the number of cycles of displacement. In addition, representative hoses are qualified by two separate dynamic test programs. In the first dynamic test, hoses are subjected to a total of 1 million cycles of vibrations in the frequency range of 5 to 100 Hz, at accelerations ranging from 3 g to 51 g. In the second test, the hoses are subjected to six biaxial, random, multifrequency input motions of 30-sec durations each. The six tests are repeated in the other horizontal orientations. The TRS envelops the applicable portion of RRS with at least a 10 percent margin. Hoses were pressurized at the start of each test series to at least the design pressure. During and following the dynamic tests the hoses maintained their pressure integrity.
Miscellaneous HVAC Axial fans Centrifugal fans Air conditioning units Backdraft dampers Bubble-tight dampers Butterfly damper Tornado damper Fire damper	The HVAC equipment listed was qualified by analysis and test. Applicable codes, standards, and guidelines include RG 1.60, 1.61, 1.89, 1.92, 1.84, 1.85, and 1.100, IEEE-323-1974, IEEE-334-1974, IEEE-334-1975, and ASME Section III.	This equipment is affected by seismic loads only. The results of the analysis of structural and functional elements of the equipment indicate that the stresses are within the allowable limits of 3.9A.2.2.2. The deflection of rotating members was determined to be within the clearances. Refer to Table 3.10A-1 for the qualification results of the fan motors and the pneumatic actuators or the electrohydraulic actuators used on the dampers.

TABLE 3.9A-4
(Sheet 3 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
Multileaf damper Single-bladed Dampers		
Centrifugal liquid chillers	Seismic qualification is by static analysis and testing. Applicable standards and guidelines include ASME Code Section III, RG 1.61, 1.89, 1.92, and 1.100, IEEE-323-1974, IEEE-334-1974, and IEEE-334-1975.	This equipment is affected by seismic loads only. The analysis of the chiller assembly and structural components is performed using a detailed finite element model. Results of the analysis indicate that the stresses are within the allowable stresses of 3.9A.2.2.2 and deflections of critical components are within limits required to maintain functional capability. The electronic control panel and the System Class 1E components were qualified by dynamic testing. See Table 3.10A-1 for test results.
Unit space cooler	The unit space coolers and air conditioning units were qualified by both test and analysis. The applicable standards and guidelines include IEEE-344-1975, IEEE-323-1974, and IEEE-334-1974, ASME Section III, and RG 1.61, 1.89, 1.92, and 1.100.	The unit space coolers and air conditioning units are affected by seismic loads only. The unit coolers are composed of three parts: the fan-motor section, coil section, and filter section. The units have either a propeller-type fan (Industrial Air) or a vaneaxial fan (Joy Manufacturing). They all have electric motors (Reliance) and motor control panels. (The air conditioning units are essentially the same as the unit coolers, except that they have no motor control panels.) All but two units have air filters (American Air Filters) and each has one or two ASME Section III cooling coils. A propeller fan space cooler and a vaneaxial fan space cooler were chosen for dynamic testing, since they were representative of the dimensions and characteristics of the other coolers. The dynamic testing is performed as follows: The units were mounted on the vibration test table so that the in-service condition is simulated. The units were instrumented to record accelerations. A resonance search was performed from 1 to 35 Hz for each of the 3 orthogonal axes. The seismic simulation vibration testing consisted of biaxial random multifrequency tests, 5 OBEs and 1 SSE in each of 2 test orientations, 90 deg apart. The units were pressurized and operational during the tests. The TRS enveloped the RRS. The cooling coils for the unit coolers were qualified by analysis. The results of the analysis indicate that the stress levels are within the allowable limits of 3.9A.2.2.2. The fan and coil sections of the air conditioning unit were qualified by dynamic testing. The units were mounted on the vibration test table to simulate plant installation. They were instrumented to record accelerations. A resonance search was performed from 1 to 33 Hz for each of the 3 orthogonal axes. The seismic simulation vibration testing consisted of biaxial random multifrequency test of 4 SSEs in each of the two test orientations, 90 deg apart. The equipment remained operational during the tests and the TRS enveloped the RRS.

TABLE 3.9A-4
(Sheet 4 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
Nonactive valves Motor-operated Air-operated Manual Solenoid	Nonactive valves are qualified by analysis. Applicable standards and guidelines are ASME Section III and RG 1.61 and 1.92.	Valves affected by seismic loads only are qualified for 3 g horizontal and 3 g vertical loadings. Those valves affected by seismic and hydrodynamic loadings have been qualified for up to 20 g horizontal and 20 g vertical loadings. Piping design acceptance criteria ensure actual loadings to be within the qualified levels for each valve. All valves were determined to have a natural frequency that is generally greater than 33 Hz. Structural and pressure integrity of the valve assemblies has been demonstrated by static analysis or through their similarity to active valves. Stresses are maintained within the limits of Tables 3.9A-7 and 3.9A-8. For ASME Class 1 valves, design reports are also prepared in accordance with ASME Section III, Subsection NB-3500. For valves affected by hydrodynamic loads, fatigue analyses of the critical components were also performed, and the CUFs are maintained below one.
Active valves Motor-operated Air-operated Solenoid Relief valves Electrohydraulic	Active valves are qualified by analysis and test. Applicable standards and guidelines are ASME Section III, RG 1.48, 1.61, 1.89, 1.92, and 1.100, and IEEE-323-1974, IEEE-344-1975 and IEEE-382.	Valves affected by seismic loads only are generally qualified for 3 g horizontal and 3 g vertical loadings. The valves affected by seismic and hydrodynamic loads were qualified for up to 11 g horizontal and 11 g vertical loadings. Piping design acceptance criteria ensures actual loadings to be within the qualified levels for each valve. All valves were determined to have natural frequencies that are generally greater than 33 Hz. For valves with a fundamental natural frequency below 33 Hz, the appropriate valve mass and stiffness properties were included in piping models, and the valve acceleration responses obtained from the piping analyses were maintained below the qualification levels. Structural and pressure integrity of the valve assemblies are demonstrated by analysis. Stresses are maintained within the limits of Tables 3.9A-7 and 3.9A-8. Deflection of critical components is well within the allowable limits. Design stress analyses were performed for ASME Class 1 valves in accordance with ASME Section III, Subsection NB-3500. For valves affected by hydrodynamic loads, fatigue analyses of the critical components were also performed, and CUFs are maintained below one. Actuators for AOVs are qualified by dynamic testing. With the exception of the RCIC pressure control valve (2ICS*PCV115), each tested actuator was mounted on the shake table as it normally would be in service, and biaxial, random multifrequency tests of 30-sec duration were performed for each of the five OBE and one SSE conditions. The tests were repeated in the second horizontal and vertical orientation. The actuator was operated through one complete cycle for each OBE and SSE test. The actuator performed its safety function and successfully completed the test. Piping design acceptance criteria ensure that actual dynamic loading is to be within the qualified levels for each valve. In the case where the TRS does not fully envelop the RRS, the general requirement for a retest may be exempted if the following criteria are met: 1) A point of the TRS may fall below the RRS by 10 percent or less, provided the adjacent 1/6 octave points are at least equal to the RRS and the adjacent 1/3 octave points are at least

TABLE 3.9A-4
(Sheet 5 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
		10 percent above; 2) A maximum of 5 of the 1/6 octave analysis points, as in 1) above, may be below the RRS, provided they are at least one octave apart. For valve 2ICS*PCV115, an entire valve assembly with a similar actuator was qualified. (The tested assembly did not include the CONOFLOW I/P converter and filter regulator. Those are addressed in Table 3.10A-1). The assembly was subjected to biaxial, random multifrequency tests for each of the five OBE and SSE conditions. The tests were repeated in the second horizontal and vertical orientation. The valve assembly functioned as required before, during and after the tests. For valves affected by combined seismic and hydrodynamic loads, the OBE and SSE test spectra enveloped the upset and faulted RRS, respectively, by a minimum margin of 10 percent, except for one direction, where the margin at one frequency is below 10 percent. However, the adjacent 1/6 octave points are above the 10 percent margin, and the adjacent 1/3 octave points are above a 20 percent margin. Additionally, test margins adequately envelope the stress cycles and durations required for the hydrodynamic loads. For the SOVs (Target Rock and Valcor) and the electric components of the valves, such as solenoid valves, electrohydraulic operators, motor operators, limit switches, etc., qualification is achieved through comprehensive environmental and dynamic test programs. Detailed results are provided in Table 3.10A-1. Operability of the valve assemblies is demonstrated by both dynamic and static load tests. Selected valves were subjected to dynamic tests to simulate the seismic and hydrodynamic loads. Other valves were qualified through static deflection tests of parent valve assemblies. The test programs conform to Paragraph 3.9A.3.2.2. Functional adequacy was verified during and after these tests.
Feedwater check valves	The feedwater check valves are qualified by analysis. The Class 1E components of the air-operated check valves are qualified by testing. Applicable standards and guidelines are ASME Section III, NRC RG 1.48, 1.61, 1.89, 1.92, and 1.100, and IEEE-323-1974 and IEEE-344-1975.	The feedwater check valves are affected by both seismic and hydrodynamic loads. The valves are qualified by dynamic analysis for the worst transient condition following a pipe break, together with the seismic/hydrodynamic loads. Stresses are maintained within the limits of Table 3.9A-7. Design analysis of the valves is also prepared in accordance with ASME Section III, Subsection NB-3500. The electrical appurtenances of the air operators (limit switch, solenoid valves) are qualified by testing. Detailed results are provided in Table 3.10A-1.
Vacuum relief valves	The vacuum relief valves are qualified by analysis. The applicable standards and guidelines are ASME Section III and NRC RG 1.48, 1.61, and 1.92.	The vacuum relief valves are affected by both seismic and hydrodynamic loads. The valves are rigid (natural frequency >100 Hz) and are analyzed for up to 16 g horizontal and 14 g vertical loadings together with the operating loads (opening and/or closing pressure transients). The design analysis met the ASME III, Subsection NC-3500, requirements. The stresses in all the critical valve components are maintained within the limits of Table 3.9A-8, and the calculated deflections do not affect the operability of the valves.

TABLE 3.9A-4
(Sheet 6 of 6)

BOP SEISMIC/DYNAMIC QUALIFICATION RESULTS - MECHANICAL EQUIPMENT

Equipment	Methods	Results
Polar crane	Dynamic analysis is performed utilizing the time-history technique. Applicable standards and guidelines are CMAA-70, the AISC Code, and NRC RG 1.61 and 1.92.	The polar crane is affected by seismic loads. A finite element lumped mass mathematical model is developed to simulate the mass and stiffness characteristics of the crane, including the trucks, trolleys, and hoist rope. Dynamic responses due to seismic loadings are evaluated for several trolley positions and load lift heights, as appropriate, in order to determine the maximum stress levels in all critical members and connections. The analysis indicates that the stresses are within the allowable limits.

TABLE 3.9A-5
(Sheet 1 of 3)

LOAD COMBINATIONS FOR ASME SECTION III CLASS 1 VALVES[(1)]

Classification	Combination
Design	Design pressure Design temperature[(2)] Deadweight Piping reactions OBE
Normal	Normal condition pressure Normal condition metal temperature Deadweight Piping reactions
Upset	Upset condition pressure Upset condition metal temperature Deadweight Dynamic load 1[(3)] Piping reactions
Emergency	Emergency condition pressure Emergency condition metal temperature Deadweight Dynamic load 3[(3)] Piping reactions
Faulted	Faulted condition pressure Faulted condition metal temperature Deadweight Dynamic load 2[(3)] Piping reactions

(1) The only ASME Class 1 components within the BOP scope are valves.
(2) Temperature is used to determine allowable stress only.
(3) The definitions of these loads are given on page 2 of this table.

TABLE 3.9A-5
(Sheet 2 of 3)

LOAD COMBINATIONS FOR ASME SECTION III CLASS 1 VALVES[1]

Load Definitions

Dynamic Load 1

Location a = $[(OBE)^2+(SRV_{ALL})^2]^{1/2}$

Location b = OBE

Dynamic Load 2

Location a; the envelope of

(i) = $[(SSE)^2 + (AP)^2]^{1/2}$
(ii) = $[(SSE)^2 + (SRV_{ONE})^2 + (CO1)^2]^{1/2}$
(iii) = $[(SSE)^2 + (SRV_{ADS})^2 + (CO2)^2]^{1/2}$
and (iv) = $[(SSE)^2 + (SRV_{ALL})^2 + (CHUG)^2]^{1/2}$

Location b = SSE

Dynamic Load 3

Location a; the envelope of

(i) = $[(OBE)^2 + (AP)^2]^{1/2}$
(ii) = $[(OBE)^2 + (SRV_{ONE})^2 + (CO1)^2]^{1/2}$
(iii) = $[(OBE)^2 + (SRV_{ADS})^2 + (CO2)^2]^{1/2}$
and (iv) = $[(OBE)^2 + (SRV_{ALL})^2 + (CHUG)^2]^{1/2}$

Location b = OBE

Where:

Location a	=	Equipment inside the reactor building
Location b	=	Equipment outside the reactor building
OBE	=	Operating basis earthquake
SSE	=	Safe shutdown earthquake
SRV_{ALL}	=	Envelope of all safety relief valve actuation cases, including symmetric, asymmetric, ADS, and single subsequent actuations
SRV_{ONE}	=	One stuck open safety relief valve actuation case
SRV_{ADS}	=	ADS safety relief valves actuation case
CO1	=	Basic condensation oscillation phase of LOCA
CO2	=	Condensation oscillation phase of LOCA, concurrent with actuation of ADS valves
AP	=	Annulus pressurization due to LOCA
CHUG	=	Envelope of symmetric and asymmetric chugging phases of LOCA

TABLE 3.9A-5
(Sheet 3 of 3)

LOAD COMBINATIONS FOR ASME SECTION III CLASS 1 VALVES[1]

LOCA	=	Envelope of CO chugging and annulus pressurization due to LOCA

NOTE: For a detailed discussion of these loads, see the Design Assessment Report (Appendix 6A).

TABLE 3.9A-6
(Sheet 1 of 1)

LOAD COMBINATIONS FOR ASME SECTION III
CLASS 2 AND 3 AND NON-ASME COMPONENTS

Design Conditions I and II are defined as:

Design Condition I = Specified design loads (temperature, pressure, etc.) + Dynamic Load 1

Design Condition II = Specified design loads (as above) + Dynamic Load 2 pipe rupture loads (if applicable)

Dynamic Load 1*

Location a = $[(OBE)^2 + (SRV_{ALL})^2]^{1/2}$

Location b = OBE

Dynamic Load 2*

Location a; the envelope of

$$(i) = [(SSE)^2 + (AP)^2]^{1/2}$$
$$(ii) = [(SSE)^2 + (SRV_{ONE})^2 + (CO1)^2]^{1/2}$$
$$(iii) = [(SSE)^2 + (SRV_{ADS})^2 + (CO2)^2]^{1/2}$$
$$\text{and } (iv) = [(SSE)^2 + (SRV_{ALL})^2 \ (CHUG)^2]^{1/2}$$

Location b = SSE

* See Table 3.9A-5 for hydrodynamic load nomenclature.

TABLE 3.9A-7
(Sheet 1 of 1)

STRESS LIMITS FOR ASME SECTION III CLASS 1 (NB)
SEISMIC CATEGORY I COMPONENTS (ELASTIC ANALYSIS)

PRESSURE BOUNDARY-DESIGNED BY ANALYSIS

Condition of Design[1]	Reference Paragraph ASME III	Primary Stress Limits			Expansion Stress Limits Pe	Primary plus Secondary Stress Limits PL+Pb+Pe+Q	Peak Stress Limits PL+Pb+Pe+Q+F
		Pm	PL	PL+Pb			
Upset[2]	NB-3223	[4]	[4]	[4]	$3S_m$	$3S_m$	S_a
Emergency[2]	NB-3224	Greater of $1.2S_m$ or $1.0S_y$	Greater of $1.8S_m$ or $1.5S_y$	Greater of $1.8S_m$ or $1.5S_y$		Not required	Not required
Faulted[2,3]	NB-3225, NB-3221, App. F F 1323.1	Lesser of $2.4S_m$ or $0.7S_u$	Lesser of $3.6S_m$ or $1.05S_u$	Lesser of $3.6S_m$ or $1.05S_u$		Not required	Not required

(1) Since design loads are used in the actual analysis, only the conditions shown require evaluation.
(2) Use design loads.
(3) Use above limits for materials of Table I-1.2 (ASME Section III). Use 0.7S for materials of Table I-1.1 (ASME Section III).
(4) Primary stresses are evaluated and combined with secondary effects as appropriate.

NOTE: The nomenclature, conditions, and applications of the above allowables are in accordance with ASME Section III. Stress limits apply to design by elastic analysis. Limit and plastic analysis is allowed in accordance with ASME Section III criteria. Special stress limits of Paragraph NB-3227 apply as applicable.

TABLE 3.9A-8
(Sheet 1 of 2)

STRESS LIMITS FOR ASME SECTION III CLASS 2 AND 3 COMPONENTS (ELASTIC ANALYSIS)

Design Condition[1]	ASME III Code Class	Primary Stress Limits: Membrane (P_m)	Primary Stress Limits: Membrane + Bending ($P_m + P_b$)
Pressure Vessels			
I	2(NC-3300) or	1.1 S	1.65 S
II	3(ND-3300)	2.0 S	2.40 S
I[2]	2(NC-3200)	1.1 S_m	1.65 S_m
II[3]		2.0 S_m	2.40 S_m
Pumps Nonactive[4,5]			
I	2(NC-3400) or	1.1 S	1.65 S
II	3(ND-3400)	2.0 S	2.40 S
Pumps Active[4,5]			
I	2(NC-3400) or	1.0 S	1.50 S
II	3(ND-3400)	1.2 S	1.80 S
Valves Active and Nonactive[5,6]			
I	2(NC-3500) or	1.1 S	1.65 S
II	3(ND-3500)	2.0 S	2.40 S
Tanks (Steel)[5]			
I	2(NC38-3900) or	1.1 S	1.65 S
II	3(ND38-3900)	2.0 S	2.40 S

KEY: S = Allowable stress values at design temperature from ASME Section III, Appendix I, as allowed by class

S_m = Design stress intensity values at design temperature from ASME Section III, Appendix I, as allowed by class

(1) Refer to Table 3.9A-7 for the definitions of Design Conditions I and II.

(2) Fatigue analysis may be required with operating conditions; see Paragraph NC-3219 and Appendix XIV of ASME Section III.

TABLE 3.9A-8
(Sheet 2 of 2)

STRESS LIMITS FOR ASME SECTION III CLASS 2 AND 3 COMPONENTS (ELASTIC ANALYSIS)

(3) When a complete analysis is performed in accordance with Subparagraph NC-3211.1(c), the faulted stress limits of Appendix F apply.

(4) In accordance with Subarticles NC-3400 and ND-3400, any design method that has been demonstrated to be satisfactory for the specified design conditions may be used.

(5) Stress limits of ASME Section III, Subsection NF, are used for the design of supports as applicable (Table 3.9A-14).

(6) The standard or alternative design rules of Subarticles NC-3500 and ND-3500 may be used in conjunction with the stress limits specified.

Valve nozzle (piping load) stress analysis is not required when both the following conditions are satisfied by calculation:

a. Section modulus and area at the plane normal to the flow passage through the region at the valve body crotch is at least 110 percent of that for the piping connected (or joined) to the valve body inlet and outlet nozzles; and,
b. Code allowable stress, S, for valve body material, is equal to or greater than code allowable stress, S, of connected piping material. If valve body material allowable stress is less than that of the connected piping, the valve section modulus and area as calculated in Item a is multiplied by the ratio of the allowable stress for the pipe divided by the allowable stress of the valve.

The design by analysis procedure of Subparagraph NB-3545.2 is an acceptable alternative method if these requirements cannot be met. A casting quality factor of 1.0 is used.

Design requirements listed in this table are not applicable to stems, cast rings, or other nonpressure-retaining parts of valves which are contained within the confines of the body and bonnet.

TABLE 3.9A-9
(Sheet 1 of 1)

SUMMARY OF ACTIVE PUMPS
SWEC SCOPE OF SUPPLY)

Identification No.	System	Equipment	ASME Section III Code Class	Equipment Size (hp)	Manufacturer	Active Function
2SWP*P1A-F	Service water	Service water pumps	3	600	Goulds Pumps, Inc.	To provide cooling water to all safety-related components
2SWP*P2A&B	Service water	Condensing water pumps	3	10	Goulds Pumps, Inc.	To maintain service water inlet temperature to the control and relay room chiller
2SFC*P1A&B	Spent fuel pool cooling and cleanup	Spent fuel pool cooling and cleanup pumps	3	450	Goulds Pumps, Inc.	To provide cooling water for the spent fuel pool
2HVK*P1A&B	Control building chilled water	Chilled water pumps	3	15	Goulds Pumps, Inc.	To provide cooling water to safety-related coolers in the control building
2EGF*P1A-D 2EGF*P2A&B	Standby diesel generator fuel oil	Transfer pumps	3	1.5	Crane Co., Deming Div. (industrial pumps)	To transfer diesel fuel from storage tanks to day tanks

TABLE 3.9A-10
(Sheet 1 of 4)

SUMMARY OF SEISMIC STRESS ANALYSIS RESULTS[1]

Components		Service Water Pumps (2SWP*P1A,B,C,D,E,F)		Spent Fuel Pumps (2SFC*P1A,B)	
		Actual	Allowable	Actual	Allowable
Motor holddown bolt stress	- shear, psi	2,503	15,000	6,558	10,000
	- tensile, psi	5,567	40,000	7,815	17,507
Pump holddown bolt stress	- shear, psi	14,101	15,390[2]	12,271	12,320
	- tensile, psi	30,711	40,500[2]	27,675	30,366
Anchor bolt stress	- shear, psi	6,792	12,500	18,551	18,900
	- tensile, psi	7,065	25,000	17,758	45,150
Shaft stress, psi		20,153	26,250	16,789	26,250
Frame stress, psi		19,125	21,600		
Thrust retainer bolt stress	- tensile, psi	3,251	21,960	2,284	20,000
Pump bearing bolt stress	- shear, psi	2,450	10,800	2,267	10,000
	- tensile, psi	6,332	21,960	4,894	20,000
Pump pedestal stress, psi		10,838	21,600	3,479	21,600
Nozzle stress	- discharge, psi	15,209	26,250	8,634	20,400
	- suction, psi	2,180	26,250	4,291	20,400
Nozzle flange stress	- discharge, psi	21,841	26,250	18,493	20,400
	- suction, psi	17,095	26,250	20,296	20,400
Pedestal weld stress, psi		3,989	10,800	4,870	10,800
Pump bearing load	- inboard, lb	54	200	104	200
	- outboard, lb	11,410	38,123	7,930	25,943
Flexible coupling misalignment, radians		0.0007	0.0178	0.00043	0.017
Impeller key stress	- shear, psi	4,042	10,500	2,624	10,500
Impeller relative deflection, in		0.005	0.007	0.005	0.0105

TABLE 3.9A-10
(Sheet 2 of 4)

SUMMARY OF SEISMIC STRESS ANALYSIS RESULTS[1]

Components		Chilled Water Pumps (2HVK*P1A,B)		Condensing Water Pumps (2SWP*P2A,B)	
		Actual	Allowable	Actual	Allowable
Motor holddown bolts stress	- shear, psi	1,726[5]	10,000	8,521	10,000
	- tensile, psi	3,447	20,000	13,754	14,366
Pump holddown bolts stress	- shear, psi	12,336	16,800	10,794	16,800
	- tensile, psi	24,551	45,150	43,702	46,200
Anchor bolt stress	- shear, psi	6,475	10,000	2,830	10,000
	- tensile, psi	14,224	17,640	4,468	20,000
Shaft stress, psi		6,760	17,500	5,917	17,500
Frame stress, psi		5,868	21,600	5,043	21,600
Thrust retainer bolt stress, psi		390	20,000	816	20,000
Upper pump frame bolt stress	- shear, psi	14,714	22,800	5,205	10,000
	- tensile, psi	81	55,200	2,019	19,672
Lower pump frame bolt stress	- shear, psi	61	10,000	2,213	10,000
	- tensile, psi	9,505	20,000	7,113	20,000
Stuffing box cover bolt stress	- tensile, psi	8,636	25,000	-	-
Stuffing box cover flange stress, psi		19,915	21,000	-	-
Maximum nozzle stress	- discharge, psi	6,456	21,000	9,159	20,640
	- suction, psi	15,586	21,000	16,603	20,640
Nozzle flange stress	- discharge, psi	14,926	21,000	10,335	20,640
	- suction, psi	18,493	21,000	16,176	20,640
Adapter/frame bolting stress	- tensile, psi	-	-	16,050	20,000
Pump bearing loads	- inboard, lb	450	10,688	480	9,104
	- outboard, lb	1,342	17,865	2,594	15,037
Frame adapter bolt stress, psi		-	-	14,291	15,000
Frame adapter flange stress, psi		-	-	14,508	21,000
Frame/stuffing box bolt stress, psi		18,528	46,200	-	-

TABLE 3.9A-10
(Sheet 3 of 4)

SUMMARY OF SEISMIC STRESS ANALYSIS RESULTS[1]

Components	Chilled Water Pumps (2HVK*P1A,B)		Condensing Water Pumps (2SWP*P2A,B)		Standby Diesel Generator Fuel Oil Transfer Pump (2EGF*P1A,B,C,D, 2EGF*P2A,B)	
	Actual	Allowable	Actual	Allowable	Actual	Allowable
Flexible coupling misalignment, radians	0.0008	0.017	0.006	0.017		
Impeller connection stress - tensile, psi - shear, psi	863 1,933	17,500 8,750	2,438 2,368	17,500 8,750		
Impeller relative deflection, in	0.0052	0.010	0.0065	0.012		
Maximum column stress, psi					19,250	22,500
Maximum column flange stress, psi bolt stress, psi					17,295 29,946	26,250 45,000
Maximum pump casing stress, psi					11,061	21,000
Maximum shaft stress, psi					16,515	17,500
Motor holddown bolt stress, psi - tensile - shear					 2,427 782.5	 20,000 10,000
Shaft key stress, psi					705.6	10,000
Shaft deflection, in					0.0279	0.05
Impeller deflection (clearance), in					0.000093	0.015
Nozzle stress, psi					17,257	21,000
Nozzle flange stress, psi bolt stress, psi					25,671 33,319	26,250 62,500
Support plate/cover bolt stress, psi - tensile - shear					 2,531 2,397	 22,500 9,300
Discharge head holddown bolts, psi - tensile - shear					 25,587 1,607	 40,000 12,320
Discharge head stress, psi					4,711	21,000

TABLE 3.9A-10
(Sheet 4 of 4)

SUMMARY OF SEISMIC STRESS ANALYSIS RESULTS[1]

Components	Chilled Water Pumps (2HVK*P1A,B)		Condensing Water Pumps (2SWP*P2A,B)		Standby Diesel Generator Fuel Oil Transfer Pump (2EGF*P1A,B,C,D, 2EGF*P2A,B)	
	Actual	Allowable	Actual	Allowable	Actual	Allowable
Motor adapter bolts, psi - tensile					5,696	20,000
- shear					1,211	10,000

(1) Values given represent the SSE + maximum nozzle + normal actual values compared to the normal (OBE) allowables.
(2) Both OBE and SSE allowables were used when calculating the pump holddown bolt interaction factors.
(3) Not applicable for this pump.
(4) Deleted.
(5) The installation of shear block to motor skid removes shear loading from the bolt. The value shown does not consider the addition of shear block and envelopes both the with and without shear block conditions.

TABLE 3.9A-11
(Sheet 1 of 1)

THIS TABLE HAS BEEN DELETED

TABLE 3.9A-12
(Sheet 1 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Reactor Plant Component Cooling (CCP)	2CCP*MOV14A,B	12	Gate	150	3	1	SMB-0-25(1)	63
	2CCP*MOV15A,B	4	Gate	150	2	1	SMB-000-5(1)	9
	2CCP*MOV16A,B	4	Gate	150	2	1	SMB-000-5(1)	9
	2CCP*MOV17A,B	4	Gate	150	2	1	SMB-000-5(1)	9
	2CCP*MOV18A,B	12	Gate	150	3	1	SMB-0-25(1)	63
	2CCP*MOV122	8	Gate	150	2	1	SMB-00-15(1)	9
	2CCP*MOV124	8	Gate	150	2	1	SMB-00-15(1)	9
	2CCP*MOV265	8	Gate	150	2	1	SMB-00-15(1)	9
	2CCP*MOV273	8	Gate	150	2	1	SMB-00-15(1)	9
	2CCP*RV64A,B	2 x 3	SRV	150/150	3	8	None	4
	2CCP*RV170	3/4 x 1	SRV	300/150	2	8	None	4
	2CCP*RV171	3/4 x 1	SRV	300/150	2	8	None	4
	2CCP*MOV94A,B	4	Gate	150	2	1	SMB-000-5(1)	9
	2CCP*AOV37A	1 1/2	Plug	150	3	4	NCB520-SR80(2)	64
	2CCP*AOV37B	2	Plug	150	3	4	NCB725-SR80(2)	64
	2CCP*AOV38A	1 1/2	Plug	150	3	4	NCB520-SR80(2)	64
	2CCP*AOV38B	2	Plug	150	3	4	NCB725-SR80(2)	64
	2CCP*V996, 997, 998, 999	4	Check	150	3	17	None	84
	2CCP*RV1019A, 1020A, 1021A, 1022A	3/4 x 1	SRV	150/150	2	8	None	56,9
Containment Atmosphere Monitoring (CMS)	2CMS*SOV23A-F	3/4	Globe	1500	2	6	76P-001(7)	18
	2CMS*SOV24A-D	3/4	Globe	1500	2	6	76P-001(7)	16,83
	2CMS*SOV26A-D	3/4	Globe	1500	2	6	76P-001(7)	16,83
	2CMS*SOV32A,B	3/4	Globe	1500	2	6	76P-002(7)	16,83
	2CMS*SOV33A,B	3/4	Globe	1500	2	6	76P-002(7)	16,83
	2CMS*SOV34A,B	3/4	Globe	1500	2	6	76P-002(7)	16,83
	2CMS*SOV35A,B	3/4	Globe	1500	2	6	76P-002(7)	16,83
	2CMS*SOV60A,B	3/4	Globe	1500	2	6	76P-001(7)	16
	2CMS*SOV61A,B	3/4	Globe	1500	2	6	76P-002(7)	16
	2CMS*SOV62A,B	3/4	Globe	1500	2	6	76P-002(7)	16
	2CMS*SOV63A,B	3/4	Globe	1500	2	6	76P-002(7)	16
	2CMS*SOV64A,B	3/4	Globe	1500	2	6	76P-001(7)	62
	2CMS*SOV65A,B	3/4	Globe	1500	2	6	76P-001(7)	62
	2CMS*EFV1A,B	3/4	Check	45	2	13	None	16
	2CMS*EFV3A,B	3/4	Check	45	2	13	None	16
	2CMS*EFV5A,B	3/4	Check	45	2	13	None	16
	2CMS*EFV6	3/4	Check	45	2	13	None	16

TABLE 3.9A-12
(Sheet 2 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Containment Atmosphere Monitoring (CMS) (cont'd.)	2CMS*EFV8A,B	3/4	Check	45	2	13	None	16
	2CMS*EFV9A,B	3/4	Check	45	2	13	None	16
	2CMS*EFV10	3/4	Check	45	2	13	None	16
Primary Containment Purge (CPS)	2CPS*AOV104	14	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV105	12	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV106	14	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV107	12	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV108	14	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV109	12	Butterfly	150	2	21	NG3012-SR4(CW)-M3(2)	9
	2CPS*AOV110	14	Butterfly	150	2	2	N721C-SR80-M3HW(2)	9
	2CPS*AOV111	12	Butterfly	150	2	21	NG3012-SR4(CW)-M3(2)	9
	2CPS*SOV119	2	Globe	1500	2	6	76P-020(7)	9
	2CPS*SOV120	2	Globe	1500	2	6	76P-027(7)	9
	2CPS*SOV121	2	Globe	1500	2	6	76P-020(7)	9
	2CPS*SOV122	2	Globe	1500	2	6	76P-027(7)	9
	2CPS*SOV132	1	Globe	1500	2	6	76P-035(7)	9
	2CPS*V50	1 1/2	Check	600	2	1	None	9
High Pressure Core Spray (CSH)	2CSH*V7	4	Check	150	2	1	None	78
	2CSH*V16	20	Check	150	2	1	None	77,78,30
	2CSH*V108	12	Check	900	1	3	None	9,16
	2CSH*RV113	3/4 x 1	SRV	150/150	2	8	None	4,56
	2CSH*RV114	3/4 x 1	SRV	150/150	2	8	None	4,56
	2CSH*V9	16	Check	900	2	3	None	23
	2CSH*V17	3	Check	900	2	1	None	30
	2CSH*V55	3	Check	900	2	1	None	30
	2CSH*V59	14	Check	150	2	1	None	22
	2CSH*EFV1	2	Check	100	2	13	None	9,16
	2CSH*EFV2	2	Check	100	2	13	None	9,16
	2CSH*EFV3	3/4	Check	1575	2	13	None	9,16
Low Pressure Core Spray (CSL)	2CSL*V101	12	Check	900	1	3		9,16
	2CSL*FV114	10	Globe	300	3	5	SMB-00-5(1)	27
	2CSL*MOV104	12	Gate	600	1	1	SB-2-60(1)	28
	2CSL*MOV107	4	Gate	300	2	1	SMB-00S-15(1)	31
	2CSL*MOV112	20	Butterfly	150	2	9	SMB-0-10/H4BC(1)	32
	2CSL*RV105	1 1/2 x 2	SRV	300/150	2	8	None	4,9,56
	2CSL*RV123	3/4 x 1	SRV	150/150	2	8	None	4,9,56

TABLE 3.9A-12
(Sheet 3 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Low Pressure Core Spray (CSL) (cont'd.)	2CSL*V4	16	Check	300	2	1	None	74
	2CSL*V14	2	Check	600	2	1	None	30
	2CSL*EFV1	3/4	Check	1250	2	13	None	16
	2CSL*V9	12	Check	150	2	1	None	22,78
	2CSL*V21	2	Check	600	2	1	None	22
Reactor Building Equipment Drains (DER)	2DER*MOV119	4	Gate	150	2	1	SMB-000-5(1)	9
	2DER*MOV120	4	Gate	150	2	1	SMB-000-5(1)	9
	2DER*MOV130	2	Globe	1500	2	1	SMB-000-5(1)	9
	2DER*MOV131	2	Globe	1500	2	1	SMB-000-5(1)	9
	2DER*EFV31	3/4	Check	1250	2	13	None	16
	2DER*RV344	3/4 x 1	SRV	150/150	2	8	None	56,9
Reactor Building Floor Drains (DFR)	2DFR*MOV120	6	Gate	150	2	1	SMB-00-10(1)	17
	2DFR*MOV121	6	Gate	150	2	1	SMB-00-10(1)	17
	2DFR*MOV139	3	Gate	150	2	1	SMB-000-5(1)	17
	2DFR*MOV140	3	Gate	150	2	1	SMB-000-5(1)	17
	2DFR*RV228	3/4 x 1	SRV	150/150	2	8	None	56,9
Standby Diesel Generator Air Startup (EGA)	2EGA*RV125	30	SRV	150	3	10	None	56
	2EGA*RV126	30	SRV	150	3	10	None	56
	2EGA*RV127	22	SRV	150	3	10	None	56
Feedwater (FWS)	2FWS*V23A,B	24	Check	900	1	3	None	9
	2FWS*MOV21A,B	24	Gate	900	1	1	SMB-4-200(1)	17
	2FWS*V12A,B	24	Check	900	1	3	None	9
Standby Diesel Generator Fuel (EGF)	2EGF*V12	1	Check	600	3	1	None	22,88,78
	2EGF*V13	1	Check	600	3	1	None	22,88,78
	2EGF*V32	1	Check	600	3	1	None	22,88,78
	2EGF*V33	1	Check	600	3	1	None	22,88,78
	2EGF*V52	1	Check	600	3	1	None	22,88,78
	2EGF*V53	1	Check	600	3	1	None	22,88,78
Nitrogen Tanks (GSN)	2GSN*V70A,B	1	Check	600	3	18	None	22,75
	2GSN*V75A,B	1	Check	600	3	1	None	76
Standby Gas Treatment (GTS)	2GTS*MOV1A,B	20	Butterfly	150	2	9	SMB-00-10/H3BC(1)	10
	2GTS*AOV2A	20	Butterfly	150	2	9	85430(3)	11
	2GTS*AOV3A	20	Butterfly	150	2	9	85430(3)	11
	2GTS*MOV4A,B	8	Gate	150	2	1	SMB-00-15(1)	11
	2GTS*AOV28A	8	Butterfly	150	2	9	86040(3)	12

TABLE 3.9A-12
(Sheet 4 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Standby Gas Treatment (GTS) (cont'd.)	2GTS*PV5A	14	Butterfly	150	2	9	86060(3)	13
	2GTS*AOV2B	20	Butterfly	150	2	9	NT420-SR3(2)	11
	2GTS*AOV3B	20	Butterfly	150	2	9	NT420-SR3(2)	11
	2GTS*AOV28B	8	Butterfly	150	2	9	NHD732-SR60(2)	12
	2GTS*PV5B	14	Butterfly	150	2	9	NHD732(2)	13
	2GTS*V68B	3/4	Check	2735	1	3	None	22
	2GTS*V74B	1	Check	2735	1	3	None	78
	2GTS*RV78B	1x2	Relief	600x150	3	8	None	4
Hydrogen Recombiner (HCS)	2HCS*MOV1A,B	3	Gate	150	2	15	SMB-00-10(1)	3,9
	2HCS*MOV2A,B	3	Globe	150	2	1	SMB-000-5(1)	3,9
	2HCS*MOV3A,B	3	Gate	150	2	15	SMB-00-10(1)	3,9
	2HCS*MOV4A,B	3	Gate	150	2	15	SMB-000-5(1)	3,9
	2HCS*MOV5A,B	3	Globe	150	2	1	SMB-000-5(1)	3,9
	2HCS*MOV6A,B	3	Gate	150	2	15	SMB-000-5(1)	3,9
	2HCS*MOV25A,B	3	Globe	1500	2	18	SMB-000-2(1)	3
	2HCS*MOV26A,B	3/4	Globe	1500	2	18	SMB-000-2(1)	3
	2HCS*SOV10A,B	1	Globe	1500	2	6	76P-024(7)	3
	2HCS*SOV11A,B	1	Globe	1500	2	6	76P-024(7)	3
Control Building Air Conditioner (HVC)	2HVC*MOV1A,B	18	Butterfly	150	3	2	SMB-000-2/H1BC(1)	8
Control Building Chilled Water (HVK)	2HVK*RV1,2	3/4 x 1	SRV	150/150	4	8	None	4,97
	2HVK*SOV36A,B	3	Globe	1500	3	6	76P-034(7)	5
	2HVK*TV21A,B	4	Globe	150	3	5	(12)	6
	2HVK*TV22A,B	4	Globe	150	3	5	(12)	7
Instrument Air (IAS)	2IAS*V448	1 1/2	Check	600	3	1	None	16,22,59
	2IAS*V449	1 1/2	Check	600	3	1	None	16,22,59
	2IAS*SOV164	1 1/2	Globe	1500	2	6	76P-019(7)	16,59
	2IAS*SOV165	1 1/2	Globe	1500	2	6	76P-019(7)	16,59
	2IAS*SOV166	1 1/2	Globe	1500	2	6	76P-019(7)	16
	2IAS*SOV167	1 1/2	Globe	1500	2	6	76P-019(7)	16
	2IAS*SOV168	1 1/2	Globe	1500	2	6	76P-019(7)	16
	2IAS*SOV180	1 1/2	Globe	1500	2	6	76P-019(7)	16
	2IAS*SOV184	1 1/2	Globe	1500	2	6	76P-019(7)	16
	2IAS*SOV185	1 1/2	Globe	1500	2	6	76P-019-1(7)	16
	2IAS*SV19A,B	3/4 x 1	SRV	600/150	3	8	None	56,59
	2IAS*SV20A,B	3/4 x 1	SRV	150/150	3	8	None	56,59
	2IAS*SOVY181	3/4	Globe	1500	3	6	76P-036	59

TABLE 3.9A-12
(Sheet 5 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Instrument Air (IAS) (cont'd.)	2IAS*SOVY186	3/4	Globe	1500	3	6	76P-036	59
	2IAS*SOVX181	1 1/2	Globe	1500	3	6	76P-037	59
	2IAS*SOVX186	1 1/2	Globe	1500	3	6	76P-037	59
	2IAS*V571	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V471	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V421	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V431	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V526	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V546	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*V581	1 1/4	Check	600	3	1	None	22,59,78
	2IAS*EFV200	3/4	Check	350	2	13	None	59,60
	2IAS*EFV201	3/4	Check	350	2	13	None	59,60
	2IAS*EFV202	3/4	Check	350	2	13	None	59,60
	2IAS*EFV203	3/4	Check	350	2	13	None	59,60
	2IAS*EFV204	3/4	Check	350	2	13	None	59,60
	2IAS*EFV205	3/4	Check	350	2	13	None	59,60
	2IAS*EFV206	3/4	Check	350	2	13	None	59,60
Reactor Core Isolation Cooling (ICS)	2ICS*AOV109	2	Globe	150	2	5	None	38
	2ICS*AOV110	2	Globe	150	2	5	None	38
	2ICS*AOV130	2	Globe	900	2	5	None	38
	2ICS*AOV131	2	Globe	900	2	5	None	38
	2ICS*V156	6	Check	900	1	4	None	40
	2ICS*V157	6	Check	900	1	4	None	40
	2ICS*MOV116	2	Globe	1500	2	1	SMB-00-5(1)	42
	2ICS*MOV120	4	Globe	900	2	3	SMB-0-25(1)	43
	2ICS*MOV121	10	Gate	900	1	1	SB-2-60(1)	17,94
	2ICS*MOV122	12	Gate	150	2	1	SMB-0-25(1)	44
	2ICS*MOV124	4	Gate	900	2	1	SB-00-10(1)	41
	2ICS*MOV126	6	Gate	900	1	1	SMB-1-60(1)	9,87
	2ICS*MOV128	10	Gate	900	1	1	SB-2-60(1)	17,94
	2ICS*MOV129	6	Gate	150	2	1	SMB-00-10(1)	46
	2ICS*MOV136	6	Gate	150	2	1	SMB-00-10(1)	47,16
	2ICS*MOV143	2	Globe	1500	2	1	SMB-00-5(1)	31
	2ICS*MOV148	1 1/2	Globe	1500	2	1	SMB-000-2(1)	16,48
	2ICS*MOV164	1 1/2	Globe	1500	2	1	SMB-000-2(1)	16,48
	2ICS*MOV170	1	Globe	1500	2	1	SMB-000-2(1)	9
	2ICS*RV112	3/4 x 1	SRV	150/150	2	8	None	4
	2ICS*RV114	3/4 x 1	SRV	150	2	8	None	4
	2ICS*V28	6	Check	150	2	1	None	82,78,22
	2ICS*V29	12	Check	150	2	1	None	80,78
	2ICS*V38	2	Check	1500	2	1	None	78

TABLE 3.9A-12
(Sheet 6 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Reactor Core Isolation Cooling (ICS) (cont'd.)	2ICS*V39	1 1/2	Check	600	2	1	None	22,48,78
	2ICS*V40	1 1/2	Check	600	2	1	None	22,48,78
	2ICS*V249	6	Check	150	2	1	None	22
	2ICS*PCV115	2	Globe	900	2	5/19	(10)	42
	2ICS*EFV1	3/4	Check	1250	2	13	None	9
	2ICS*EFV2	3/4	Check	1250	2	13	None	9
	2ICS*EFV3	3/4	Check	1250	2	13	None	9
	2ICS*EFV4	3/4	Check	1250	2	13	None	9
	2ICS*EFV5	3/4	Check	1250	2	13	None	9
Reactor Vessel Instrumentation (ISC)	2ISC*RV33A,B	24	Vac Brkr	150	2	10	(4)	1
	2ISC*RV34A,B	24	Vac Brkr	150	2	10	(4)	1
	2ISC*RV35A,B	24	Vac Brkr	150	2	10	(4)	1
	2ISC*RV36A,B	24	Vac Brkr	150	2	10	(4)	1
	2ISC*EFV1	3/4	Check	1250	2	13	None	60
	2ISC*EFV2	3/4	Check	1250	2	13	None	60
	2ISC*EFV3	3/4	Check	1250	2	13	None	60
	2ISC*EFV4	3/4	Check	1250	2	13	None	60
	2ISC*EFV5	3/4	Check	1250	2	13	None	60
	2ISC*EFV6	3/4	Check	1250	2	13	None	60
	2ISC*EFV7	3/4	Check	1250	2	13	None	60
	2ISC*EFV8	3/4	Check	1250	2	13	None	60
	2ISC*EFV9	3/4	Check	1250	2	13	None	60
	2ISC*EFV10	3/4	Check	1250	2	13	None	60
	2ISC*EFV11	3/4	Check	1250	2	13	None	60
	2ISC*EFV12	3/4	Check	1250	2	13	None	60
	2ISC*EFV13	3/4	Check	1250	2	13	None	60
	2ISC*EFV14	3/4	Check	1250	2	13	None	60
	2ISC*EFV15	3/4	Check	1250	2	13	None	60
	2ISC*EFV16	3/4	Check	1250	2	13	None	60
	2ISC*EFV17	3/4	Check	1250	2	13	None	60
	2ISC*EFV18	3/4	Check	1250	2	13	None	60
	2ISC*EFV19	3/4	Check	1250	2	13	None	60
	2ISC*EFV20	3/4	Check	1250	2	13	None	60
	2ISC*EFV21	3/4	Check	1250	2	13	None	60
	2ISC*EFV22	3/4	Check	1250	2	13	None	60
	2ISC*EFV23	3/4	Check	1250	2	13	None	60
	2ISC*EFV24	3/4	Check	1250	2	13	None	60
	2ISC*EFV25	3/4	Check	1250	2	13	None	60
	2ISC*EFV26	3/4	Check	1250	2	13	None	60
	2ISC*EFV27	3/4	Check	1250	2	13	None	60
	2ISC*EFV28	3/4	Check	1250	2	13	None	60

TABLE 3.9A-12
(Sheet 7 of 16)

ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Reactor Vessel Instrumentation (ISC) (cont'd.)	2ISC*EFV29	3/4	Check	1250	2	13	None	60
	2ISC*EFV30	3/4	Check	1250	2	13	None	60
	2ISC*EFV31	3/4	Check	1250	2	13	None	60
	2ISC*EFV32	3/4	Check	1250	2	13	None	60
	2ISC*EFV33	3/4	Check	1250	2	13	None	60
	2ISC*EFV34	3/4	Check	1250	2	13	None	60
	2ISC*EFV35	3/4	Check	1250	2	13	None	60
	2ISC*EFV36	3/4	Check	1250	2	13	None	60
	2ISC*EFV37	3/4	Check	1250	2	13	None	60
	2ISC*EFV38	3/4	Check	1250	2	13	None	60
	2ISC*EFV39	3/4	Check	1250	2	13	None	60
	2ISC*EFV40	3/4	Check	1250	2	13	None	60
	2ISC*EFV41	3/4	Check	1250	2	13	None	60
	2ISC*EFV42	3/4	Check	1250	2	13	None	60
Containment Leakage Monitoring (LMS)	2LMS*SOV152	3/4	Globe	1500	2	6	76P-001(7)	16
	2LMS*SOV153	3/4	Globe	1500	2	6	76P-001(7)	16
	2LMS*SOV157	3/4	Globe	1500	2	6	76P-001(7)	16
	2LMS*SOV156	3/4	Globe	1500	2	6	76P-001(7)	16
Main Steam System (MSS)	2MSS*MOV111	6	Globe	600	1	1	SMB-2-25(1)	8,9,16
	2MSS*MOV112	6	Globe	600	1	1	SMB-2-25(1)	8,9,16,45
	2MSS*MOV208	2	Globe	1500	1	1	SMB-000-5(1)	16,8,9
	2MSS*PSV120	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV121	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV122	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV123	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV124	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV125	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV126	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV127	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV128	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV129	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV130	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV131	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV132	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV133	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV134	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*PSV135	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV136	8 x 10	SRV	1500/300	1	14	None	56
	2MSS*PSV137	8 x 10	SRV	1500/300	1	14	None	56,59
	2MSS*EFV1A-D	3/4	Check	1250	2	13	None	60,16

TABLE 3.9A-12
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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Main Steam System (MSS) (cont'd.)	2MSS*EFV2A-D	3/4	Check	1250	2	13	None	60,16
	2MSS*EFV3A-D	3/4	Check	1250	2	13	None	60,16
	2MSS*EFV4A-D	3/4	Check	1250	2	13	None	60,16
Reactor Coolant Recirculation (RCS)	2RCS*SOV68A,B	3/4	Globe	2500	2	6	76P-040(7)	9
	2RCS*SOV65A,B	2	Globe	1500	2	6	76P-038(7)	9
	2RCS*SOV66A,B	1	Globe	2500	2	6	76P-039(7)	9
	2RCS*SOV67A,B	2	Globe	1500	2	6	76P-038(7)	9
	2RCS*SOV79A,B	2	Globe	1500	2	6	76P-038(7)	9
	2RCS*SOV80A,B	1	Globe	2500	2	6	76P-039(7)	9
	2RCS*SOV81A,B	2	Globe	1500	2	6	76P-038(7)	9
	2RCS*SOV82A,B	3/4	Globe	2500	2	6	76P-040(7)	9
	2RCS*SOV104	3/4	Globe	1500	2	20	V526-5688-19(11)	9
	2RSC*SOV105	3/4	Globe	1500	2	20	V526-5688-19(11)	9
	2RCS*V59A,B	3/4	Check	1500	2	1	None	9
	2RCS*V60A,B	3/4	Check	1500	2	1	None	9
	2RCS*V90A,B	3/4	Check	1500	2	1	None	9
	2RCS*EFV44A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV45A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV46A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV47A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV48A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV52A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV53A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV62A,B	3/4	Check	1250	2	13	None	16
	2RCS*EFV63A,B	3/4	Check	1250	2	13	None	16
Residual Heat Removal (RHS)	2RHS*MOV1A,B	24	Butterfly	300	2	9	SMB-2-60(1)	16,49,52, 53,55
	2RHS*MOV1C	24	Butterfly	300	2	9	SMB-0-25(1)	16,49
	2RHS*MOV2A,B	18	Butterfly	300	2	9	SMB-0-25(1)	50,52
	2RHS*MOV9A,B	18	Butterfly	300	2	2	SMB-00-10(1)	50,53,55
	2RHS*V3	18	Check	300	2	1	None	49,50,53, 55,78
	2RHS*V16A,B,C	12	Check	900	1	3	None	40
	2RHS*V39A,B	12	Check	900	1	3	None	50,16
	2RHS*AOV126	3/4	Ball	150	3	17	NCB315-SR80(2)	51,52
	2RHS*AOV150	16	Check	300	2	3	4-A-FFX-8-3/4-Y(5)	51
	2RHS*FV38A,B	14	Globe	300	2	5	SMB-00-5(1)	52,53
	2RHS*FV38C	14	Globe	300	2	5	SMB-00-5(1)	52
	2RHS*MOV4A-C	6	Gate	300	2	1	SMB-00S-15(1)	54,52

TABLE 3.9A-12
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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Residual Heat Removal (RHS) (cont'd.)	2RHS*MOV15A,B	16	Gate	300	2	1	SMB-2-80(1)	52,55,16
	2RHS*MOV24A,B,C	12	Gate	900	1	1	SMB-3-100(1)	49,52,16
	2RHS*MOV25A,B	16	Gate	300	2	1	SMB-2-80(1)	52,55,16
	2RHS*MOV26A,B	1	Globe	1500	2	1	SMB-000-2(1)	52,16
	2RHS*MOV27A,B	1	Globe	1500	2	1	SMB-000-2(1)	52,16
	2RHS*MOV30A,B	18	Butterfly	300	2	9	SMBO-25/H4BC(1)	53,54,16
	2RHS*MOV8A,B	18	Butterfly	300	2	9	SMB-1-25/H5BC(1)	49,50,52
	2RHS*V60	2	Check	600	2		None	22
	2RHS*V143	6	Check	900	1	1	None	50,78
	2RHS*MOV33A,B	4	Globe	300	2	1	SMB-000-5(1)	52,55,16
	2RHS*MOV37A,B	4	Globe	300	2	1	SMB-000-5(1)	52
	2RHS*MOV40A,B	12	Globe	900	1	1	SMB-3-80(1)	50,52,16, 95
	2RHS*MOV67A,B	2	Globe	1500	1	1	SMB-000-5(1)	16
	2RHS*MOV104	6	Globe	900	1	1	SMB-0-10(1)	50,52,16
	2RHS*MOV112(1)	20	Gate	900	1	1	SB-3-150(1)	16
	2RHS*MOV113(1)	20	Gate	900	1	1	SB-3-150(1)	16
	2RHS*MOV115	16	Gate	300	2	1	SMB-0-25(1)	51,89
	2RHS*MOV116	16	Gate	150	3	1	SMB-0-25(1)	51,89
	2RHS*MOV142(1)	3	Globe	300	2	1	SMB-000-5(1)	52
	2RHS*MOV149(1)	3	Gate	300	2	1	SMB-000-5(1)	52
	2RHS*RV20A-C	3/4 x 1	SRV	300/150	2	8	None	56
	2RHS*RV110	3/4 x 1	SRV	300/150	2	8	None	56
	2RHS*RV152	3/4 x 1	SRV	900/150	1	8	None	56
	2RHS*SOV35A,B	3/4	Globe	1500	2	6	76P-032(7)	52,34
	2RHS*SOV36A,B	3/4	Globe	1500	2	6	76P-030(7)	52,34
	2RHS*RVV35A,B	10	Vac Brkr	150	2	10	None	57
	2RHS*RVV36A,B	10	Vac Brkr	150	2	10	None	57
	2RHS*MOV12A	18	Butterfly	300	2	2	SMB-00-10(1)	50,53,55

TABLE 3.9A-12
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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Residual Heat Removal (RHS) (cont'd.)	2RHS*MOV12B	18	Butterfly	300	2	2	SMB-00-10(1)	50,51,53, 55
	2RHS*V17	2	Stop Chk	600	2	1	None	22
	2RHS*V47	2	Stop Chk	600	2	1	None	22
	2RHS*V61	2	Stop Chk	600	2	1	None	22
	2RHS*V18	2	Check	600	2	1	None	22
	2RHS*V48	2	Check	600	2	1	None	22
	2RHS*V1	18	Check	300	2	1	None	49,50,53, 55
	2RHS*V2	18	Check	300	2	1	None	49,50,53, 55
	2RHS*EFV5	3/4	Check	1250	2	13	None	16
	2RHS*EFV6	3/4	Check	1250	2	13	None	16
	2RHS*EFV7	3/4	Check	1250	2	13	None	16
	2RHS*RV57A,B	3/4 x 1	SRV	300/300	2	8	None	4
Spent Fuel Pool Cooling and Cleanup (SFC)	2SFC*AOV153	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	45
	2SFC*AOV154	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	45
	2SFC*AOV19A,B	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	45
	2SFC*HV6A,B	10	Butterfly	150	3	2	N721C-SR80-M3HW(2)	35
	2SFC*HV17A,B	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	36
	2SFC*HV18A,B	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	35,36
	2SFC*HV37A,B	8	Butterfly	300	3	2	N721C-SR80-M3HW(2)	35
	2SFC*V11	8	Check	150	3	1	None	78
	2SFC*V20A,B	8	Check	300	3	1	None	22,78
	2SFC*V9	8	Check	150	3	1	None	78
Standby Liquid Control System (SLS)	2SLS*MOV1A,B	3	Globe	150	2	1	SB-00-5(1)	66
	2SLS*MOV5A,B	2	Stop Chk	1600	1	1	SMB-00-10(1)	66,16
	2SLS*RV2A,B	3/4 x 1	SRV	1600/150	2	8	None	56
	2SLS*V10	2	Check	1600	1	1	None	16,22,78
	2SLS*V12	1 1/2	Check	1600	2	1	None	66,78,22
	2SLS*V14	1 1/2	Check	1600	2	1	None	66,78,22
Main Steam Safety/ Relief Valves, Vents and Drains (SVV)	2SVV*RVV101	10	Check	600	3	10	None	21
	2SVV*RVV102	10	Check	600	3	10	None	21
	2SVV*RVV103	10	Check	600	3	10	None	21
	2SVV*RVV104	10	Check	600	3	10	None	21
	2SVV*RVV105	10	Check	600	3	10	None	21
	2SVV*RVV106	10	Check	600	3	10	None	21
	2SVV*RVV107	10	Check	600	3	10	None	21
	2SVV*RVV108	10	Check	600	3	10	None	21

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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Main Steam Safety/ Relief Valves, Vents and Drains (SVV) (cont'd.)	2SVV*RVV109	10	Check	600	3	10	None	21
	2SVV*RVV110	10	Check	600	3	10	None	21
	2SVV*RVV111	10	Check	600	3	10	None	21
	2SVV*RVV112	10	Check	600	3	10	None	21
	2SVV*RVV113	10	Check	600	3	10	None	21
	2SVV*RVV114	10	Check	600	3	10	None	21
	2SVV*RVV115	10	Check	600	3	10	None	21
	2SVV*RVV116	10	Check	600	3	10	None	21
	2SVV*RVV117	10	Check	600	3	10	None	21
	2SVV*RVV118	10	Check	600	3	10	None	21
	2SVV*RVV201	10	Check	600	3	10	None	21
	2SVV*RVV202	10	Check	600	3	10	None	21
	2SVV*RVV203	10	Check	600	3	10	None	21
	2SVV*RVV204	10	Check	600	3	10	None	21
	2SVV*RVV205	10	Check	600	3	10	None	21
	2SVV*RVV206	10	Check	600	3	10	None	21
	2SVV*RVV207	10	Check	600	3	10	None	21
	2SVV*RVV208	10	Check	600	3	10	None	21
	2SVV*RVV209	10	Check	600	3	10	None	21
	2SVV*RVV210	10	Check	600	3	10	None	21
	2SVV*RVV211	10	Check	600	3	10	None	21
	2SVV*RVV212	10	Check	600	3	10	None	21
	2SVV*RVV213	10	Check	600	3	10	None	21
	2SVV*RVV214	10	Check	600	3	10	None	21
	2SVV*RVV215	10	Check	600	3	10	None	21
	2SVV*RVV216	10	Check	600	3	10	None	21
	2SVV*RVV217	10	Check	600	3	10	None	21
	2SVV*RVV218	10	Check	600	3	10	None	21
	2SVV*RVV301	2 1/2	Check	150	3	10	None	21
	2SVV*RVV302	2 1/2	Check	150	3	10	None	21
	2SVV*RVV303	2 1/2	Check	150	3	10	None	21
	2SVV*RVV304	2 1/2	Check	150	3	10	None	21
	2SVV*RVV305	2 1/2	Check	150	3	10	None	21
	2SVV*RVV306	2 1/2	Check	150	3	10	None	21
	2SVV*RVV307	2 1/2	Check	150	3	10	None	21
	2SVV*RVV308	2 1/2	Check	150	3	10	None	21
	2SVV*RVV309	2 1/2	Check	150	3	10	None	21
	2SVV*RVV310	2 1/2	Check	150	3	10	None	21
	2SVV*RVV311	2 1/2	Check	150	3	10	None	21
	2SVV*RVV312	2 1/2	Check	150	3	10	None	21
	2SVV*RVV313	2 1/2	Check	150	3	10	None	21

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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Main Steam Safety/ Relief Valves, Vents and Drains (SVV) (cont'd.)	2SVV*RVV314	2 1/2	Check	150	3	10	None	21
	2SVV*RVV315	2 1/2	Check	150	3	10	None	21
	2SVV*RVV316	2 1/2	Check	150	3	10	None	21
	2SVV*RVV317	2 1/2	Check	150	3	10	None	21
	2SVV*RVV318	2 1/2	Check	150	3	10	None	21
Service Water (SWP)	2SWP*AOV20A,22A	1 1/2	Plug	150	3	4	NCB520-SR80(2)	64
	2SWP*AOV20B,22B	2	Plug	150	3	4	NCB725-SR80(2)	64
	2SWP*AOV97A,B	6	Plug	150	3	4	NTB12-SR3-M3HW(2)	68
	2SWP*AOV572	2 1/2	Plug	150	3	4	NCB725-SR80(2)	68
	2SWP*AOV78A,B	2	Plug	150	3	4	NCB725-SR80(2)	68
	2SWP*FV54A,B	30	Butterfly	150	3	21	G5028-SRI(CW)*SEIS*(2)	71
	2SWP*MOV1A-F	4	Ball	150	3	11	SMB-000-2/H1BC(1)	2
	2SWP*MOV3A,B	30	Butterfly	150	3	9	SMB-2-60/H6BC(1)	45
	2SWP*MOV19A,B	20	Butterfly	150	3	21	SMB-1-15/H4BC(1)	45
	2SWP*MOV33A,B	18	Butterfly	150	3	9	SMB-0-25/H4BC(1)	67
	2SWP*FV47A,B	30	Butterfly	150	3	21	G5028-SRI(CW)*SEIS*(2)	71
	2SWP*MOV50A,B	36	Butterfly	150	3	9	SMB-3-150/H6BC(1)	71
	2SWP*MOV74A,C,E	18	Butterfly	150	3	21	SMB-0-40/H4BC(1)	69
	2SWP*MOV74B,D,F	18	Butterfly	150	3	9	SMB-0-40/H4BC(1)	69
	2SWP*MOV90A,B	18	Butterfly	150	3	9	SMB-0-25/H4BC(1)	67
	2SWP*MOV17A,B	12	Gate	150	3	1	SMB-0-25(1)	91
	2SWP*MOV18A,B	12	Gate	150	3	1	SMB-0-25(1)	91
	2SWP*MOV21A,B	3	Gate	150	3	1	SMB-000-5(1)	36
	2SWP*MOV66A,B	8	Gate	150	3	1	SMB-00-15(1)	65
	2SWP*MOV67A,B	4	Gate	150	3	1	SMB-000-5(1)	68
	2SWP*MOV94A,B	8	Gate	150	3	1	SMB-00-15(1)	65
	2SWP*MOV95A,B	8	Gate	150	3	1	SMB-00-15(1)	92
	2SWP*MOV599	30	Butterfly	150	3	9	SMB-1-25/H5BC(1)	45
	2SWP*MOV93A,B	24	Butterfly	150	3	21	SMB-1-15/H4BC(1)	45
	2SWP*MOV30A,B	48 x 72	Rotary Gte	150	3	12	SMB-0-15/H4BC(1)	72
	2SWP*MOV77A,B	54 x 54 (overall) 48 x 48 (nominal)	Rotary Gte	150	3	12	SMB-00-10/H3BC(1)	73
	2SWP*RV34A,B	4 x 6	SRV	300/150	3	8	None	56
	2SWP*TV35A,B	4	Globe	150	3	5	(3)	93
	2SWP*V1A-F	18	Check	150	3	9	None	22,78
	2SWP*V202A	30	Check	150	3	9	None	22,78
	2SWP*V202B	30	Check	150	3	9	None	22
	2SWP*V219A,B	4	Check	150	3	1	None	78
	2SWP*V240A	4	Check	150	3	16	None	22,78

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ACTIVE VALVES (BOP)

System Name	Mark Number	Size	Valve Type	Pressure Rating(*)	ASME Class	Mfg.	Valve Operator Model (Mfg.)	Active Function
Service Water (SWP) (cont'd.)	2SWP*V240B	4	Check	150	3	16	None	22,78
	2SWP*V259	8	Check	150	3	1	None	22,78
	2SWP*V260	8	Check	150	3	1	None	22,78
	2SWP*V1002A,B	3	Check	150	3	1	None	78,90
	2SWP*V1027	30	Check	150	3	9	None	22,78
	2SWP*V1024	6	Check	150	3	1	None	22,78
	2SWP*V1025	6	Check	150	3	1	None	22,78
	2SWP*AOV154A,B	1 1/2	Plug	150	3	4	NCB520-SR80(2)	68
	2SWP*AOV571	1 1/2	Plug	150	3	4	NCB520-SR80(2)	68
	2SWP*AOV581	1 1/2	Plug	150	3	4	NCB520-SR80(2)	68
	2SWP*AOV573	2	Plug	150	3	4	NCB725-SR80(2)	68
	2SWP*AOV574	2	Plug	150	3	4	NCB725-SR80(2)	68
	2SWP*V1194,1195, 1196,1197	6	Check	150	3	17	None	85
Reactor Water Cleanup (WCS)	2WCS*MOV102	8	Globe	600	1	1	SB-2-60(1)	16
	2WCS*MOV112	8	Globe	600	1	1	SB-2-60(1)	16
	2WCS*MOV200	8	Globe	900	1	1	SMB-1-25(1)	16
	2WCS*EFV221	3/4	Check	1250	2	13	None	16
	2WCS*EFV222	3/4	Check	1250	2	13	None	16
	2WCS*EFV223	3/4	Check	1250	2	13	None	16
	2WCS*EFV224	3/4	Check	1250	2	13	None	16
	2WCS*EFV300	3/4	Check	1250	2	13	None	16

(1) Normally de-energized in the closed position and the power source removed for main control room fire concerns.

(*) Pressure Rating - Inlet/Outlet

<u>Key to Manufacturer</u>

1 = Velan Corp.
2 = Posi-Seal
3 = Anchor-Darling
4 = Atwood & Morill
5 = Copes-Vulcan
6 = Target Rock
7 = Gulf & Western
8 = Crosby
9 = Clow
10 = GPE Controls
11 = Contromatics
12 = Henry Pratt Co.
13 = Dragon
14 = Dikkers
15 = Westinghouse
16 = Enertech
17 = BNL Industries, Inc.
18 = Edward
19 = Control Components, Inc.
20 = Valcor
21 = Weir

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ACTIVE VALVES (BOP)

Key to Valve Operator/Manufacturer

1	=	Motor/Limitorque
2	=	Air/Bettis
3	=	Electrohydraulic/Borg-Warner
4	=	Pneumatic/Parker-Hannifin (cylinder)
5	=	Air/Anchor-Darling
6	=	Air/Parker-Hannifin (piston)
7	=	Target Rock
8	=	(Deleted)
9	=	Electrohydraulic/Paul Monroe
10	=	Air/Control Components
11	=	Valcor
12	=	Air/Copes-Vulcan

Key to Active Functions

1	=	Relieve pressure from suppression chamber to drywell.
2	=	Pressure control (open and close) for self-cleaning strainers for service water pumps.
3	=	Hydrogen recombiner isolation (active function to open required only after approximately 2 days following a LOCA).
4	=	Pressure relief.
5	=	Computer room isolation (safety class change).
6	=	Temperature control of control room air-conditioning unit.
7	=	Temperature control of relay room air-conditioning unit.
8	=	High radiation isolation valve.
9	=	Containment isolation during LOCA.
10	=	Open to provide flow path to GTS from reactor building ventilation system.
11	=	GTS filter train operation.
12	=	GTS filter train isolation upon high temperature of one of the GTS trains.
13	=	Modulate to maintain the required reactor building pressure differential. (Following design basis accidents and transients.)
14	=	Isolation between GTS and CPS.
15	=	(Deleted)
16	=	Primary containment isolation.
17	=	Isolation valves for penetrations through primary containment wall.
18	=	Drywell sample selector valves.
19	=	(Deleted)
20	=	(Deleted)
21	=	Vacuum breaker, water hammer mitigation for main steam SRV discharge piping.
22	=	Prevent reverse flow.
23	=	HPCS system injection valve.
24	=	HPCS suction from 2CNS-TK1B, isolates on low level in tank.
25	=	HPCS suction from suppression pool, opens on low level in 2CNS-TK1B.
26	=	HPCS system test valve to be closed to ensure maximum flow is injected into the vessel. Valve is opened to allow flow to return to suppression pool during full flow.
27	=	LPCS system test valve to be closed on LOCA signal to ensure maximum flow is injected into the vessel.
28	=	Open for LPCS system injection and close for containment isolation when LPCS service is terminated.
29	=	LPCS system test valve to be closed to ensure maximum flow is injected into condensate tank.
30	=	Prevent reverse flow and provide pressure boundary.

TABLE 3.9A-12
(Sheet 15 of 16)

ACTIVE VALVES (BOP)

Key to Active Functions (cont'd.)

31	=	Minimum flow bypass to protect pump. Close on discharge line flow signal. A vent hole was drilled in the disc of 2CSL*MOV107 to prevent pressure locking.
32	=	Containment isolation on low suppression pool level, and open to provide suction flow path.
33	=	Reactor vessel drain line isolation and class break (ASME III to ANSI B31.1).
34	=	Sample isolation.
35	=	SFC loop isolation.
36	=	Open to provide makeup for spent fuel pool.
37	=	Cask handling area isolation.
38	=	RCIC turbine drain pot drain isolation.
39	=	Cooling loop shutoff valve.
40	=	Containment isolation, open for injection.
41	=	Isolates RCIC test return.
42	=	Open to allow lube oil cooling.
43	=	RCIC turbine steam supply valve.
44	=	RCIC turbine exhaust - containment isolation.
45	=	Safety class change isolation.
46	=	Isolates on low CST level.
47	=	Opens on low CST level.
48	=	Turbine exhaust vacuum relief.
49	=	LPCI injection.
50	=	Shutdown cooling.
51	=	RHR/SWP cross-connect isolation for post-LOCA containment flooding; they are modified to meet the requirements of Generic Letter 95-07.
52	=	System boundary isolation.
53	=	Suppression pool cooling.
54	=	RHR pump miniflow.
55	=	Containment spray.
56	=	Overpressure protection.
57	=	Vacuum breaker/water hammer mitigation.
58	=	(Deleted)
59	=	Automatic depressurization system.
60	=	Prevent excess flow.
61	=	(Deleted)
62	=	Hydrogen/oxygen analyzer isolation valves to open on loss of offsite power.
63	=	SWP/CCP crosstie isolation for SFC heat exchanger.
64	=	SWP/CCP crosstie for RHR pump seal coolers.
65	=	SWP supply to/from diesel generators.
66	=	Standby liquid control injection.
67	=	SWP supply to/from RHR heat exchangers.
68	=	SWP supply to/from safety-related unit coolers/chillers.
69	=	SWP pump discharge valves. Open and close with pump start and stop.
70	=	SWP makeup to CWS.
71	=	SWP divisional cross-connect isolation.
72	=	Intake bay cross-connect isolation.

TABLE 3.9A-12
(Sheet 16 of 16)

ACTIVE VALVES (BOP)

<u>Key to Active Functions</u> (cont'd.)

73	=	Intake bay traveling screen bypass.
74	=	LPCS injection.
75	=	Allow flow to ADS accumulator tanks.
76	=	Allow emergency nitrogen flow.
77	=	HPCS system suppression pool supply line.
78	=	Allow flow in the forward direction.
79	=	(Deleted)
80	=	RCIC turbine exhaust.
81	=	(Deleted)
82	=	RCIC system suppression pool supply line.
83	=	CMS atmosphere sample valves.
84	=	Maintain secondary containment integrity during operation of alternate drywell cooling system.
85	=	Maintain secondary containment integrity during SWP chemical cleaning. Note: During normal plant operation, valve/piping assemblies (2SWP*V1194/V1195 and 2SWP*V1196/V1197) will be removed and penetrations will be secured with blind flanges.
86	=	Provides secondary containment integrity.
87	=	Open for RCIC injection and close for containment/reactor isolation.
88	=	Fuel oil day tank transfer line.
89	=	Opens for containment flooding; they are modified to meet the requirements of Generic Letter 95-07.
90	=	Emergency makeup to spent fuel pool.
91	=	SWP/CCP crosstie for SFC heat exchanger. Open to provide service water flow to SFC heat exchanger.
92	=	Close on low header pressure to isolate SWP supply line to diesel generator.
93	=	Flow/temperature modulation only.
94	=	Close to isolate steam line break.
95	=	Open for "pseudo LPCI" mode of RHR.
96	=	(Deleted)
97	=	The pressure relief valve is not required to maintain pressure boundary. It provides overpressure protection for the HVK system. It meets the requirements of ASME Section VIII.

TABLE 3.9A-13
(Sheet 1 of 3)

LOAD COMBINATIONS FOR COMPONENT SUPPORTS AND
STRESS LIMITS FOR PLATE AND SHELL-TYPE SUPPORTS

A. Load Combinations for Component Supports

Plant Condition	Loading Combination	Service Level
Normal	DL+S+D+R+A+E	A
Upset	DL+S+D_1+R+A+E+D	B
Emergency	Not Applicable	C
Faulted	DL+S+D_2+E+D	D

KEY:

To Loading Combinations

DL = Dead load
S = Superimposed loads
D_1,D_2 = Dynamic Loads 1 and 2, respectively (for definitions, see Table 3.9A-6)
R = Restrained thermal expansion
A = Anchor and support movement
E = Environmental loads
D = Other external dynamic loads

NOTES: For each operating condition, the loadings as given in the table are to be considered simultaneously. Symbols used are defined in the key.

The specific loads of each type which are applied during the applicable operating condition are dependent on the particular system conditions. The following listing identifies some of these specific loads which are used as a general checklist when determining loading conditions as related to plant operating conditions.

Dead Load

Component maximum operating weight (with appurtenances)
Hydrostatic test weight
Operational test weight
Component support weight

TABLE 3.9A-13
(Sheet 2 of 3)

LOAD COMBINATIONS FOR COMPONENT SUPPORTS AND
STRESS LIMITS FOR PLATE AND SHELL-TYPE SUPPORTS

Superimposed
- Pressure
- Temperature
- Piping system reactions
- LOCA building deflections

Dynamic
- OBE
- SSE
- Pipe rupture
- Hydrodynamic loads
- Jet impingement
- Missile impact
- Vibrations
  - Handling loads (construction, installation, servicing)
  - Thermal transients
  - Water hammer
  - Steam hammer
  - Valve trips

Anchor and Support Movement
- OBE/SSE effects
- Thermal growth
- LOCA

Environmental
- Radiation
- Moisture
- Chemicals

TABLE 3.9A-13
(Sheet 3 of 3)

LOAD COMBINATIONS FOR COMPONENT SUPPORTS AND
STRESS LIMITS FOR PLATE AND SHELL-TYPE SUPPORTS

B. Stress Limits for Plate and Shell-Type Supports

Service Level	1	(1 + 2)	3
A	1.0S	1.5S	0.5S
B	1.0S	1.5S	0.5S
C	1.2S	1.8S	0.5S
D	lesser of 1.5S or 0.4Su	lesser of 2.25S or 0.6Su	0.5S

KEY:

To Stress Limits

1 = Membrane stress
2 = Bending stress
3 = Maximum tensile stress at the contact surface of a weld producing a tensile load in a direction through the thickness of a plate
S = ASME Section III allowable stress
Su = ASME Section III minimum ultimate tensile strength

TABLE 3.9A-14
(Sheet 1 of 1)

LOAD CONDITIONS FOR PIPE SUPPORTS

Load Condition Number	Plant Condition	Loads	Description	Allowable Stress
1	Normal	Primary sustained	DL	ASME III (1974, including Summer 1974 Addenda), Subsection NF; and Subsection NA, App. XVII, Article XVII-2000
2	Upset	Primary sustained and occasional associated with upset	DL+SRSS (OBEI,OCCU)	
3	Upset	All primary and secondary	DL+THER+SRSS (OBET,OCCU)	
4	Emergency	Primary sustained and occasional associated with emergency	DL+SRSS (OBEI,OCCE)	ASME III (1974, including Summer 1974 Addenda), Subsection NA, App. XVII, Article XVII-2110
5	Faulted	Primary sustained and occasional associated with faulted	DL+SRSS (SSEI,OCCF)	ASME III (1974, including Summer 1974 Addenda), App. F, Paragraph F-1370

KEY:
- DL = Dead load
- OBEI = Operating basis earthquake inertia load of piping
- OBET = Operating basis earthquake total, i.e., the absolute sum of the amplitudes of OBE inertia load and load due to OBE anchor movements
- OCC(U,E,F) = Primary occasional mechanical operating loads associated with upset, emergency, and faulted operating conditions, respectively, but excluding earthquake loads. Occasional loads may be vibratory or nonvibratory for load combination purposes. They are combined with each other and with other load types in the same way as in the associated piping analysis. (See notes to load combinations for piping, Table 3.9A-2.) The maximum and the minimum response from each time history is used with the associated sign in the combination.
- SSE = Safe shutdown earthquake inertia load of piping
- THER* = Thermal load; a secondary load
  - THER 1 = Selecting the three moments from that thermal load whose three moments represent the maximum square root of the sum of the squares of the moments. The forces selected are the most (+) of each force component along with its proper sign (each force component chosen may come from a different thermal load).
  - THER 2 = Same as for THER 1, except that the most (-) of each force component with signs is chosen.
  - THER 3 = Forces and moments are those for the normal operating condition.

* For feedwater piping, includes applicable thermal stratification load.

TABLE 3.9A-15
(Sheet 1 of 3)

REQUIREMENTS FOR SAFETY CLASSES 2 AND 3
INSTRUMENT AND PNEUMATIC TUBING AND SUPPORTS

(TUBING SIZES UP TO AND INCLUDING 1/2 IN O.D.)*

1. Design loads and limits are calculated in accordance with ASME III.

2. Procurement of material is in accordance with ASME III except that alternate QA Category I materials may be used for supports. See Figure 3.9A-1.

3. Fabrication and installation control utilizes QA Category I material marking of exclusive purchase of QA Category I materials with control to point of use.

4. Automatic Class 2 welding follows the requirements of ASME III Code Case N-127 except that Category I documentation is used in lieu of N-127 and the Authorized Nuclear Inspector (ANI) involvement as noted in 5.a below.

5. Fabrication, installation, NDE, and hydrostatic inspections are as follows:

   a. Pressure boundary welds

      (1) Welders and welding procedures are qualified to ASME Section IX.

      (2) 100% documentation of completion of all construction steps by Contractor's construction prior to release to Contractor's QA Program.

      (3) 100% liquid penetrant check of Class 2 field welds (automatic and manual) and visual inspection of all Class 3 field welds by Contractor FQC documented by the Contractor's QA Program.

      (4) Contractor FQC in-process inspection documented by the Contractor's QA Program.

* This program also applies to safety-related instrument tubing for radiation protection process monitoring up to 1 in when the process piping, equipment, or component is not ASME Section III construction (e.g., HVAC duct).

TABLE 3.9A-15
(Sheet 2 of 3)

REQUIREMENTS FOR SAFETY CLASSES 2 AND 3
INSTRUMENT AND PNEUMATIC TUBING AND SUPPORTS

(5) Pressure test to be performed in accordance with ASME Section III pressure test requirements and document via pressure test reports.

(6) Surveillance inspections by the ANI of approximately 10 percent of in-process activities (welding and hydro) documented by SIS report.

(7) Compression fittings are an acceptable substitute for welded fittings.

b. Compression Fittings

(1) Compression fittings which meet ASME material requirements and the following installation requirements shall be used. The specific design criteria used in the application of compression fittings at Unit 2 are ASME Section III, Subsections NC/ND, Paragraphs 3671.4 and 3673.2.

(2) 100-percent visual inspection of compression fitting makeup is performed by construction prior to release to Contractor's QA Program.

(3) Documentation of the completion of all construction is required.

(4) 100-percent inspection of fitting makeup is performed by FQC using vendor-supplied tools and procedures.

(5) Documentation of the FQC inspection is required.

(6) Pressure test to be performed in accordance with ASME Section III pressure test requirements and document via pressure test reports.

c. Supports

(1) Welders and welding procedures are qualified to Category I specification requirements invoking ASME Section IX or AWS standards as appropriate to the support type.

(2) 100-percent documentation of completion of all construction steps by Contractor's construction prior to release to Contractor's QA Program.

TABLE 3.9A-15
(Sheet 3 of 3)

REQUIREMENTS FOR SAFETY CLASSES 2 AND 3
INSTRUMENT AND PNEUMATIC TUBING AND SUPPORTS

(3) 100-percent Contractor FQC visual inspection of all field welds using ASME, ANSI, or AWS acceptance criteria as required in accordance with the installation specification (except undercut not exceeding 1/32-in deep is acceptable in lieu of AWS D1.1 requirements). These inspections shall be documented by the Contractor's QA Program. For alternate weld inspection, refer to Section 3.8.4.6.

(4) ASTM A515, Gr 65, may be considered an AWS D1.1 prequalified group no. 1 material.

6. Visual examination acceptance for pressure-retaining field welds.

All weld surfaces are sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to allow examination. The following indications are unacceptable:

a. Cracks, external surface.

b. Fillet weld dimension not meeting Figure NC/ND 4427-1 or butt weld reinforcement greater than specified in Figure NC/ND 4427-1.

c. Lack of fusion on the surface.

7. Unsatisfactory conditions noted by the SWEC FQC on SIS reports are to be addressed and resolved via existing Engineering and QA procedures.

TABLE 3.9A-16
(Sheet 1 of 1)

BASIS FOR DESIGN AND CONSTRUCTION
OF ASME AND NON-ASME PIPING SUPPORTS

Criteria	ASME III Program	AISC Program
Design	Per ASME	a) Per AISC b) Load combinations and allowable stresses per Section 3.8.4.3
Material		
Weld filler metal	Procured - ASME III	Procured - ASME II
Standard components	Procured - ASME III	Procured - AISC
Bulk material	Procured - ASME III	Procured - AISC
Traceability	Class 1 - Heat number to Certified Material Test Report Class 2, 3 - To Certificate of Compliance	Cat. I - A-36 steel traceable until delivery and placed in segregated storage Cat. I - High-strength steel traceable at all times to its locations in structure
Welding		
Welders	Qualified to ASME IX	Qualified to AWS D1.1 or ASME IX
Procedures/weld techniques	Qualified to ASME IX	Qualified or prequalified to AWS D1.1 or qualified to ASME IX
Inspectors	Qualified to ASME III	Welding inspectors qualified to ANSI N45.2.6
Inspection criteria	Per ASME III	Per RG 1.94 (and ANSI N45.2.5) as described in Table 1.8-1 Welding inspection per AWS D1.1
Examination	Per ASME III	Visual examination per AWS D1.1, followed by RT, UT, or MT examination of full-penetration welds
Authorized nuclear inspector	Surveillance inspection based on hold points per SWEC QA requirements; 100% review of documentation per SWEC QA Program	NA
In-service inspection	ASME Section XI	NA

3.9B MECHANICAL SYSTEMS AND COMPONENTS (GE SCOPE OF SUPPLY)

3.9B.1 Special Topics for Mechanical Components

3.9B.1.1 Design Transients

This section describes the transients that are used in the design of major NSSS ASME Section III, Safety Class 1 core support, reactor internals, and CRD components. The number of cycles or events for each transient is included. These transients are included in the design specifications and/or stress reports for components. Transients or combinations of transients are classified with respect to the component operating condition categories identified as Normal, Upset, Emergency, Faulted, or Testing in ASME Section III as applicable. (The first four conditions correspond to Service Levels A, B, C, and D, respectively.)

3.9B.1.1.1 Control Rod Drive Transients

The normal and test service load cycles used for the design and fatigue analysis for the 40-yr life of the CRD are as follows:

	Transient	Category	Cycles
1.	Reactor startup/shutdown	Normal/upset	120
2.	Vessel pressure tests	Normal/upset	130
3.	Vessel overpressure	Normal/upset	10
4.	Scram test plus startup scrams	Normal/upset	300
5.	Operational scrams	Normal/upset	300
6.	Jog cycles	Normal/upset	30,000
7.	Shim/drive cycles	Normal/upset	1,000

In addition to the above cycles, the following have been considered in the design of the CRD.

	Transient	Category	Cycles
8.	Scram with inoperative buffer	Normal/upset	10
9.	Scram with stuck control blade	Normal/upset	1
10.	Operating basis earthquake (OBE)*	Normal/upset	10
11.	Safe shutdown earthquake (SSE)**	Faulted	1

12.	Control rod ejection accident	Faulted	1

All ASME Section III, Class 1 components of the CRD have been evaluated according to the requirements of the Code. The capacity of the CRD system to withstand emergency and faulted conditions is verified by tests rather than analysis.

3.9B.1.1.2 Control Rod Drive Housing and In-core Housing Transients

The number of transients, their cycles, and classification as considered in the design and fatigue analysis of the CRD housing and in-core housing are as follows:

	Transient	Category	Cycles
1.	Normal startup and shutdown	Normal/upset	120
2.	Vessel pressure tests	Normal/upset	130
3.	Vessel overpressure tests	Normal/upset	10
4.	Interruption of feedwater flow	Normal/upset	80
5.	Scrams	Normal/upset	200
6.	OBE	Normal/upset	10
7.	SSE	Faulted	1
8.	Stuck rod scram	Normal/upset	1
9.	Scram with inoperative buffer	Normal/upset	10

* The frequency of occurrence of this transient would indicate emergency category. However, for conservatism the OBE condition is analyzed as an upset condition. Ten peak OBE cycles are postulated.

** SSE is a faulted condition; however, in the stress analysis it was treated as emergency with lower stress limits.

3.9B.1.1.3 Hydraulic Control Unit Transients

The transients used in the design and analysis of the HCU and its components are:

Transient	Category	Cycles

1.	Reactor startup/shutdown	Normal/upset	120
2.	Scram tests	Normal/upset	300
3.	Operational scrams	Normal/upset	300
4.	Jog cycles	Normal/upset	30,000
5.	Scram with stuck scram discharge valve	Normal/upset	1
6.	OBE	Normal/upset	10
7.	SSE	Faulted	1

3.9B.1.1.4 Core Support and Reactor Internals Transients

The cycles listed in Table 3.9B-1 were considered in the design and fatigue analysis for the reactor internals.

3.9B.1.1.5 Main Steam System Transients

See Section 3.9A.1.

3.9B.1.1.6 Recirculation System Transients

The following transients are considered in the stress analysis of the recirculation piping:

	Transient	Category	Cycles
1.	Startup	Normal	120
2.	Turbine roll and increase to power	Normal	120
3.	Loss of feedwater heater	Upset	10
4.	Partial feedwater heater bypass	Upset	70
5.	Scrams	Upset	180
6.	Shutdown	Normal	111
7.	Loss of feedwater pumps isolation valves closed	Upset	10
	Transient	Category	Cycles
8.	Single SRV blowdown	Upset	8
9.	Hydrotest	Test	130
10.	OBE	Upset	50

3.9B.1.1.7 Reactor Assembly Transients

The reactor assembly includes the RPV, support skirt, shroud support, and shroud plate. The cycles listed in Table 3.9B-1 were specified in the reactor assembly design and fatigue analysis.

3.9B.1.1.8 Main Steam Isolation Valve Transients

The transients considered in the analysis of the MSIVs are as follows:

	Transient	Category	Cycles
1.	Heatup from 70°F to 552°F (100°F/hr)	Normal/upset	300
2.	Cooldown from 552°F to 70°F (100°F/hr)	Normal/upset	300
3.	Small temperature changes of 29°F (either increase or decrease) at any temperature between 70°F and 552°F	Normal/upset	600
4.	Temperature changes of 50°F (either increase or decrease) at any temperature between 70°F and 552°F	Normal/upset	200
5.	Loss of feedwater pumps in which the temperature jumps from 552°F to 573°F in 3 sec, drops down to 525°F in 9 min, rises to 573°F in 6 min, drops down to 485°F in 7 min, rises to 573°F again in 8 min, and drops down to 485°F in 7 min	-	10
6.	Turbine bypass, single relief or safety valve blowdown in which the temperature drops from 552°F to 375°F in 10 min	-	8
7.	Reactor overpressure with delay scram in which the temperature rises from 552°F to 586°F in 2 sec, and the pressure rises from 1050 to 1375 psig immediately followed by	Emergency	1

	cooling transient in which the temperature drops from 586°F to 561°F in 30 sec. The pressure drops down to 1125 psig.		
8.	Automatic blowdown in which the temperature changes from 552°F to 375°F in 3.3 min immediately followed by a change from 375°F to 259°F in 19 min (300°F/hr)	Emergency	1
9.	Pipe rupture and blowdown in which the temperature changes from 552°F to 259°F in 15 sec	Faulted	1
10.	Installed hydrotests at 100°F		
	a. 1250 psig	Testing	130
	b. 1575 psig	Testing	3

3.9B.1.1.9 Safety/Relief Valve Transients

The transients considered in the analysis of the SRVs are as follows:

	Transient	Category	Cycles
1.	Preoperational and in-service testing (100°F/hr)	Normal/upset	150
2.	Startup (100°F/hr) and pressure increase (0 psig to 1,000 psig)	Normal/upset	120
3.	Shutdown (100°F/hr, pressure decrease to 0 psig)	Normal/upset	120
4.	Scram	Normal/upset	180
5.	System pressure and temperature decay from 1,000 psig and 546°F to 35 psig and 281°F within 15 sec	Emergency/ faulted	1
6.	System temperature change from 546° to 375°F within 3.3 min and from 375° to 281°F at 300°F/hr. Pressure change from 1,000	Emergency/ faulted	1

	to 35 psig.		
7.	System temperature change from 546° to 375°F within 10 min and from 375° to 281°F at 100°F/hr. Pressure change from 1,000 to 35 psig.	Emergency/ faulted	8
8.	System temperature change from 546° to 583°F within 2 sec, from 583° to 538°F within 30 sec, and from 538° to 400°F and return to 546°F at 100°F/hr. Pressure change from 1,000 to 1,350 psig, then to 240 psig and return to 1,000 psig.	Emergency/ faulted	1
9.	System temperature changes, greater than 30°F, from 561° to 500°F within 7 min and from 500° to 400°F and return to normal operating temperature of 546°F at 100°F/hr. Pressure change from 1,000 to 1,180 to 240 psig and return to normal operating of 1,000 psig.	Emergency/ faulted	10

Paragraph NB-3552 of ASME Section III excludes various transients and provides a means for combining those that are not excluded. Review and approval of the equipment supplier's certified calculations provides assurance of proper accounting of the specified transients.

The SRVs used for Unit 2 are those normally supplied for BWR 6 projects. The stress (including fatigue) analysis of this SRV model is performed on the basis of BWR 6 plant conditions. These include transients that are anticipated to be more numerous and more severe than the transients shown above for Unit 2. The SRV is, therefore, qualified for the above transients.

3.9B.1.1.10 Recirculation Flow Control Valve Transients

The following pressure and temperature transients were considered in the design of the recirculation system flow control valve (FCV):

	Transient	Category	Cycles
1.	Startup (100°F/hr heatup rate 70°F to design temperature)	Normal/upset	300

2.	Small temperature step changes (29°F step)	Normal/upset	600
3.	50°F step changes	Normal/upset	200
4.	SRV blowdowns (single valve) 522° to 375°F in 10 min)	Normal/upset	8
5.	Safety valve transient (110% of design pressure)	Normal/upset	1
6.	Installed hydrostatic tests		
	a. 1,300 psig	Testing	130
	b. 1,670 psig	Testing	3
7.	Automatic blowdown 552° to 375°F in 3.3 min, followed by a change from 375° to 281°F in 19 min	Emergency	1
8.	Improper start of pump in cold loop over a period of 15 sec	Emergency	1

3.9B.1.1.11 Recirculation Pump Transients

The following pressure transients were considered in the design of the recirculation pumps:

	Transient	Category	Cycles
1.	Startup (100°F/hr heatup rate 70°F to design temperature)	Normal/upset	300
2.	Small temperature changes (29°F step)	Normal/upset	600
3.	50°F step changes	Normal/upset	200
4.	SRV blowdowns (single valve) (552° to 375°F in 10 min)	Normal/upset	8
5.	Safety valve transient (110% of design pressure)	Normal/upset	1
6.	Installed hydrotests		
	a. 1,300 psig	Testing	130
	b. 1,670 psig	Testing	3
7.	Automatic blowdown (552° to 375°F in 3.3 min and	Emergency	1

	375° to 281°F in 19 min)		
8.	Improper start of pump in cold loop (100° to 552°F over a period of 15 sec)	Emergency	1
9.	Cooling transient, 552° to 281°F in 15 sec	Faulted	1

3.9B.1.1.12 Recirculation Gate Valve Transients

The following transients are considered in the design of the recirculation gate valves:

	Transient	Cycles
1.	50° to 575° to 50°F at a rate of 100°F/hr	300
2.	±29°F between limits of 50° and 575°F, instantaneous	600
3.	±50°F between limits of 50° and 546°F, instantaneous	200
4.	552° to 375°F, instantaneous	9
5.	546° to 281°F, instantaneous	1
6.	130° to 546°F, instantaneous	1
7.	110% of design pressure at 575°F	1
8.	1,300 psi at 100°F installed hydrostatic test	130
9.	1,670 psi at 100°F installed hydrostatic test	3

3.9B.1.2 Computer Programs Used in Analysis

The following sections discuss computer programs used in the analysis of specific components. (Computer programs were not used in the analysis of all components, thus, not all components are listed.) The NSSS programs can be divided into two categories, GE programs and vendor programs.

GE Programs

Verification of the following GE programs has been performed in accordance with the requirements of 10CFR50 Appendix B. Evidence of the verification of input, output, and methodology is documented in GE Design Record Files.

SEISM	FTFLG01

MASS		ANSYS
SNAP (MULTISHELL)		POSUM
HEATER	PDA	BILRD
ANSI7	EZPYP	DYSEA
PISYS	SAP4G	SPECA
		COSMOS/M

Vendor Programs

Verification of the following vendor (CB&I) programs is assured by contractual requirements between GE and the vendor. In accordance with the requirements, the QA procedure of these proprietary programs used in the design of N-stamped equipment is in full compliance with 10CFR50 Appendix B.

711 GENOZZ	9-28 TGRV	953
948 NAPALM	962 E0962A	1666
1027	984	1684
846	992 GASP	E1702A
781 KALNINS	1037 DUNHAM'S	955 MESHPLOT
979 ASFAST	1335	1028
7-66 TEMAPR	1606 & 1657 HAP	1038
7-67 PRINCESS	1635	

3.9B.1.2.1 Reactor Pressure Vessel and Internals

Reactor Pressure Vessel

CB&I Program 7-11 - GENOZZ The GENOZZ computer program is used to proportion barrel and double taper-type nozzles to comply with the specifications of ASME Section III and contract documents. The program will either design such a configuration or analyze the configuration input into it. If the input configuration does not comply with the specifications, the program modifies the design and redesigns it to yield an acceptable result.

CB&I Program 9-48 - NAPALM The basis for the program NAPALM (Nozzle Analysis Program - All Loads Mechanical) is to analyze nozzles for mechanical loads and find the maximum stress intensity and location. The program analyzes at specified locations from the point of application of the mechanical loads. At each location, the program calculates the maximum stress intensity for both the inside and outside surfaces of the nozzle, and its angular location around the circumference of the nozzle from the reference location. The principal stresses are also printed. The stresses resulting from each component of loading (bending, axial, shear, and torsion) are printed, as well as the loads that caused these stresses.

CB&I Program 1027 This program is a computerized version of the analysis method contained in the Welding Research Council Bulletin No. 107, August 1965. Part of the program provides for the determination of the shell stress intensities (S) at each of four cardinal points at both the upper and lower shell plate surfaces (ordinarily considered outside and inside surfaces) around the perimeter of a loaded attachment on a cylindrical or spherical vessel. With the determination of each S, the components of that S (two normal stresses, σ_x and σ_z , and one shear stress τ) are also determined. This program provides the same information as the manual calculation, and the input data are essentially the geometry of the vessel and attachment.

<u>CB&I Program 846</u> This program computes the required thickness of a hemispherical head with a large number of circular parallel penetrations by means of the area replacement method in accordance with the ASME Section III. In cases where the penetration has a counterbore, the thickness is determined so that the counterbore does not penetrate the outside surface of the head.

<u>CB&I Program 781 - KALNINS</u> This program is a thin elastic shell program for shells of revolution. The basic method of analysis was developed and published by Dr. A. Kalnins of Lehigh University[(1)]. Extensive revisions and improvements have been made by Dr. J. Endicott to yield the CB&I version of this program. The program is used to establish the shell influence coefficient and to perform detail stress analysis of the vessel.

The stresses and the deformations of the vessel can be computed for any combination of the following axisymmetric loading:

1. Preload condition.

2. Internal pressure.

3. Thermal load.

<u>CB&I Program 979 - ASFAST</u> The ASFAST program performs stress analysis of axisymmetric, bolted closure flanges between head and cylindrical shell.

<u>CB&I Program 7-66 - TEMAPR</u> This program reduces any arbitrary temperature gradient through the wall thickness to an equivalent linear gradient. The resulting equivalent gradient has the same average temperature and the same temperature-moment as the given temperature distribution. Input consists of plate thickness and actual temperature distribution. Output contains average temperature and total gradient through the wall thickness. The program is written in FORTRAN IV language.

<u>CB&I Program 7-67 - PRINCESS</u> The PRINCESS program calculates the maximum alternating stress amplitudes from a series of stress values by the method in ASME Section III.

<u>CB&I Program 9-28 - TGRV</u> The TGRV program is used to calculate temperature distributions in structures or vessels. Although it is primarily a program for solving the heat conduction equations, some provisions have been made for including radiation and convection effects at the surfaces of the vessel.

The TGRV program is a greatly modified version of the TIGER heat transfer program written about 1958 at Knolls Atomic Power Laboratory by A. P. Bray. There have been many versions of TIGER in existence including TIGER II, TIGER II B, TIGER IV, and TIGER V, in addition to TGRV.

The program uses an electrical network analogy to obtain the temperature distribution of any given system as a function of time. The finite difference representation of the three-dimensional equations of heat transfer are repeatedly solved for small time increments and continually summed. Linear mathematics are used to solve the mesh network for every time interval. Included in the analysis are the three basic forms of heat transfer; i.e., conduction, radiation, and convection, as well as internal heat generation.

Given any odd-shaped structure, which is represented by a three-dimensional field, its geometry and physical properties, boundary conditions, and internal heat generation rates, TGRV calculates and gives as output the steady-state or transient temperature distributions in the structure as a function of time.

CB&I Program 962 - E0962A Program E0962A is one of a group of programs (E0953A, E1606A, E0962A, E0992N, E1037N, and E0984N) used together to determine the temperature distribution and stresses in pressure vessel components by the finite element method.

Program E0962A is primarily a plotting program. Using the nodal temperatures calculated by program E1606A or program E0928A, and the node and element cards for the finite element model, it calculates and plots lines of constant temperature (isotherms). These isotherm plots are used as part of the stress report to present the results of the thermal analysis. They are also very useful in determining at which points in time the thermal stresses should be determined.

In addition to its plotting capability, the program can determine the temperatures of some of the nodal points by interpolation. This feature of the program is intended primarily for use with the compatible TGRV and finite element models generated by program E0953A.

CB&I Program 984 Program 984 is used to calculate the stress intensity of the stress differences, on a component level, between two different stress conditions. The calculation of the stress intensity of stress component differences (the range of stress intensity) is required by ASME Section III.

CB&I Program 992 - GASP The GASP program, originated by Prof. E. L. Wilson of the University of California at Berkeley, uses the finite element method to determine the stresses and displacements of plane or axisymmetric structures of arbitrary geometry and is written in FORTRAN IV[2]. The structures may have arbitrary geometry and linear or nonlinear material properties. The loadings may be thermal, mechanical, accelerational, or a combination of these.

The structure to be analyzed is broken up into a finite number of discrete elements or finite elements which are interconnected at a finite number of nodal points or nodes. The actual loads on the structure are simulated by statically equivalent loads acting at the appropriate nodes. The basic input to the program consists of the geometry of the stress model and the boundary conditions. The program then gives the stress components at the center of each element and the displacements at the nodes, consistent with the prescribed boundary conditions.

<u>CB&I Program 1037 - DUNHAM'S</u> DUNHAM'S program is a finite ring element stress analysis program. It determines the stresses and displacements of axisymmetric structures of arbitrary geometry subjected to either axisymmetric loads or nonaxisymmetric loads represented by Fourier series. This program is similar to the GASP program (CB&I 992). The major differences are that DUNHAM'S can handle nonaxisymmetric loads (which requires that each node have 3 degrees of freedom) and the material properties for

DUNHAM'S must be constant. As in GASP, the loadings may be thermal, mechanical, and accelerational.

<u>CB&I Program 1335</u> To obtain stresses in the shroud support, the baffle plate must be considered as a continuous circular plate. This program makes this modification and allows the baffle plate to be included in CB&I Program 781 as two isotropic parts and an orthotropic portion at the middle (where the diffuser holes are located).

<u>CB&I Programs 1606 and 1657 - HAP</u> The HAP program is an axisymmetric nonlinear heat analysis program. It is a finite element program and is used to determine nodal temperatures in a two-dimensional or axisymmetric body subjected to transient disturbances. Programs 1606 and 1657 are identical except that 1606 has a larger storage area allocated and can thus be used to solve larger problems. The model for Program 1606 is compatible with CB&I stress Programs 992 and 1037.

<u>CB&I Program 1635</u> Program 1635 offers three features to aid the stress analyst in preparing a stress report:

1. Generates punched card input for Program 7-67 (PRINCESS) from the stress output of Program 781 (KALNINS).

2. Writes a stress table in a format that can be incorporated into a final stress report.

3. Has the option to remove through-wall thermal bending stress and report these results in a stress table similar to the one mentioned in Item 2.

<u>CB&I Program 953</u> The program is a general purpose program which does the following:

1. Prepares input cards for the thermal model.

2. Prepares the node and element cards for the finite element model.

3. Sets up the model in such a way that the nodal points in the TGRV model correspond to points in the finite element model.

They have the same number so that there is no possibility of confusion in transferring temperature data from one program to the other.

CB&I Program 1666 This program is primarily written to calculate the temperature differences at selected critical sections of the nuclear reactor vessel components at different time points of thermal transients during its life of operation and to list them all in a tabular form. Since there is no involved calculation applicable particularly to nuclear components, this program can be used with any other kind of model that is subjected to thermal transients over a period of time. This program helps ascertain the time points in thermal transients when the thermal stresses may be critical.

CB&I Program 1684 This program, an expansion of Program 984, is written to expedite the fatigue analysis of nuclear reactor components as required by ASME Section III. The features of this program allow the user to easily perform the complete secondary stress and fatigue evaluation including partial fatigue usage calculation of a component in one run. An additional option allows the user to completely document the input stress values in a format suitable for a stress analysis report. The program is written to allow for a minimum amount of data handling by the user once the initial deck is established.

CB&I Program E1702A This program evaluates the stress-intensity factor K_I due to pressure, temperature, and mechanical load stresses for a number of different stress conditions (times) and at a number of different locations (elements). It then calculates the maximum reference temperature nil ductility transition (RT_{NDT}) the actual material can have based on a 1/4T flaw size and compares it with the ordered RT_{NDT}. If the ordered RT_{NDT} is larger than the maximum RT_{NDT}, the maximum allowable flaw size is calculated. The rules of ASME Code Appendix G are used except that Welding Research Council (WRC) 175 can be used to calculate K_I due to pressure in a nozzle-to-shell junction.

For a more thorough description of the fracture problem, see WRC Bulletin No. 175[3].

CB&I Program 955 - MESHPLOT This program plots input data used for finite element analysis. The program plots the finite element mesh in one of three ways: without labels, with node labels, or with element labels. The output consists of a listing and a plot. The listing gives all node points with their coordinates and all elements with their node points. The plot is a finite element model with the requested labels.

CB&I Program 1028 This program calculates the necessary form factors for the nodes of the model that simulates heat transfer by radiation. Inputs are shape and dimensions of the head-to-skirt knuckle junction. The program is limited to junctions with a toroidal knuckle part.

CB&I Program 1038 This program calculates the loads required to satisfy the compatibility between the shroud baffle plate and the jet pump adaptors for a GE BWR vessel.

Vessel Internals

Fuel Support Loads Program - SEISM SEISM computes the vertical fuel support loads using the component element methods in dynamics[4].

Other Programs The following programs are also used in the analysis of core support structures and other safety-related reactor internals: MASS, SNAP (MULTISHELL), and HEATER. These programs are described in detail in Section 4.1.

pc-Crack Program The pc-Crack program performs linear elastic fracture mechanics, elastic-plastic fracture mechanics, and limit load, in accordance with applicable codes and standards, to establish crack growth and weld overlay design. Verification of this program has been performed in accordance with the requirements of 10CFR50 Appendix B.

3.9B.1.2.2 Piping

Piping Analysis Program - PISYS PISYS is a specialized computer code for piping load calculations. It utilizes selected stiffness matrices representing standard piping components, which are assembled to form a finite element model of a piping system. The technique relies on dividing the pipe model into several discrete substructures, called pipe elements, which are connected to each other via nodes called pipe joints. It is through these joints that the model interacts with the environment, and loading of the structure becomes possible. PISYS is based on linear classical elasticity in which the resultant deformation and stresses are proportional to the loading, and the superposition of loading is valid.

PISYS has a full range of static and dynamic analysis options that include distributed weight, thermal expansion, differential support motion modal extraction, response spectra, and time-history analysis by modal or direct integration. The PISYS program has been benchmarked against five NRC piping models for the option-of-response-spectrum analysis, and the results are documented in a report to the NRC, NEDO-24210[5].

Component Analysis - ANSI 7 The ANSI 7 program determines stress and accumulative usage factors in accordance with Subarticle NB-3600 of ASME Section III. The program was written to perform stress analysis in accordance with the ASME sample problem, and has been verified by reproducing the results of the sample problem analysis.

SUPERPIPE Computer Program The SUPERPIPE computer program is described in Appendix 3A.

Piping Dynamic Analysis Program - PDA The pipe whip analysis was performed using the PDA program to determine the response of a pipe subjected to the thrust force occurring after a pipe break. The program treats the situation in terms of a 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-dependent stress-strain relations are used to

model the pipe and the restraint. Similar to the popular elastic hinge concept, bending of the pipe is assumed to occur only at the fixed end and at the location supported by the restraint.

Shear deformation is neglected. The pipe bending moment-deflection (or rotation) relation used for these locations is obtained from a static nonlinear cantilever beam analysis.

Using moment-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.

<u>Piping Analysis Program - EZPYP</u> EZPYP links the ANSI-7 and SAP programs. The EZPYP program can be used to run several SAP cases by making user-specified changes to a basic SAP pipe model. By controlling files and SAP runs, the EZPYP program gives the analyst the capability to perform a complete piping analysis in one computer run.

3.9B.1.2.3 Recirculation Pump

The ANSYS code is used in the analysis of the recirculation pump casing for various thermal and mechanical loads during plant operating and postulated conditions.

In general, the finite element techniques are used to solve temperature distribution in heat transfer transient problems, and to perform stress analysis for various thermal and mechanical loadings by using the same finite element model representing the pump body. The output of these programs is in the form of temperature profiles, deflections, and stresses at the nodal points of the finite element idealization of the pump structure.

3.9B.1.2.4 Emergency Core Cooling System Pumps and Motors

<u>Structural Analysis Program - SAP4G</u> SAP4G is used to analyze the structural and functional integrity of the ECCS pump and motor systems. This is a general structural analysis program for static and dynamic analysis of linear elastic complex structures. The finite element displacement method is used to solve the displacements and stresses of each element of the structure. The structure can be composed of an unlimited number of three-dimensional truss, beam, plate, shell, solid, plate strain-plane stress and spring elements that are axisymmetric. The program can treat thermal and various forms of mechanical loading. The dynamic analysis includes mode superposition, time-history, and response spectrum analysis. Seismic loading and time-dependent pressure can be treated. The program is versatile and efficient in analyzing large and complex structural systems. The output contains displacements of each nodal point as well as stresses at the surface of each element.

Effects of Flange Joint Connections - FTFLGO1 The flange joints connecting the pump bowl castings are analyzed using FTFLGO1. This program uses the local forces and moments determined by SAP4G to perform flat flange calculations in accordance with the rules set forth in Appendix II and ASME Boiler and Pressure Vessel Code Section III.

Structural Analysis of Discharge Head - ANSYS ANSYS is used to analyze the pump discharge head flange and bolting taking into account the prying action developed by the flat face contact surface. The program is described in detail in Section 4.1.

Beam Element Data Processing - POSUM POSUM is a computer code designed to process SAP-generated beam element data for pump or heat exchanger models. The purpose is to determine the load combination that would produce the maximum stress in a selected beam element. It is intended to be used on RHR heat exchangers with four nozzles or ECCS pumps with two nozzles.

3.9B.1.2.5 RHR Heat Exchangers

Structural Analysis Program - SAP4G SAP4G is used to evaluate the structural and functional integrity of the RHR heat exchangers. A description of this program is provided in Section 3.9B.1.2.4.

Calculation of Shell Attachment Parameters and Coefficients/BILRD BILRD is used to calculate the shell attachment parameters and coefficients used in the stress analysis of the support-to-shell junction. The method, in accordance with WRC Bulletin No. 107, is implemented in BILRD to calculate local membrane stress due to the support reaction loads on the heat exchanger shell.

Beam Element Data Processing/POSUM POSUM is used to process SAP-generated beam element data. The description of this program is provided in Section 3.9B.1.2.4.

3.9B.1.2.6 Dynamic Load Analysis

Dynamic Analysis Program - DYSEA DYSEA simulates a beam model in the annulus pressurization dynamic analysis. A description of DYSEA is provided in Section 4.1. DYSEA employs a preprocessor program named GEAPL. GEAPL converts pressure time-histories into time-varying loads and forcing functions for DYSEA. The overall resultant forces and moments time-histories at specified points of resolution can also be obtained from GEAPL.

Acceleration Response Spectrum Program - SPECA SPECA generates acceleration response spectra for an arbitrary input time-history of piece-wise linear accelerations, i.e., to compute maximum acceleration responses for a series of single degree-of-freedom systems subjected to the same input. It can accept acceleration time-histories from a random file. It also can generate the broadened/enveloped spectra when the spectral points are generated equally spaced on a logarithmic scale axis of period/frequency. This program is also used in seismic and SRV transient analyses.

3.9B.1.3 Experimental Stress Analysis

The following sections list those NSSS components for which experimental stress analysis was used and provide a discussion of the analysis.

3.9B.1.3.1 Experimental Stress Analysis of Piping Components

The following components have been tested to verify their design adequacy:

1. Snubbers

2. Pipe whip restraints

Descriptions of the snubbers and pipe whip restraint tests are contained in Sections 3.9B.3.4 and 3.6B.2.2.2, respectively.

3.9B.1.3.2 Orificed Fuel Support, Vertical and Horizontal Load Tests

A series of horizontal and vertical load tests were performed on the orificed fuel support (OFS) in order to verify the design. Results from these tests indicate that the seismic and hydrodynamic loading of the OFS are below allowable load limits, with a safety margin of at least 2.0 for normal, upset and faulted conditions. (The allowable load limits were arrived at by applying a 0.75 quality factor to the ASME Code allowables of 0.44 x test load for upset and 0.80 x test load for faulted condition.)

3.9B.1.4 Considerations for the Evaluation of Faulted Conditions

Each item of Category I equipment is evaluated for faulted loading conditions. In all cases, calculated stresses are within the allowable limits. This section provides examples of the treatment of faulted conditions for the major components on a component-by-component basis. Additional discussion of faulted analysis is found in Sections 3.9B.3 and 3.9B.5, and Table 3.9B-2.

Sections 3.9B.2.2 and 3.7B discuss the treatment of dynamic loads resulting from the postulated faulted condition. Section 3.9B.2.5 discusses the dynamic analysis of loads on reactor internals resulting from blowdown. Deformations under faulted conditions have been evaluated in critical areas, and no cases have been identified where design limits, such as clearance limits, are exceeded.

3.9B.1.4.1 Control Rod Drive System Components

Control Rod Drives

The major CRD components that have been analyzed for the faulted conditions are the ring flange, main flange, and indicator tube. The maximum stresses for these components and for various plant operating conditions including the faulted condition are given in Table 3.9B-2a.

The ASME Section III Code components of the CRD have been analyzed for conditions in Section 3.9B.1.1.1. The loads and stresses are within the elastic limits of the material.

The design adequacy of noncode components of the CRD has been verified by extensive testing programs on both (Code and non-Code) component parts, specially instrumented prototype drives, and production drives. The testing has included postulated abnormal events as well as the service life cycle listed in Section 3.9B.1.1.1.

Hydraulic Control Unit

The seismic and hydrodynamic loads adequacy of the HCU is demonstrated by tests. Section 3.9B.2.2.2 discusses the dynamic qualification of the HCU.

3.9B.1.4.2 Standard Reactor Internal Components

Control Rod Guide Tube

The maximum calculated stress on the control rod guide tube occurs in its base during the faulted condition. Under the combination of primary membrane (general or local) plus bending stresses, the faulted limit is 3.6 S_m or 57,600 psi at the design temperature in accordance with ASME Section III, Table F 1322.2-1. According to ASME Section III, Appendix I, Table I-1.2, S_m = 16,000 psi at 575°F. The analysis and limiting stresses for various plant operating conditions are given in Table 3.9B-2b.

In-core Housing

The maximum calculated stress on the in-core housing occurs at the outer surface of the vessel penetration during the faulted condition. The allowable stress for the elastic analysis used is 2.4 S_m = 40,000 psi. The analysis for various operating conditions is summarized in Table 3.9B-2c which shows that the calculated stresses are within the allowables.

Jet Pump

The elastic analysis for the jet pump faulted conditions shows that the maximum stress is due to impulse loading of the diffuser during a pipe rupture and blowdown. The maximum allowable for this condition, in accordance with ASME Section III Appendix F is 3.6 S_m or 60,000 psi. Table 3.9B-2d summarizes the results of the stress analysis.

LPCI Coupling

The calculated stress at the highest stressed location is bounded by the allowable stress which is 3.6 S_m. Table 3.9B-2e summarizes the criteria, loading conditions, the calculated and allowable stresses.

Orificed Fuel Support

OFS is analyzed for the faulted condition. The analysis and testing are described in Section 3.9B.1.3.2. Results of the analysis are provided in Table 3.9B-2f.

CRD Housing

The CRD housing is analyzed for the faulted condition, considering SSE and hydrodynamic loads.

Table 3.9B-2g shows that the calculated stress values for the highly stressed areas of the CRD housing are within the allowable limits.

3.9B.1.4.3 Reactor Pressure Vessel Assembly

For the faulted condition, the RPV and the shroud support were evaluated using elastic analysis methods. For the support skirt and shroud support, an elastic analysis was performed, and buckling was evaluated for the compressive load.

The support skirt is designed in compliance with ASME III requirements for the Class 1 pressure-retaining portion of the vessel.

A generic BWR 4/5 study was conducted on the Limerick 1 and 2 cylindrical support skirt, which has the smallest ratio of thickness to radius. The study examined the skirt buckling under axial compression, hoop stress, and transverse shear (Section 3.9.6-13) and showed that, in each case, the critical buckling stress was much greater than the yield stress.

Since this study showed that inelastic stability limits the skirt integrity, the permissible compressive load is limited to 90 percent of the load which produces yield stress, divided by a safety factor of 1.125 for faulted conditions to account for the effects of fabrication or any eccentricity.

For faulted conditions, the RPV support skirt design can meet the allowable limit of two-thirds of the critical buckling stress in accordance with ASME Boiler and Pressure Vessel Code, Section III, paragraph F-1370(c). An analysis of the RPV support skirt shows that the design has the capability to meet this allowable stress at temperature.

Table 3.9B-2h lists the calculated and allowable stresses for the various load combinations.

3.9B.1.4.4 Core Support Structure

The core support structure is evaluated for the faulted condition. The bases for determining the faulted loads due to seismic and hydrodynamic events are discussed in Sections 3.7B and 3.9B.5, respectively. The calculated stresses and allowables are summarized in Table 3.9B-2i.

3.9B.1.4.5 Recirculation Gate, Safety/Relief Valves, and Main Steam Isolation Valves

Tables 3.9B-2j, 3.9B-2k, and 3.9B-2z provide a summary of the analysis of the SRV, recirculation gate valve, and MSIV, respectively.

Standard design rules, as defined in ASME Section III, are used in the analysis of pressure boundary components of Category I valves. Conventional, elastic stress analysis is used to evaluate components not defined in the Code. The Code allowable stresses are applied to determine acceptability of the structure under applicable loading conditions including the faulted condition.

3.9B.1.4.6 Recirculation System Flow Control Valve

The recirculation system FCV is analyzed for faulted conditions using the elastic analysis methods from ASME Section III. The analysis is summarized in Table 3.9B-2l.

3.9B.1.4.7 Recirculation Piping

For recirculation system piping, elastic analysis methods are used for evaluating faulted loading conditions. The equivalent allowable stresses using elastic techniques are obtained from the ASME Section III, Appendix F, and the calculated stresses are within these elastic limits. Additional information on the recirculation piping is in Table 3.9B-2m.

3.9B.1.4.8 Nuclear Steam Supply System Pumps, Heat Exchanger, and Turbine

The recirculation, ECCS, RCIC, and SLC pumps, RHR heat exchangers, and RCIC turbine have been analyzed for the faulted loading conditions identified in Section 3.9B.1.1. In all cases, stresses were within the elastic limits. The analytical methods, stress limits, and allowable stresses are summarized in Table 3.9B-2 in the respective equipment table.

3.9B.1.4.9 Control Rod Drive Housing Supports

The calculated stresses and the allowable stress limits for faulted conditions for the CRD housing supports are shown in Table 3.9B-2y.

3.9B.1.4.10 Fuel Storage Racks

Examples of the calculated stresses and stress limits for the faulted conditions for the new fuel storage racks are shown in Table 3.9B-2n.

3.9B.1.4.11 Fuel Assembly (Including Channels)

GE BWR fuel assembly design bases, analytical methods, and evaluation results, including those applicable to the faulted conditions, are contained in NEDE-24011[6], NEDE-24011-US[7], NEDE-21175-3-P[13], and NEDE-31152[20]; for GE 11 fuel, NEDE-31917P[17], for GE 14 fuel, NEDC-32868P[19] and GE-NE-0000-0016-5640-00[18]; and for GNF2 fuel, 003N2003[22] and NEDC-

33270P[23]. Maximum fuel horizontal and vertical acceleration values are summarized in Table 3.9B-2o.

3.9B.1.4.12 Refueling Equipment

Refueling equipment and servicing equipment that are important to safety are classified as essential components in accordance with the requirements of 10CFR50 Appendix A. This equipment and other equipment whose failure would degrade an essential component are defined in Section 3.9B.1 and are classified as Category I. These components are subjected to an elastic dynamic finite element analysis to generate loadings. This analysis utilizes appropriate seismic floor response spectra and combines loads at frequencies up to 33 Hz for seismic and up to 80 Hz for hydrodynamic 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 those allowed by Industrial Codes, ASME, ANSI, AISC, or Industrial Standards allowables.

The calculated stresses and allowable limits for the faulted condition for the fuel storage rack, fuel preparation machine, and refueling platform are documented in Table 3.9B-2n.

3.9B.2 Dynamic Testing and Analysis

3.9B.2.1 Piping Vibration, Thermal Expansion, and Dynamic Effects

The test program is divided into three phases: piping vibration, thermal expansion, and dynamic effects.

3.9B.2.1.1 Piping Vibration

Preoperational and Startup Vibration Testing of Recirculation Piping

The purpose of the preoperational vibration test phase is to verify that operating vibrations in the recirculation piping are within acceptable limits. This phase of the test uses visual observation to supplement remote measurements. If, during steady-state operation, visual observation indicates that vibration is significant, measurements are made with a hand-held vibrograph. Visual observations and manual and remote measurements are made during the following steady-state conditions:

1. Recirculation pumps at minimum flow.

2. Recirculation pumps at 50 percent of rated flow.

3. Recirculation pumps at 75 percent of rated flow.

4. Recirculation pumps at 100 percent of rated flow.

5. RHR suction piping at 100 percent of rated flow in the shutdown cooling mode.

Preoperational Vibration Testing of Small Attached Piping

During visual observation of test conditions 1 through 5, special attention will be given to small attached piping and instrument connections to ensure that they are not in resonance with the recirculation pump motors or flow-induced vibrations. If the operating vibrations acceptance criteria are not met, corrective action such as modification of supports will be undertaken.

Operating Transient Loads on Recirculation Piping

The purpose of the operating transient test phase is to verify that pipe stresses are within code limits. The amplitude of displacements and number of cycles per transient of the recirculation piping are measured and the displacements compared with acceptance criteria. The deflections are correlated with stresses to verify that the pipe stresses remain within Code limits. Remote vibration and deflection measurements are taken during the following transients:

1. Recirculation pump starts.

2. Recirculation pump trip at 100 percent of rated flow.

3. Turbine stop valve closure at 100 percent power.

4. Manual discharge of each SRV at 1,000 psig and at planned transient tests that result in SRV discharge.

3.9B.2.1.2 Thermal Expansion Testing of Recirculation Piping

A thermal expansion, preoperational and startup testing program, performed through the use of potentiometer sensors, has been established to verify that normal thermal movement occurs in the piping systems. The main purpose of this program is to ensure the following:

1. The piping system during system heatup and cooldown is free to expand, contract, and move without unplanned obstruction or restraint in the x, y, and z directions.

2. The piping system is working in a manner consistent with the assumption of the NSSS stress analysis.

3. There is adequate agreement between calculated values of displacements and measured value of displacement.

4. There is consistency and repeatability in thermal displacements during heatup and cooldown of the NSSS systems.

Limits of thermal expansion displacements are established prior to the start of piping testing to which the actual measured displacements are compared, to determine acceptability of the actual motion. If the measured displacement does not vary from the acceptance limits values by more than the specified tolerances, the piping system is responding in a manner consistent with predictions and is, therefore, acceptable. Two levels of displacement limits are established to check the systems as explained in Section 3.9B.2.1.4.

3.9B.2.1.3 Dynamic Effects Testing of Recirculation Piping

To verify that snubbers are adequately performing their intended function during plant operation, a program for dynamic testing, as a part of the normal startup operation testing, is planned. The main purpose of this program is to ensure the following:

1. The vibration levels from the various dynamic loadings during transient and steady-state conditions are below the predetermined acceptable limits.

2. Long-term fatigue failure does not occur due to underestimating the dynamic effects caused by cyclic loading during plant transient operations.

This dynamic testing is to account for the acoustic wave due to the SRV lifts (RV1), SRV load resulting from air clearing (RV2), and turbine stop valve closure (TSVC) load. The maximum stresses developed in the piping by the RV1, RV2, and TSVC transient analyses are used as a basis for establishing criteria that assure proper functioning of the snubbers. If field measurements exceed criteria limits, the snubbers are not operating properly. Sample production snubbers of each size (i.e., 10, 20, 50 kips) are qualified and tested for design and faulted condition loadings prior to shipment to the field. Snubbers are tested to allow free piping movements at low velocity. During plant startup, the snubbers are checked for proper settings.

The criteria for vibration displacements are based on assumed linear relationship between displacements, snubber loads, and the magnitude of applied loads for any function and response of system. Thus, the magnitude of limits of displacements, snubber loads, and nozzle loads are all proportional. Maximum displacements (Level 1 limits) are established to prevent the maximum stress in the piping systems from exceeding the normal and upset primary stress limits and/or the maximum snubber load from exceeding the maximum load to which the snubber has been tested.

Based on the above criteria, Level 1 displacement limits are established for all instrumented points in the piping system. These limits are compared with the field measured piping displacements. The method of acceptance is explained in the following section.

3.9B.2.1.4 Test Evaluation and Acceptance Criteria for Recirculation Piping

The piping response to test conditions is considered acceptable if the test results verify that the piping responded in a manner consistent with the predictions of the stress report and/or that piping stresses are within code limits (ASME Section III, Subarticle NB-3600). Acceptable deflection and acceleration limits are determined after the completion of piping system stress analysis and are provided in the startup test specifications. To ensure test data integrity and test safety, criteria have been established to facilitate assessment of the test while it is in progress. These criteria, designated Levels 1 and 2, are described in the following sections.

3.9B.2.1.4.1 Level 1 Criterion

Level 1 establishes the maximum limits for the level of pipe motion which, if exceeded, makes a test hold or termination mandatory. If the Level 1 limit is exceeded, the plant will be placed in a satisfactory hold condition, and the responsible piping design engineer will be advised. Following resolution, applicable tests must be repeated to verify that the requirements of the Level 1 limits are satisfied.

3.9B.2.1.4.2 Level 2 Criteria

If the Level 2 criteria are satisfied for both steady-state and operating transient vibrations, there will be no fatigue damage to the piping system due to steady-state vibration, and all operating transient vibrations are bounded by the values in the stress report.

Exceeding the Level 2 specified pipe motion requires that the responsible piping design engineer be advised. Plant operating and startup testing plans would not necessarily be altered. Investigations of the measurements, criteria, and calculations used to generate the pipe motion limits would be initiated. An acceptable resolution must be reached by all appropriate and involved parties, including the responsible piping design engineer. Detailed evaluation is needed to develop corrective action or show that the measurements are acceptable. Depending upon the nature of such resolution, the applicable tests may or may not have to be repeated.

3.9B.2.1.4.3 Acceptance Limits

For steady-state vibration, the piping peak stress due to vibration only (neglecting pressure) will not exceed 10,000 psi for Level 1 criteria and 5,000 psi for Level 2 criteria. These limits are below the piping material fatigue endurance limits defined in Design Fatigue Curves in Appendix I of the ASME Code for 10^6 cycles.

For operating transient vibration, the piping bending stress (zero to peak) will not exceed 1.2 S_m or pipe support loads will not exceed service Level D ratings for Level 1 criteria. The 1.2 S_m limit ensures that the total primary stress, including pressure and deadweight, will not exceed 1.8 S_m, the Code service Level B limit. Level 2 criteria are based on pipe stresses and support loads not exceeding design basis predictions. Design basis criteria require that operating transient stresses and loads not exceed any service Level B limits, including primary stress limits, fatigue usage factor limits, and allowable loads on snubbers.

3.9B.2.1.5 Corrective Actions for Recirculation Piping

During the course of the tests, the remote measurements are regularly checked to determine compliance with Level 1 criteria. If trends indicate that Level 1 criteria may be violated, the measurements are monitored at more frequent intervals. The test is interrupted as soon as Level 1 criteria are violated. As soon as possible after the test hold or termination, the following corrective actions are taken:

1. <u>Installation Inspection</u> A walkdown of the piping and suspension is made to identify any obstruction or improperly operating suspension components. If vibration exceeds criteria, the source of the excitation must be identified to determine if it is related to equipment failure. Action is taken to correct any discrepancies before repeating the test.

2. <u>Instrumentation Inspection</u> The instrumentation installation and calibration are checked, and any discrepancies are corrected. Additional instrumentation is added, if necessary.

3. <u>Repeat Test</u> If actions 1 and 2 identify discrepancies that could account for failure to meet the Level 1 criteria, the test will be repeated.

4. <u>Resolution of Findings</u> If the Level 1 criteria are violated on the repeat test, or no relevant discrepancies are identified as described in actions 1 and 2, the test results and criteria are reviewed to ensure that the test can be safely continued.

If the test measurements indicate failure to meet the Level 2 criteria, the following corrective actions are taken after completion of the test:

1. <u>Installation Inspection</u> A walkdown of the piping and suspension is made to identify any obstruction or improperly operating suspension components.

   Snubbers are installed at about the midpoint of the total range at operating temperature. Hangers are installed in their operating range between the hot and cold settings. If vibration exceeds limits, the source of the vibration is identified. Action is taken to correct any discrepancies.

2. <u>Instrumentation Inspection</u> The instrumentation installation and calibration are checked and any discrepancies are corrected.

3. <u>Repeat Test</u> If inspections described in actions 1 and 2 above identify a malfunction or discrepancy that could account for failure to comply with Level 2 criteria and appropriate corrective action has been taken, the test is repeated.

4. <u>Documentation of Discrepancies</u> If the test is not repeated, the discrepancies found under actions 1 and 2 are documented in the test evaluation report and correlated with the test condition. The test is not complete until the test results are reconciled with the acceptance criteria.

3.9B.2.1.6 Measurement Locations for Recirculation Piping

Remote shock and vibration measurements are made in the three orthogonal directions on the piping between the recirculation pump discharge and the first downstream valve. During preoperational testing prior to fuel load, visual inspection of the piping is made, and any visible vibration is measured with a hand-held instrument.

For each of the selected remote measurement locations, Level 1 and 2 deflection and acceleration limits are prescribed in the startup test specification.

3.9B.2.2 Seismic and Hydrodynamic Qualification of Safety-Related Mechanical Equipment

This section describes the criteria for dynamic qualification of safety-related mechanical equipment and the qualification testing and/or analysis applicable to this plant for all the major components on a component-by-component basis. In some cases, a module or assembly consisting of mechanical and electrical equipment is qualified as a unit (e.g., ECCS pumps). These modules are generally discussed in this section rather than in Sections 3.10B and 3.11. Dynamic load qualification testing for pumps and valves is also discussed in Section 3.9B.3.2. Electrical supporting equipment such as control consoles, cabinets, and panels that are part of the NSSS are discussed in Section 3.10B.

3.9B.2.2.1 Tests and Analysis Criteria and Methods

The ability of equipment to perform its safety-related function during and after the application of dynamic loads (earthquake) is demonstrated by tests and/or analysis. Selection of testing, analysis, or a combination of the two is determined by the type, size, shape, and complexity of the equipment being considered. When practical, equipment operability is demonstrated by testing. Otherwise, operability is demonstrated by mathematical analysis.

Equipment that is large, simple, and/or consumes large amounts of power is usually qualified by analysis or test to show that the loads, stresses, and deflections are less than the allowable maximum. Analysis testing is also used to show that there are no natural frequencies below 33 Hz for seismic loads and 60 Hz for hydrodynamic loads. If a lower natural frequency is discovered, dynamic tests may be conducted and, in conjunction with mathematical analysis, used to verify operability and structural integrity at the required dynamic input conditions. A similar dynamic test and/or analysis is performed for hydrodynamic loads over a frequency range to include contributions from all significant modes in the total response. When the equipment is qualified by dynamic test, the response spectrum or time-history of the attachment point is used in determining input motion.

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

Equipment being dynamically tested is mounted on a fixture that simulates the intended service mounting and causes no dynamic coupling to the equipment.

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

Random Vibration Input

When random vibration input is used, the actual input motion envelops the appropriate floor input motion at the individual modes. However, single frequency input such as sine waves can be used provided one of the following conditions is met:

1. The characteristics of the required input motion are dominated by one frequency.

2. The anticipated response of the equipment is adequately represented by one mode.

3. The input has sufficient intensity and duration to excite all modes to the required magnitude, in such a way that the testing response spectra envelop the corresponding response spectra of the individual modes.

Application of Input Motion

When dynamic tests are performed, the input motion is applied to one vertical and one horizontal axis simultaneously. However, if the equipment response along the vertical direction is not sensitive to the vibratory motion along the horizontal direction, and vice versa, then the input motion is applied to one direction at a time. In the case of single frequency input, the time phasing of the inputs in the vertical and horizontal directions are such that a purely rectilinear resultant input is avoided.

Fixture Design

The fixture design simulates the actual service mounting and causes no dynamic coupling to the equipment.

Prototype Testing

Equipment testing is conducted on prototypes of the equipment installed in this plant.

3.9B.2.2.2 Seismic and Hydrodynamic Load Qualification of Specific NSSS Mechanical Components

The following sections discuss the testing or analytical qualification of NSSS equipment. Seismic qualification is also described in Sections 3.9B.1.4, 3.9B.3.1, and 3.9B.3.2.

Jet Pumps

A dynamic analysis of the jet pumps is performed and stresses from the analysis are below the design allowables.

CRD and CRD Housing

The dynamic qualification of the CRD housing (with enclosed CRD) is done analytically, and the stress results of their analysis established the structural integrity of these components. Preliminary dynamic tests have been conducted to verify the operability of the CRD during a dynamic event. A simulated test, imposing a static bow in the fuel channels, is performed with the CRD functioning satisfactorily.

Core Support (Fuel Support and Control Rod Guide Tube)

A detailed analysis imposing dynamic effects due to seismic and hydrodynamic events showed that the maximum stresses developed during these events are much lower than the maximum allowed for the component material.

Hydraulic Control Unit

The seismic and hydrodynamic load adequacy of the HCU has been demonstrated by tests. A complete HCU assembly was qualified by multiaxis/multifrequency testing in the frequency range from 1 to 100 Hz. The required safety function of initiating reactor scram was demonstrated successfully.

Fuel Assembly (Including Channels)

GE BWR fuel channel design bases, analytical methods, and evaluation results, including seismic and hydrodynamic considerations, are contained in NEDE-24011[6], NEDE-24011-US[7], NEDE-21175-3-P[13], and NEDE-31152[20]; for GE 11 fuel, NEDE-31917P[17]; for GE14 fuel, NEDC-32868P[19] and GE-NE-0000-0016-5640-00[18]; and for GNF2 fuel, 003N2003[22] and NEDC-33270P[23]. Section 3.9B.1.4.11.

Recirculation Pump and Motor Assembly

Calculations were made to assure that the recirculation pump and motor assembly is designed to withstand the specific static equivalent seismic and hydrodynamic loads. The flooded assembly was analyzed as a free body supported by constant support hangers from the brackets on the motor mounting member with snubbers attached to brackets located on the pump case and the top of the motor frame.

Primary stresses due to horizontal and vertical seismic (including hydrodynamic) forces are considered to act simultaneously and are conservatively added directly. Horizontal and vertical dynamic forces are applied to mass centers, and equilibrium reactions are determined for motor and pump brackets.

ECCS Pump and Motor Assembly

The qualification of the ECCS pump and motor assemblies as a unit while operating under faulted conditions was provided in the form of a static earthquake-acceleration analysis. The maximum specified vertical and horizontal accelerations were constantly applied simultaneously in the worst-case combination and the results of the analysis indicate the pump is capable of sustaining these loadings without overstressing the pump components.

Analysis is used for qualification when motors are similar in design features and insulation to previously qualified motors. Differences in design features and insulation are identified in a comparison study or similarity analysis. Also included in this comparison study are data showing that the differences have no impact on qualification. In addition to the comparison study, motor unique seismic analysis is required to assure that the motors can handle the design loads.

A motor of similar design has been seismically qualified via a combination of static analysis and dynamic testing. The complete motor assembly has been seismically qualified via dynamic testing, in accordance with IEEE-344-1975. The qualification test program included demonstration of startup and shutdown capabilities, as well as no-load operability during seismic and hydrodynamic loading conditions.

RCIC Pump Assembly

The RCIC pump construction is a barrel-type on a large cross-section pedestal. The RCIC pump assembly is analytically qualified by static analysis for seismic and hydrodynamic loading as well as the design operating loads of pressure, temperature, and external piping loads. The results of this analysis confirm that the stresses are substantially less than the allowables.

Because of their large size and weight, pumps are not included in the test list. Analysis is the most viable qualification method.

RCIC Turbine Assembly

The RCIC turbine is qualified for seismic and hydrodynamic loads via a combination of static analysis and dynamic testing. The turbine assembly consists of rigid masses, wherein static analysis has been utilized, interconnected with control levers and electronic control systems, necessitating final qualification by dynamic testing. Static loading analysis has been employed to verify the structural integrity of the turbine assembly and the adequacy of bolting under operating and seismic loading conditions. The RCIC electrohydraulic system integrated with the turbine governing valve is of a safety-grade design. The entire turbine assembly has been tested for seismic qualification in accordance with IEEE-344-1975. The electrohydraulic system was in its operational modes during the test program. The qualification test program included demonstration of startup and shutdown capabilities, as well as no-load operability during seismic loading conditions.

The specification for seismic qualification of the RCIC turbine and its accessories states that they shall be capable of withstanding the specified seismic accelerations at all frequencies within the range of 0.25 to 33 Hz. Proper performance may be demonstrated by tests, analysis, or a combination of both. If all natural frequencies of the turbine, the component parts, and the accessories are greater than 33 Hz (as defined by test and/or analysis), a static load analysis may be performed. The seismic forces of each component or assembly are obtained by concentrating its mass at the center of mass and multiplying by the seismic acceleration (earthquake coefficient). The magnitude of the earthquake coefficients is 1.5 g for both horizontal and vertical. If component parts and/or accessories have natural frequencies below 33 Hz, these parts must be dynamically analyzed or tested, demonstrating satisfaction of the floor response spectra.

Standby Liquid Control Pump and Motor Assembly

Each of the two SLC pumps is a positive displacement pump and motor mounted on a common base plate that is qualified by static analysis.

The SLC pump and motor assembly is analytically qualified by static analysis for seismic and hydrodynamic loads as well as the design operating loads of pressure, temperature, and external piping loads. The results of this analysis confirm that the stresses are substantially less than 90 percent of allowable.

RHR Heat Exchangers

A dynamic analysis is performed to verify that the RHR heat exchanger can withstand seismic and hydrodynamic loads. Seismic testing is an impractical method to verify the seismic adequacy of passive equipment.

Standby Liquid Control Tank

The SLC storage tank is a cylindrical tank, 9 ft in diameter and 12 ft high, bolted to the concrete floor. The SLC tank is qualified for seismic and hydrodynamic loads by analysis for:

1. Stresses in the tank bearing plate.

2. Bolt stresses.

3. Sloshing loads imposed at natural frequency of sloshing = 0.58 Hz.

4. Minimum wall thickness.

5. Buckling.

The results of the analysis confirm that stresses are less than the allowables.

Main Steam Isolation Valves

The MSIVs are qualified for seismic and hydrodynamic loads by analysis and test.

The fundamental requirement of the MSIV following a SSE or other faulted hydrodynamic loading is to close and remain closed after the event. This is demonstrated by the test and analysis as outlined in Section 3.9B.3.2.3.

Main Steam Safety/Relief Valves

Due to the complexity of the structure and the performance requirements of the valve, the total assembly of the SRV (including electrical, pneumatic devices) is dynamically tested at seismic acceleration equal to or greater than the combined SSE and hydrodynamic loading determined for this plant. Satisfactory operation of the valves was demonstrated during and after the test.

3.9B.2.3 Dynamic Response of Reactor Internals Under Operational

The major reactor internal components are subjected to extensive testing coupled with dynamic system analyses to properly describe the resulting flow-induced vibration phenomena incurred from normal reactor operation and anticipated operational transients.

In general, the vibration forcing functions for operational flow transients and steady-state conditions are not predetermined by detailed analysis. Special analysis of the response signals measured for reactor internals of many similar designs are performed to obtain the parameters that determine the amplitudes and modal contributions in the vibration responses. These studies provide useful predictive information for extrapolating the results from tests of components with similar designs to components of different designs. This vibration prediction method is appropriate where standard hydrodynamic theory cannot be applied due to the complexity of the structure and flow conditions. Elements of the vibration prediction method are outlined as follows:

1. Dynamic analysis of major components and subassemblies is performed to identify vibration modes and frequencies. The

analysis models used for Category I structures are similar to those outlined in Section 3.7B.2.

2. Data from previous plant vibration measurements are assembled and examined to identify predominant vibration response modes of major components. In general, response modes are similar, but response amplitudes vary among BWRs of differing size and design.

3. Parameters are identified that are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions.

4. Correlation functions of the variable parameters are developed which, multiplied by response amplitudes, tend to minimize the statistical variability between plants. A correlation function is obtained for each major component and response mode.

5. Predicted vibration amplitudes for components of the prototype plant are obtained from these correlation functions, based on applicable values of the parameters for the prototype plant. The predicted amplitude for each dominant response mode is stated in terms of a range, taking into account the degree of statistical variability in each of the correlations. The predicted mode and frequency are obtained from the dynamic analyses of Item 1 above.

The dynamic modal analysis also forms the basis for interpretation of the preoperational and initial startup test results (Section 3.9B.2.4). Modal stresses are calculated, and relationships are obtained between sensor response amplitudes and peak component stresses for each of the lower normal modes. The allowable amplitude in each mode is that which produces a peak stress amplitude of ±10,000 psi.

3.9B.2.4 Preoperational Flow-Induced Vibration Testing of Reactor Internals

Vibration testing of reactor internals is performed on all GE BWR plants. At the time of the original issue of AEC RG 1.20, test programs for compliance were instituted. The first BWR 5 plant of each size is considered a prototype and is instrumented and subjected to preoperational and startup flow testing to demonstrate that flow-induced vibrations similar to those expected during operation cause no damage. Subsequent plants that have internals similar to those of the prototypes are also tested in compliance with the requirements of RG 1.20.

Unit 2 reactor internals will be tested in accordance with RG 1.20, Revision 2, for nonprototype, Category IV plants using Tokai-2 as the limited valid prototype. The test procedure will require vibration measurements to determine the vibration characteristics of vessel internals during the initial power ascension. Vibratory responses at various power levels and recirculation flow rates are recorded using accelerometers on the shroud head assembly and strain gauges on two selected jet pump riser pipe braces.

Reactor internals for Unit 2 are substantially the same as the internals design configurations that have been tested in prototype BWR 4 plants. Exceptions are the jet pumps, which are of the BWR 5 design. A vibration measurement and inspection program has been conducted at Tokai-2 to verify the design of the jet pumps with respect to vibration. Results of the prototype tests are presented in NEDE-24057-P (Class III) and NEDO-24057 (Class I)[8].

3.9B.2.5 Dynamic System Analysis of Reactor Internals Under Faulted Conditions

To ensure that no significant dynamic amplification of load occurs as a result of the oscillatory nature of the blowdown forces, a comparison is made of the periods of the applied forces and the natural periods of the core support structures being acted upon by the applied forces. These periods are determined from a 12-node vertical dynamic model of the RPV and internals. In addition to the real masses of the RPV and core support structures, hydrodynamic masses including fluid-structure interaction effects are accounted for.

Time-varying pressures are applied to the dynamic model of the reactor internals described above. Except for the nature and locations of the forcing functions and the dynamic model, the dynamic analysis method is identical to that described for seismic analysis and is detailed in Section 3.7B.2.1. The dynamic components of forces from these loads are combined with dynamic force components from other dynamic loads (including seismic and hydrodynamic), all acting in the same direction, by the SRSS method. This resultant force is then combined with other steady-state and static loads on an absolute sum basis to determine the design load in a given direction. Results of the dynamic analysis are summarized in Table 3.9B-2i.

3.9B.2.6 Correlations of Reactor Internals Vibration Tests With Analytical Results

Prior to initiation of the instrumented vibration test program for the prototype plant, extensive dynamic analyses of the reactor and internals were performed. The results of these analyses were used to generate the allowable vibration levels during the vibration test. The vibration data obtained during the test were analyzed in detail. The results of the data analysis, vibration amplitudes, natural frequencies, and mode shapes were then compared to those obtained from the theoretical analysis.

Such comparisons provided insight into the dynamic behavior of the reactor internals. The additional knowledge gained was utilized in the generation of the dynamic models for seismic and LOCA analyses for this plant. The models used for this plant are similar to those used for the vibration analysis of the prototype plant, Tokai-2.

3.9B.3 ASME Section III, Safety Class 1, 2, and 3 Components, Component Supports, and Core Support Structures

3.9B.3.1 Load Combinations, Design Transients, and Stress Limits

This section delineates criteria for selection and definition of design limits and load combinations associated with normal operation, postulated accidents, and specified seismic and hydrodynamic events for the design of safety-related ASME Code NSSS components.

This section also lists the major ASME Section III, Safety Class 1, 2, and 3, NSSS pressure parts and associated equipment on a component-by-component basis and identifies the applicable loadings, calculation methods, calculated stresses, and allowable stresses. Design transients for ASME Section III, Safety Class 1 equipment are addressed in Section 3.9B.1.1. Seismic-related loads are discussed in Section 3.7B. The hydrodynamic loads are described in the Mark II Containment Dynamic Forcing Functions Information Report (DFFR)[9].

Table 3.9B-2 is the major part of this section; it presents the load combinations, analytical methods (by reference or example), and calculated stress or other design values for the most critical areas in the design of each component. These values are also compared to applicable Code allowables. Table 3.9B-2 presents the generic load combinations required to be considered for the design and analysis of a plant, and is applicable to all ASME Safety Class 1, 2, and 3 component supports and core support structures.

3.9B.3.1.1 Plant Conditions

All events that the plant might credibly experience during a reactor year are evaluated to establish a design basis for plant equipment. These events are divided into four plant conditions. The plant conditions described in the following sections are based on event probability (i.e., frequency of occurrence) and correlated design conditions defined in the ASME Section III.

<u>Normal Condition</u>

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

<u>Upset Condition</u>

Upset conditions are any deviations from normal conditions anticipated to occur often enough that design should include a capability to withstand the conditions without operational impairment. The upset conditions include transients that result from any single Operator error or control malfunction, transients caused by a fault in a system component requiring its isolation from the system, and transients due to loss of load or power. Vibrations due to OBE are conservatively treated as upset. Hot standby with the main condenser isolated is an upset condition.

Emergency Condition

Emergency conditions are deviations from normal conditions that require shutdown for correction of the conditions or repair of damage in the RCPB. These conditions have a low probability of occurrence, but are included to provide assurance that no gross loss of structural integrity results as a concomitant effect of any damage developed in the system. Emergency condition events include, but are not limited to, transients caused by one of the following: a multiple valve safety/relief blowdown of the reactor vessel; loss of reactor coolant from a small break or crack that does not depressurize the reactor system or result in leakage beyond normal makeup system capacity, but which requires the safety functions of isolation of containment and reactor shutdown; improper assembly of the core during refueling; and vibration of an OBE in combination with associated system transients.

Faulted Condition

These are combinations of conditions associated with extremely low probability, postulated events whose consequences are such that the integrity and operability of the system may be impaired to the extent that considerations of public health and safety are involved. Faulted conditions encompass events that are postulated because their consequences would include the potential for the release of significant amounts of radioactive material. These postulated events are the most drastic that must be designed against and thus represent limiting design bases. Faulted condition events include, but are not limited to, one of the following: a control rod drop accident (CRDA), a fuel handling accident, a MSL break, a recirculation loop break, the combination of any pipe break plus the seismic motion associated with a SSE and hydrodynamic loads plus a LOOP, or the SSE.

Correlation of Plant Conditions with Event Probability

The probability of an event occurring per reactor year associated with the plant conditions is listed below. This correlation can be used to identify the appropriate plant condition for any hypothesized event or sequence of events.

Plant Condition	Event Encounter Probability Per Reactor Year
Normal (planned)	1.0
Upset (moderate probability)	$1.0 > P > 10^{-2}$
Emergency (low probability)	$10^{-2} > P > 10^{-4}$
Faulted (extremely low probability)	$10^{-4} > P > 10^{-6}$

Safety Class Functional Criteria

For any normal or upset design condition event, Safety Class 1, 2, and 3 equipment is capable of accomplishing its safety functions as required by the event and incurs no permanent changes that adversely affect its ability to accomplish its safety functions as required by any subsequent design condition event.

For any emergency or faulted design condition event, Safety Class 1, 2, and 3 equipment is capable of accomplishing its safety functions as required by the event, but repairs could be required to ensure its ability to accomplish its safety functions as required by any subsequent design condition event.

Compliance with Regulatory Guide 1.48 RG 1.48 was issued after the design of this plant was established and was therefore not used as a design basis requirement. However, GE design basis was representative of good industry practices at the time of design, procurement, and manufacture and is shown to be in general agreement with the requirement of RG 1.48 through the use of the alternate approach cited in Table 3.9B-3.

RG 1.48 delineates acceptable design limits and appropriate combinations of loadings associated with normal operation, postulated accidents, and specified seismic events for the design of the Category I fluid system components.

For a comparison of NSSS compliance with RG 1.48 refer to Table 3.9B-3. This comparison reflects general GE practice on BWR 5 plants and therefore is applicable to this plant.

3.9B.3.1.2 Reactor Pressure Vessel Assembly

The RPV assembly consists of the RPV support structure and shroud support. The RPV support structure and shroud support are constructed in accordance with ASME Section III. The shroud support consists of the shroud support plate and the shroud support cylinder and its legs. The RPV assembly components are classified as ASME Safety Class 1. Complete stress reports on these components have been prepared in accordance with ASME requirements. Table 3.9B-2h summarizes the loading conditions, calculated stresses, and allowables. The stress analyses performed for the reactor vessel assembly, including the faulted conditions, were completed using elastic methods. Except as noted in Section 3.9B.1.4.3, the load combinations and stress analyses for the core support structure and other reactor internals are discussed in Section 3.9B.5.

3.9B.3.1.3 Main Steam Piping

The main steam piping is discussed in Section 3.9A.

3.9B.3.1.4 Recirculation Loop Piping

The recirculation system piping bounded by the RPV nozzles is designed in accordance with ASME Section III, Subarticle NB-3600. The load conditions, stress criteria, calculated stresses, and allowables are shown in Table 3.9B-2m. The rules contained in Appendix F of ASME

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 Appendix F.

3.9B.3.1.5 Recirculation System Valves

The recirculation system flow control and suction and discharge gate valves are designed in accordance with ASME Section III, Safety Class 1, Subarticle NB-3500. These valves are not required to operate under the SSE. Load combinations and other stress analysis information are presented in Tables 3.9B-2l (FCVs) and 3.9B-2k (gate valves).

3.9B.3.1.6 Recirculation Pump

In the design of the recirculation pumps, the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1971 Edition with latest addenda was used as a guide in calculations made for determining the thickness of pressure-retaining parts and in sizing the pressure-retaining bolting.

The pump vendor made calculations for the design of the pressure-containing components to include the determination of minimum wall thickness, allowable stress, and pressures. The loading conditions and other stress analysis information are presented in Table 3.9B-2p.

Load, shear, and moment diagrams were constructed to scale, using live loads, dead loads, and calculated snubber reactions. Combined bending, tension, and shear stresses were determined for each major component of the assembly, including the pump driver mount, motor flange bolting, and pump case. The maximum combined tensile stress in the cover bolting was calculated using tensile stress from design pressure. Combined primary stresses did not exceed 150 percent of the Code allowable stress shown in Section VIII of the ASME Boiler and Pressure Vessel Code, 1971 Edition. These methods and calculations demonstrate that the pump will maintain pressure integrity at all times.

3.9B.3.1.7 Standby Liquid Control Tank

The SLC tank is designed in accordance with ASME Boiler and Pressure Vessel Code, Section III. The loading conditions, stress criteria, calculated stresses, and allowables are summarized in Table 3.9B-2q.

3.9B.3.1.8 Residual Heat Removal Heat Exchangers

The RHR heat exchangers are designed in accordance with the ASME Boiler and Pressure Vessel Code Section III. The calculated stresses and allowables are shown in Table 3.9B-2r.

3.9B.3.1.9 RCIC Turbine

Although not under the jurisdiction of the ASME Code, the RCIC turbine is designed and fabricated following the basic guidelines for an ASME Section III, Safety Class 2 component.

Design conditions for the RCIC turbine include:

1. Turbine inlet - 1,250 psig at saturated temperature.

2. Turbine exhaust - 165 psig at saturated temperature.

Table 3.9B-2s summarizes the criteria, calculated stresses, and allowables for the RCIC turbine components.

3.9B.3.1.10 RCIC Pump

The RCIC pump is designed and fabricated to the requirements for an ASME Section III Safety Class 2 component. Operating conditions for the RCIC pump are tested under surveillance together with the RCIC turbine. A 92-day operation test is performed where the RCIC pump takes condensate from the CST and at design flow discharges condensate back to the CST via a closed test loop.

Design conditions for the RCIC pump include:

1. Available NPSH minimum — 23 ft

2. Total head

   High speed — 3,080 ft
   Low speed — 610 ft at 165 psia reactor pressure

3. Constant flow rate — 660 gpm

4. Normal ambient operating temperature — 60° to 100°F

5. Normal plus upset conditions which control the pump design include:

   Design pressure — 1,525 psig
   Design temperature — 40° min - 140°F max
   OBE — 2/3 of SSE

Table 3.9B-2t contains a summary of the design calculations for the RCIC pump components.

3.9B.3.1.11 ECCS Pumps

The RHR, LPCS, and HPCS pumps are designed and fabricated to the requirements of ASME Section III.

Table 3.9B-2u summarizes the design calculations for the ECCS pumps.

3.9B.3.1.12 Standby Liquid Control Pump

The SLC pump is designed and fabricated following the requirements for an ASME Section III, Safety Class 2 component. Operating conditions for the SLC pump and motor are functionally tested by pumping demineralized water through a closed test loop. The SLC pump is capable of injecting the net contents of the storage tank into the reactor in 50 to 125 min. The pump is capable of injecting flow into the reactor against zero psig up to the initial setpoint of the reactor relief valves.

Design conditions for the SLC pump include:

1.	Flow rate	45 gpm
2.	Available NPSH, maximum	12.9 psi
3.	Maximum operating discharge pressure	1,355.8 psig
4.	Ambient conditions:	
	Temperature	70° - 104°F
	Relative humidity	20 - 95%
5.	Normal plus upset conditions that control the pump design include:	
	Design pressure	1,600 psig
	Design temperature	150°F
	OBE	2/3 of SSE

A summary of the design calculations for the SLC pump components is provided in Table 3.9B-2v.

3.9B.3.1.13 Main Steam Isolation and Safety/Relief Valves

The MSIVs and SRVs are designed in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section III, Subarticle NB-3500, Safety Class 1 components. Load combination, analytical methods, calculated stresses, and allowable limits for the SRVs and MSIVs are shown in Tables 3.9B-2j and 3.9B-2z.

3.9B.3.1.14 Reactor Water Cleanup System Pump and Heat Exchangers

The RWCU pump and regenerative and nonregenerative heat exchangers are not part of a safety system and are not designed to Category I requirements.

The requirements of ASME Boiler and Pressure Vessel Code, Section III, Safety Class 3 components are used as guidelines in evaluating the RWCU system pump and heat exchanger components. The loading conditions, stress criteria, and calculated and allowable stresses are summarized in Tables 3.9B-2w and 3.9B-2x.

3.9B.3.2 Pump and Valve Operability Assurance

The active pumps and valves are listed in Table 3.9B-4. Active mechanical equipment classified as Category I is designed to perform its functions during the life of the plant under postulated plant conditions. Equipment with faulted condition functional requirements includes active pumps and valves in fluid systems such as the ECCS and MSS system. (Active equipment must perform a mechanical motion during the course of accomplishing a safety function.)

Safety-related valves are qualified by testing and analysis, and satisfy stress and deformation criteria at critical locations. Operability is assured by satisfying the requirements of the programs detailed in the following sections.

3.9B.3.2.1 ECCS Pumps and Motors

All active pumps and motors are qualified for operability by first being subjected to rigorous tests before and after installation in the plant. The in-shop tests include 1) hydrostatic tests of pressure-retaining parts to 125 percent of the design pressure (multiplied by the ratio of material allowable stress at room temperature to the allowable stress value at the design temperature), 2) seal leakage tests, and 3) performance tests, while the pump is operated with flow, to determine total developed head, minimum and maximum head, and NPSH requirements. Also monitored during these operating tests are bearing temperatures (except water-cooled bearings) and vibration levels. Both are shown to be below specified limits. After the pump is installed in the plant, it undergoes preservice tests, functional tests, and the required periodic inservice inspections and inservice tests. These tests demonstrate reliability of the pump for the design life of the plant.

In addition to these tests, the safety-related active pumps are analyzed for operability during a faulted condition by imposing the following criteria: 1) the pump is not damaged during the faulted event, and 2) the pump continues operating despite the faulted loads.

<u>Analysis of Loading, Stress, and Acceleration Conditions</u>

To avoid damage during the faulted plant condition, the stresses caused by the combination of normal operating loads, SSE, hydrodynamic, and dynamic system loads are limited to the material elastic limit, as indicated in Section 3.9B.3.1 and Table 3.9B-2.

A three-dimensional finite element model of the pump/motor and its support was developed and dynamically analyzed using the response spectrum analysis method. The same model was analyzed for static nozzle loads, pump thrust loads, and deadweight. Critical location stresses were evaluated and compared with the allowable stress criteria. Critical location deflection and acceleration were evaluated to assure operability. The maximum seismic nozzle loads from the attached piping system are also considered in an analysis of the pump support to assure that there will be no geometric/dimensional deformation of the pump components.

Since the pumps and motors are structurally coupled, the dynamic acceleration values at the motor were obtained by performing a pump/motor response spectrum dynamic analysis to transfer the floor RRS to the motor and determine the peak vibration acceleration amplitude at the point of highest acceleration in the motor. This analysis showed that the maximum acceleration was less than the values used in the detailed motor analyses.

Pump Operation During and Following SSE Loading

Active 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 rotor and the nature of the random, short duration loading characteristics of the seismic event prevent the rotor from becoming seized. In actuality, the seismic and hydrodynamic loadings cause only a slight increase, if any, in the torque (i.e., motor current) necessary to drive the pump at the constant design speed. Therefore, the pump does not shut down during the faulted load and continues to operate at the design speed.

The functional ability of the active pumps after a faulted condition is assured since only normal operating loads and steady-state nozzle loads exist. For the active pumps, the faulted condition is greater than the normal condition only due to seismic SSE and hydrodynamic loads on the equipment. These events are infrequent and of relatively short duration compared to the design life of the equipment.

Since it is demonstrated that the pumps are not damaged during the faulted event, the postfaulted condition operating loads are no worse than the normal plant operating limits. This is ensured by requiring that the imposed nozzle loads (steady-state loads) for normal conditions and postfaulted conditions are limited by the magnitudes of the normal condition nozzle loads. The postfaulted condition ability of the pumps to function under these applied loads is proven during the normal operating plant conditions for active pumps.

ECCS Motors

The analysis of the ECCS motors is performed by a computer program that consists of the mechanical analysis of the motor rotor assembly when acted upon by external forces including magnetic and centrifugal forces at any point along the shaft. The calculation for the seismic and hydrodynamic condition assumes that the motor is operating and the seismic, hydrodynamic, magnetic, and centrifugal forces all act simultaneously and in phase on the rotor shaft assembly. Other components of the motor, such as stator frame, lower-end shield, stator supports, base fasteners, top cap, and conduit box, are checked for the combined effects of seismic, self-weight, hydrodynamic, and operational loads, including consideration of bending, shear, torsion, and direct bearing loads.

The analysis and tests that are used for qualifications of ECCS pump motors were performed on an ECCS test motor of very similar mechanical construction.

The type test has been performed on a 1,250-hp vertical motor in accordance with IEEE-323-1974, by first simulating normal operation during the design life, then with the motor being subjected to a number of seismic and hydrodynamic events, and to the abnormal environmental conditions possible during and after a LOCA.

The test plan for the type test was as follows:

1. Thermal aging of the motor electrical insulation system (which is a part of the stator only) was based on extrapolation in accordance with the temperature life characteristic curve to satisfy the requirements of IEEE-275-1966 and from test data for the insulation type used on the ECCS motors. The amount of aging was equivalent to the total estimated days at maximum insulation temperature.

2. Radiation aging of the motor electrical insulation equals the maximum estimated integrated dose of gamma during normal and abnormal conditions.

3. The dynamic deflection analysis on the rotor shaft, performed to ensure adequate rotation clearance, has been verified by static loading and deflection of the rotor for the type test motor.

4. Dynamic load aging and testing has been performed on a biaxial test table in accordance with IEEE-344-1975. During this type test the shake table input simulated the maximum design limit of the SSE and hydrodynamic loads, combined with motor starts and operational combinations that may possibly occur during plant life. The acceleration values of the motor in the type test were significantly higher than those found in the structurally-coupled motor and pump dynamic analyses.

5. An environmental test simulating a LOCA condition with 100-days duration time has been performed with the test motor fully loaded, simulating pump operation. The test consisted of startup and 6-hr operation at 212°F ambient temperature and 100-percent steam environment. Another startup and operation of the test motor after 1-hr standstill in the same environment was followed by sufficient operation at high humidity and temperature, based on extrapolation in accordance with the temperature life characteristic curve to satisfy the requirements of IEEE-275-1966 for the insulation type used on the ECCS motors.

3.9B.3.2.2 SLC Pump and Motor Assembly and RCIC Pump Assembly

These equipment assemblies are small, compact, rigid assemblies, with natural frequencies well above 33 Hz. With this fact verified, each equipment assembly has been seismically qualified by static analysis. This static qualification verifies operability under seismic conditions, and assures structural loading stresses within Code limitations.

3.9B.3.2.3 NSSS Valves

3.9B.3.2.3.1 Safety Class 1 Active Valves

The Safety Class 1 active valves are the MSIVs, SRVs, SLC valves, and HPCS injection valves. Each of these valves is designed to perform its mechanical function in conjunction with a DBA including hydrodynamic loads. Qualification for operability is unique for each valve type. The method of qualification is described below.

Main Steam Isolation Valves

The MSIVs are evaluated for operability during seismic and hydrodynamic load events by both analysis and test.

1. The valve body is designed in accordance with ASME Code Section III, Subsection NB (Table 3.9B-2z), which limits deformation to within the elastic limit of the material by limiting pressure and pipe reaction input loads (including seismic and hydrodynamic loads). This ensures that only small deformations are allowed in the operating area of the valve body, hence, no interference with valve operability.

2. The entire topworks assembly was dynamically qualified by a bidirectional, random-frequency shake test. The loadings include SRV aging, OBE and SSE motions, and chugging motions. The SRV aging lasted 15 min for each pair of vertical axes and one of the two major horizontal axes. The motion simulation involved 5 intervals of 30 sec each for the 2 bidirectional combinations. The SSE simulation involved 1 interval of 30 sec each for the two bidirectional combinations. The chugging motion involved 15 min of bidirectional loadings lasting 15 min for each pair of major orthogonal axes. The testing covered seismic and hydrodynamic loads. The TRS exceeded the RRS by 10 percent. During each test interval, the MSIV topworks was cycled from full open to full closed to demonstrate operability. After the complete dynamic test program, the MSIV topworks was again cycled to ensure operability.

   Pipe anchors and restraints are provided in such a way as to limit the dynamic response and amplified accelerations to within design limits for the MSIVs. The mathematical modeling of the assembly accounts for the natural frequencies of the assembly as determined by the analysis and confirmed by a generic test.

The actuator solenoid valve cluster assemblies for the MSIVs have been changed from the original design. The cluster assembly was evaluated for operability during seismic and hydrodynamic load events using the same test intervals and combinations as addressed above. The RRS used for testing were generated at the MSIV/actuator solenoid valve cluster assembly interface. In certain low-frequency ranges, the TRS did not envelop the corresponding RRS. However, in the frequency range of interest (above 0.85 times the replacement cluster's fundamental frequency), the TRS does envelop the corresponding RRS.

3. MSIV operability following a downstream line break was demonstrated by the "state line test," as defined in the report APED-5750 (March 1969)[14]. The test specimen was a 20-in valve of a design representative of the MSIVs.

Main Steam Safety/Relief Valves

SRVs are qualified by test for operability during a seismic and hydrodynamic loading event. Each valve is designed for maximum moments that may be imposed when installed in service. These moments are resultants due to deadweight plus seismic and hydrodynamic loading of both the valve and the connecting pipe, the thermal expansion of the connecting pipe, and the reaction forces from valve discharge.

The SRVs were qualified by testing for seismic and hydrodynamic loads. The natural frequencies were determined to be greater than 33 Hz for seismic and 60 Hz for hydrodynamic loading.

The SRV design has been upgraded to NUREG-0588 Category 1 requirements. The SRV qualification program consists of:

1. Radiation aging of electropneumatic actuator assembly for a 5-yr (minimum) period.

2. Thermal aging of the SRV assembly for a 5-yr (minimum) period at 300°F.

3. Thermal cycling of the SRV from 135°F to 220°F back to 135°F 80 times and simultaneously actuating the SRV assembly approximately 130 times during the environmental transient condition.

4. Mechanical cycling of the SRV assembly 1,250 times in a 150°F ambient environment before subjecting the actuator assembly to a series of external pressurization tests.

The dynamic tests for SRV assembly envelope the Unit 2 RRS and hydrodynamic loading condition. The dynamic testing consists of vibration aging in accordance with IEEE-382-1980, 40-yr equivalent hydrodynamic aging, and upset and faulted loading conditions. SRV operability was demonstrated by periodically actuating (opening and closing) the valve successfully without malfunction.

<u>Standby Liquid Control (Explosive) Valve</u>

The SLC valve has been qualified by test in compliance with NUREG-0588, Category 1 requirements. The qualification includes compliance with IEEE-323-1974, IEEE-344-1975, and IEEE-382-1980. Prior to seismic and hydrodynamic testing, the explosive valve was subjected to radiation and thermal aging. No mechanical cycling was performed since this valve is designed for one-time use and, therefore, not subjected to operational cycles. Fatigue testing due to pipe-induced vibration, however, was performed by simulating SRV, OBE, and SSE loads to demonstrate functional operability.

<u>HPCS Gate Valve</u>

There is one Class 1 HPCS valve. This valve is a motor-operated gate valve. The valve body design, analysis, and testing is in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Class 1 requirements. The environmental testing (radiation, thermal, and mechanical aging) in accordance with IEEE-382-1980 and dynamic testing per IEEE-344-1975 of a specimen motor actuator will be performed for the equivalent of 40-yr normal environment and 100-day post-LOCA environment to demonstrate functional operability.

3.9B.3.2.3.2 Safety Class 2 and 3 Active Valves

There are six HPCS gate valves and four CRD globe valves in this category. There is no Class 3 active valve in the NSSS scope of supply.

<u>HPCS Gate Valves</u>

These MOVs are qualified by testing valves that are generally typical of the valves supplied by GE. Operability is ensured by testing at the static design basis load. The actuators are qualified to IEEE-382-1980 to levels that exceed the design loadings.

<u>CRD Globe Valves</u>

These four CRD SDV vent and drain valves are air-operated globe valves. They were dynamically qualified by test, in accordance with IEEE-344-1975, to demonstrate operational and structural integrity under seismic and hydrodynamic load conditions.

3.9B.3.3 Design and Installation of Pressure Relief Devices

3.9B.3.3.1 Main Steam Safety/Relief Valves

SRV valve opening results in a transient that produces momentary unbalanced forces acting on the discharge piping system for the period from opening of the SRV until a steady discharge flow from the RPV to the suppression pool is established. This period includes clearing of the water slug from the end of the discharge piping submerged in the suppression pool. Pressure waves traveling through the discharge piping following the relatively rapid opening of the SRV cause the SRV discharge piping to vibrate. This in turn produces forces that act on the main steam piping.

The analysis of the relief valve discharge transient consists of a stepwise time-history solution of the fluid flow equation to generate a time-history of the fluid properties at numerous locations along the pipe. The fluid transient properties are calculated based on the maximum SRV set pressure specified in the steam system specification, and the value of the ASME flow rating increased by a factor to account for the conservative method of establishing the rating. Simultaneous discharge of all valves is assumed in the analysis as this is considered to induce maximum stress in the piping. Reaction loads on the pipe are determined at each elbow location. These loads are composed of pressure times area, momentum change, and fluid friction terms. The method of analysis to determine piping system response to relief valve operation is time-history integration. The forces are applied at locations on the piping system where fluid flow changes direction, thus causing momentary reactions. The resulting loads on the SRV, the MSL, and the discharge piping are combined with loads due to other effects as specified in Section 3.9B.3.1. The Code stress limits corresponding to load combination classifications of normal, upset, emergency, and faulted are applied to the steam and discharge pipe.

3.9B.3.4 Component Supports

3.9B.3.4.1 Piping

Piping supports are designed in accordance with Subsection NF of ASME Section III. Supports are either designed by load rating in accordance with Subsubarticle NF-3260 or to the stress limits for linear supports in accordance with Subsubarticle NF-3231. To avoid buckling in the component supports, Appendixes F and XVII of ASME Section III require that the allowable loads be limited to two-thirds of the critical buckling loads. The critical buckling loads for ASME Safety Class 1 component supports in the NSSS scope subjected to faulted loads that are more severe than normal, upset, and emergency loads, are determined by the vendor using the methods discussed in Appendix F of the ASME Code. In general, the load combinations for the conditions correspond to those used to design the supported pipe. Design transient cyclic data are not applicable to piping supports as no fatigue evaluation is necessary to meet the Code requirements. See Appendix 3E for a discussion of stresses in supports due to thermal growth of piping and seismic anchor motion.

The design criteria and dynamic testing requirements for component supports are as follows:

Stiff Pipe Clamps

Stiff pipe clamps are used on the recirculation piping system. There are 3 E-system pipe clamps on each recirculation loop. This is the only use of stiff pipe clamps.

The clamps were not used to meet stiffness criteria; they were designed to meet the requirements for strength and load distribution using a minimum of space.

The clamp design utilizes a double nut arrangement to prevent the nuts from backing off. The low temperature (<600°) and stresses in the bolt from preloads will not cause a relaxation of the material; consequently, no lift-off from the piping will occur.

Although bolt preloads are not addressable under ASME III rules for piping, preload could result in damage to the pipe if a clamp is poorly designed. Calculations have been made to ensure that bolt preload will not result in plastic deformation of recirculation pipe walls.

Equation 9 (of ASME III, Subsection NB) is aimed at preventing collapse of the piping system due to loads that produce primary stresses. Collapse is prevented by keeping the stresses due to pressure, deadweight, and inertia effects of dynamic loads less than prescribed values. The existence of clamps on piping systems does not adversely affect the moment carrying capability or reduce the ability of the piping system to resist collapse under combined loadings that produce primary stresses.

The only concern is the loading transmitted from the snubber through the clamp pads to the pipe. This bearing load will result in local stress in the pipe wall. These stresses are conservatively calculated using the indices method and added to the membrane and overall bending stresses computed by Equation 9 of the Code.

Clamp-induced stresses caused by the constraint of pipe expansion due to internal pressure have been added to other operating secondary and peak stresses by calculating effective increases in local bending stresses.

Clamp-induced stresses due to differential temperatures and material expansion coefficients have been accounted for by computing effective increases in local bending stresses. These stresses have been added to other operating secondary and peak stresses.

The fatigue usage at each clamp location has been conservatively computed, taking into consideration clamp-induced stresses from internal pressure, differential thermal expansion, and snubber loads.

The clamp-induced stresses were added to the stresses computed for each load set using Equations 10 and 11 of NB-3650. Cumulative fatigue usage was computed by the rules of the Code.

The stresses induced at each clamp location were calculated and compared to Code acceptance criteria. The primary stresses computed by Equation 9 were shown to be nongoverning. The thermal expansion stresses computed by Equation 12 were also shown to be nongoverning. The stress ratchet criteria of Equation 13 and the fatigue usage criteria of Equation 14 meet Code criteria, with significant margins.

Component Supports

All component supports, which include piping clamps, hangers, snubbers, struts, and attachments (e.g., clevis) to the building structure are designed, fabricated, and assembled so they cannot become disengaged by the movement of the supported pipe or equipment after they have been installed. All component supports are designed in accordance with the rules of Subsection NF of the Code. For the NSSS scope of supply, valve operators mounted on Safety Class 1 piping are not used as component supports.

Table 3.9B-2 includes loads and load combinations which are used also for the NSSS piping supports. The stress limits are in accordance with ASME III, Subsection NF.

No specific deformation limit is required. Deformation is limited by requiring proper stress limits.

Hangers

The design load on hangers is the load caused by deadweight. The hangers are calibrated to ensure that they support the design load at both their hot and cold load settings. Hangers provide a specified down travel and up travel in excess of the specified thermal movement.

Snubbers

Required Load Capacity and Snubber Location The entire piping system, including valves and suspension system between anchor points, is mathematically modeled for complete structural analysis. In the mathematical model, the snubbers are modeled as springs with a given spring stiffness depending on the snubber size. The analysis determines the forces and moments acting on each component and the forces acting on the snubbers due to all dynamic loading conditions defined in the piping design specification. The design load on snubbers includes those loads caused by seismic forces (OBE and SSE), hydrodynamic forces, system anchor movements, and reaction forces caused by relief valve discharge, turbine stop valve closure, and others.

The snubber location and loading direction are first decided by estimation to confine the stresses in the piping system to acceptable values. The snubber locations and direction are refined by performing the computer analysis on the piping system as described above.

The spring constant required by the suspension design specification 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 load direction have been confirmed. If the spring constants are not in agreement, they are brought into 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 compatible.

Design Specification Requirements To assure that the required structural and mechanical performance characteristics and product quality are achieved, the following requirements for design and testing are imposed on the manufacturer:

1. The snubbers are required by the suspension design specification to be designed in accordance with all rules and regulations of ASME Section III, Subsection NF. This design requirement includes analysis wherein the stresses in the snubber component parts are calculated under normal, upset, emergency, and faulted loads. These calculated stresses are then compared against the allowable stresses of the material as given in ASME Section III to ensure that they are below the allowable limit.

2. The snubbers are tested to ensure that they can perform as required during the OBE, the SSE, and hydrodynamic events under anticipated operational transient loads or other mechanical loads associated with the design requirements for the plant. Operability requirements are described in TRM Section 3.7.3. The test requirements include:

   a. Snubbers are subjected to force or displacement versus time loading at frequencies within the range of significant modes of the piping system.

   b. Displacements are measured to determine the performance characteristics specified.

   c. Tests are conducted at various temperatures to ensure operability over the specified range.

   d. Peak test loads in both tension and compression are equal to or higher than the rated load requirements.

   e. Tests are conducted for various abnormal environmental conditions. Upon completion of the above abnormal environmental transient test, the snubber is tested dynamically at a frequency with a specified frequency range. The snubber must operate as designed during the dynamic test.

Snubber Installation Requirements An installation instruction manual is required by the suspension 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.

The suspension 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.

Inspection, Testing, Repair, and/or Replacement of Snubbers The suspension 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 for inspection.

Struts

The design load on struts includes those loads caused by deadweight, thermal expansion, primary seismic forces (OBE and SSE), hydrodynamic loads, system anchor displacements, and reaction forces caused by relief valve discharge, turbine stop valve closure, etc. Struts are designed in accordance with ASME Section III, Article NF-3000 to be capable of carrying the design load for all operating conditions.

3.9B.3.4.2 Reactor Pressure Vessel Stabilizer

The RPV stabilizer, which is massive and well supported, 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 RPV stabilizers attach to the ring girder/star truss structure. The ring girder/star truss structure, which is the top extension of the shield wall, is considered building steel and is designed to AISC criteria (see Section 3.8.3.2). The stabilizer provides a reaction point near the upper end of the RPV to resist horizontal loads due to effects such as earthquake and pipe rupture. The design loads and load combinations, stress criteria, calculated stresses, and allowable stresses in the critical areas are summarized in Table 3.9B-2f.

Deformation is limited by requiring proper stress limits.

3.9B.3.4.3 NSSS Floor-Mounted Equipment (Pumps, Heat Exchanger, and RCIC Turbine)

The NSSS floor-mounted equipment is analyzed to verify the adequacy of its support structures under various plant operating conditions. In all cases the stress loads in the critical support areas are within the ASME Code allowables. The loading conditions, stress criteria, and the allowable stresses in the critical support areas are given in Table 3.9B-2 in the respective equipment table.

3.9B.3.4.4 Supports for ASME Safety Class 1, 2, and 3 Active Components

ASME Safety Class 1, 2, and 3 active components are either pumps or valves. Since valves are supported by piping and not tied to building structures, pipe design criteria govern.

Category I active pump supports are qualified for seismic and hydrodynamic loads by testing when the pump supports and the pumps fulfill the following conditions:

1. Simulate actual mounting conditions.

2. Simulate all static and dynamic loadings on the pump.

3. Monitor pump operability during testing.

4. Normal operation of the pump during and after the test indicates that the supports are adequate. Any deflection or deformation of the pump supports that precludes the operability of the pump is not accepted.

5. Supports are inspected for structural integrity after the test. Any cracking or permanent deformation is not accepted.

Seismic and hydrodynamic qualification of component supports by analysis is generally accomplished as follows:

1. Stresses at all support elements and parts such as pump holddowns, and baseplate holddown bolts, pump support pads, pump pedestal, and foundation are checked to be within the allowable limits as specified in ASME Subsection NF.

2. For normal and upset plant conditions, the deflections and deformations of the support are assured to be within the elastic limits and must not exceed the values permitted by the designer based on his design verification tests to ensure the operability of the pumps.

3. For emergency and faulted plant conditions, the deformations must not exceed the values permitted by the designer to ensure the operability of the pumps.

3.9B.3.4.5 Bolting Support

Component Support Bolting

The support bolting of the RWCU pump is designed for the effects of pipe and SSE loads to the requirements of ASME Section III, Appendix XVII. The stress limits of 0.25Sy for tension and 0.20Sy for shear are used.

The equipment-to-base plate bolting of RCIC/SLC pumps and RCIC turbine satisfies the following design criteria: For normal and upset conditions, 1.0S is used for primary membrane and 1.5S for primary membrane plus bending, where S is the allowable stress limit from ASME Section III, Appendix I, Table I-7.3. For emergency and faulted conditions, stresses shall be less than 1.2 times the allowable limits for normal and upset conditions.

Piping Supports and Pipe-Mounted Equipment Supports

The allowable stresses for bolts meet the criteria of ASME Section III, Subsection NF. For service levels A and B, the bolts meet the criteria of NF-3280. For service levels C and D, XVII-2460 with factors indicated under XVII-2110 is applicable to the design requirements of bolting. The calculated stresses under these categories do not exceed the specified minimum yield stresses at temperature.

High-Strength Bolts

Bolts SA-193, Gr B7, and ASTM A-490-76a are used on Bergen-Patterson riser clamps for hanger attachments and E-systems clamps for snubber attachments, respectively.

The RWCU pump and driver motor holddown bolts are SA-193, Gr B7, and SAE Gr 8, respectively.

The RCIC pump and holddown bolts are SA-449.

The SLC pump and driver motor holddown bolts are SA-193, Gr B7, and SAE Gr 8, respectively.

3.9B.4 Control Rod Drive System

Unit 2 is equipped with a hydraulic CRD system that includes the CRD mechanism, the HCU, the condensate supply system, and the SDV, and extends to the coupling interface with the control rods.

3.9B.4.1 Descriptive Information on CRD System

Descriptive information on the CRDs and the entire drive and control system is contained in Section 4.6.

3.9B.4.2 Applicable CRD System Design Specifications

The CRD system is designed to meet the functional design criteria outlined in Section 4.6 and consists of the following:

1. Locking piston CRD.
2. Hydraulic control unit.
3. Hydraulic power supply (pumps).
4. Interconnecting piping.
5. Flow, and pressure and isolation valves.
6. Instrumentation and electrical controls.

Quality group classification is not applicable to the CRD.

Those components of the CRD forming part of the primary pressure boundary are designed according to ASME Section III.

The quality group classification of the CRD hydraulic system is outlined in Table 3.2-1, and the components are designed according to the codes and standards governing the individual quality groups.

Pertinent aspects of the design and qualification of the CRD system components are discussed in the following sections: transients in Section 3.9B.1.1, faulted conditions in Section 3.9B.1.4, seismic testing in Section 3.9B.2.2, load combinations and stress limits in Table 3.9B-2a.

Tables 3.9B-2g and 3.9B-2y show the load combinations, analytical methods, and allowable and calculated stress values for the highly stressed areas of the CRD housing and supports.

3.9B.4.3 Design Loads, Stress Limits, and Allowable Deformation

The ASME Code components of the CRD system have been evaluated analytically, and the design load combinations and stress limits are listed in Table 3.9B-2a. For the non-Code components, experimental testing was used to determine the CRD performance under all possible conditions as described in Section 3.9B.4.4. Deformation has been compared with the allowables and is not a limiting factor in the analysis of the CRD components.

3.9B.4.4 CRD Performance Assurance Program

The CRD test program consists of the following tests:

1. Development tests.
2. Factory quality control tests.
3. 5-yr maintenance life tests.
4. 1.5 x design life tests.
5. Operational tests.
6. Acceptance tests.
7. Surveillance tests.

All the above tests except 3 and 4 are discussed in Sections 4.6.3 through 4.6.3.1.1.5. Tests 3 and 4 are discussed as follows:

<u>Test 3 - 5-Yr Maintenance Life Tests</u> Four CRDs are normally picked at random from the production stock each year and subjected to various tests under simulated reactor conditions and more than one-eighth of the cycles specified in Section 3.9B.1.1. Upon completion of the test program, CRDs must meet or surpass the minimum specified performance requirements. This sample size is based on the large production volume during the manufacturing of CRDs through and including Model 7RDB144C.

The practice of testing the CRDs continues for Model 7RDB144EG001. However, due to the lower production volume expected for this model, fewer drives per year are tested.

Test 4 - 1.5 x Design Life Tests When a significant design change is made to the components of the drive, the drive is subjected to a series of tests equivalent to 1.5 times the life test cycles specified in Section 3.9B.1.1. Two CRDs underwent such testing in 1976. Upon completion of the test program, these CRDs met or exceeded the minimum specified performance requirements.

3.9B.5 Reactor Core Support Structures and Pressure Vessel Internals

3.9B.5.1 Design Arrangements

The core support structures and reactor vessel internals (exclusive of fuel, control rods, CRDs, and in-core nuclear instrumentation) are identified below:

1. Core support structures:
    a. Shroud.
    b. Shroud support.
    c. Core plate and holddown bolts.
    d. Top guide.
    e. Fuel supports.
    f. CRD housing.
    g. Control rod guide tubes.
2. Reactor internals:
    a. Jet pump assemblies and instrumentation penetration seal, instrumentation lines.*
    b. Feedwater spargers.*
    c. Vessel head spray nozzle.
    d. Differential pressure and liquid control lines.
    e. In-core flux monitor guide tubes.
    f. Initial startup neutron sources.*
    g. Surveillance sample holders.*
    h. Core spray lines and spargers.

i. In-core instrument housings.

j. LPCI coupling.

k. Steam dryer.*

l. Shroud head and steam separator assembly.*

m. Guide rods.*

n. CRD thermal sleeves.*

* Nonsafety-class equipment.

A general assembly drawing of the important reactor components is shown on Figure 5.3-4.

The floodable inner volume of the RPV inside the core shroud up to the level of the jet pump suction inlet and internal flow path following a postulated recirculation line break are depicted in Figure 3.9B-2.

The design arrangement of the reactor internals such as the jet pumps, steam separators, and guide tube, is such that one end is unrestricted and thus free to expand.

3.9B.5.1.1 Core Support Structures

These structures form partitions within the reactor vessel to sustain pressure differentials across the partitions, direct the flow of the coolant water, and laterally locate and support the fuel assemblies.

<u>Shroud</u>

The shroud support, shroud, and top guide make up a stainless steel cylindrical assembly. The first two structures provide a partition to separate the upward flow of coolant through the core from the downward recirculation flow. This partition separates the core region from the downcomer annulus, providing a floodable region following a recirculation line break. The volume enclosed by this assembly is characterized by three regions. The upper portion surrounds the core discharge plenum, which is bounded by the shroud head on top and the top guide grid plate below. The central portion of the shroud surrounds the active fuel and forms the longest section of the assembly. This section is bounded at the top by the grid plate and at the bottom by the core plate. The lower portion, surrounding part of the lower plenum, is welded to the RPV shroud support.

<u>Shroud Support</u>

The shroud support is designed to support the shroud and to support and locate the jet pumps. The shroud support provides an annular baffle between the RPV and the shroud. The jet pump discharge diffusers penetrate the shroud support to introduce the coolant to the inlet plenum below the core.

Shroud Head and Steam Separator Assembly

This component is not a core support structure or safety class component. It is discussed here to describe the coolant flow paths in the RPV. The shroud head and steam separator assembly is bolted to the top of the top guide to form the top of the core discharge plenum. This plenum provides a mixing chamber for the steam-water mixture before it enters the steam separators. Individual stainless steel axial flow steam separators are attached to the top of standpipes that are welded into the shroud head. The steam separators have no moving parts. In each separator, the steam-water mixture rising through the standpipe passes vanes that impart a spin to establish a vortex, separating the water from the steam. The separated water flows from the lower portion of the steam separator into the downcomer annulus.

Core Plate

The core plate consists of a circular stainless steel plate with bored holes stiffened with a rim-and-beam structure. The plate provides lateral support and guidance for the control rod guide tubes, in-core flux monitor guide tubes, peripheral fuel supports, and startup neutron sources. The last two items are also supported vertically by the core support plate. The entire assembly is bolted to a support ledge on the lower portions of the shroud.

Top Guide

The top guide is formed by a series of stainless steel beams joined at right angles to form square openings and fastened to a peripheral rim. Each opening provides lateral support and guidance for four fuel assemblies or, in the case of peripheral fuel, less than four fuel assemblies. Sockets are provided in the bottom of the beam intersections to anchor the in-core flux monitors and startup neutron sources. The rim of the top guide rests on a ledge between the upper and central portions of the shroud. The top guide has alignment pins that engage and bear against slots in the shroud that are used to position the assembly correctly before it is secured. Lateral restraint is provided by wedge blocks between the top guide and the shroud wall.

Fuel Support

The fuel supports shown on Figure 3.9B-3 are of two basic types: peripheral supports and four-lobed orificed fuel supports. The peripheral fuel support is located at the outer edge of the active core and is not adjacent to control rods. Each peripheral fuel support supports one fuel assembly and contains a single orifice assembly designed to ensure proper coolant flow to the peripheral fuel assembly. Each four-lobed orificed fuel support supports four fuel assemblies and has four orifice plates to ensure proper coolant flow distribution to each rod-controlled fuel assembly. The four-lobed orificed fuel supports rest in the top of the control rod guide tubes which are supported laterally by the core plate. The control rods pass through slots in the center of the four-lobed orificed fuel support. A control rod and the four adjacent fuel assemblies represent a core cell described in Section 4.4.2.

Control Rod Guide Tubes

The control rod guide tubes, located inside the vessel, extend from the top of the CRD housings up through holes in the core plate. Each tube is designed as the guide for a control rod and as the vertical support for a four-lobed orificed fuel support piece and the four fuel assemblies surrounding the control rod. The bottom of the guide tube is supported by the CRD housing, which in turn transmits the weight of the guide tube, fuel support, and fuel assemblies to the reactor vessel bottom head. A thermal sleeve is inserted into the CRD housing from below and is rotated to lock the control rod guide tube in place. A key is inserted into a locking slot in the bottom of the CRD housing to hold the thermal sleeve in position.

3.9B.5.1.2 Reactor Vessel Internals

Jet Pump Assemblies

The jet pump assemblies are not core support structures but are discussed here to describe coolant flow paths in the RPV. The jet pump assemblies are located in two semicircular groups in the downcomer annulus between the core shroud and the RPV wall. The design and performance of the jet pump are covered in detail in APED-5460[10] and NEDO-10602[11]. Each stainless steel jet pump consists of driving nozzles, suction inlet, throat or mixing section, and diffuser (Figure 3.9B-4). The driving nozzle, suction inlet, and throat are joined together as a removable unit, and the diffuser is permanently installed. High-pressure water from the recirculation pumps is supplied to each pair of jet pumps through a riser pipe welded to the recirculation inlet nozzle thermal sleeve. A riser brace consists of cantilever beams welded to a riser pipe and to pads on the RPV wall.

The nozzle entry section is connected to the riser by a metal-to-metal, spherical-to-conical seal joint. Firm contact is maintained by a holddown clamp. The throat section is supported laterally by a bracket attached to the riser. There is a slip-fit joint between the throat and diffuser. The diffuser is a gradual conical section changing to a straight cylindrical section at the lower end.

Unit 2 will reduce the preload on the beams from 30 to 25 kips in accordance with GE's recommendations. The expected life of these beams without cracking is 19 to 40 yr for Group 2 beams and 240 yr for Group 3 beams. ISI of the jet pump holddown beam will be performed to detect cracking. Inspection frequencies will be based on BWRVIP-41[21] requirements.

Steam Dryers

The steam dryer assembly is neither a core support structure nor a safety class component. It is discussed here to describe coolant flow paths in the vessel. The steam dryers remove moisture from the wet steam leaving the steam separators. The extracted moisture flows down

the dryer vanes to the collecting troughs, then flows through tubes into the downcomer annulus. A skirt extends from the bottom of the dryer vane housing to the steam separator standpipe below the water level. This skirt forms a seal between the wet steam plenum and the dry steam flowing from the top of the dryers to the steam outlet nozzles.
The steam dryer and shroud head are positioned in the vessel during installation with the aid of vertical guide rods. The dryer assembly rests on steam dryer support brackets attached to the RPV wall. Upward movement of the dryer assembly, which may occur under accident conditions, is restricted by steam dryer holddown brackets attached to the RPV top head.

<u>Feedwater Spargers</u>

These components are not core support structures nor safety class components. They are discussed here to describe flow paths in the vessel. The feedwater spargers are stainless steel headers located in the mixing plenum above the downcomer annulus. A separate sparger is fitted to each feedwater nozzle and is shaped to conform to the curve of the vessel wall. Sparger end brackets are pinned to vessel brackets to support the spargers. Feedwater flow enters the center of the spargers and is discharged radially inward to mix the cooler feedwater with the downcomer flow from the steam separators and steam dryer before it contacts the vessel wall. The feedwater also serves to condense the steam in the region above the downcomer annulus and to subcool the water flowing to the jet pumps and recirculation pumps.

<u>Core Spray Lines</u>

This component is not a core support structure. It is discussed here to describe a safety class feature inside the RPV. The core spray lines are the means for directing flow to the core spray nozzles, which distribute coolant during accident conditions.

Two core spray lines enter the RPV through the two core spray nozzles (Section 5.4). The lines divide immediately inside the RPV. The two halves are routed to opposite sides of the RPV and are supported by clamps attached to the vessel wall. The lines are then routed downward into the downcomer annulus and pass through the top guide cylinder immediately below the flange. The flow divides again as it enters the center of the semicircular sparger, which is routed halfway around the inside of the top guide cylinder. The two spargers are supported by brackets designed to accommodate thermal expansion. The line routing and supports are designed to accommodate differential movement between the top guide and vessel. The other core spray line is identical except that it enters the opposite side of the vessel and the spargers are at a slightly different elevation inside the top guide cylinder. The correct spray distribution pattern is provided by a combination of distribution nozzles pointed radially inward and downward from the spargers (Section 6.3).

<u>Vessel Head Spray Nozzle</u>

This component is not a core support structure. It is included here to describe a safety class feature in the RPV. When reactor coolant is returned to the RPV, part of the flow can be diverted to a spray nozzle in the reactor head. This spray maintains saturated conditions in the RPV head volume by condensing steam being generated by the hot RPV walls and internals. The spray also decreases thermal stratification in the RPV coolant. This ensures that the water level in the RPV can rise. The higher water level provides conduction cooling to more of the mass of metal of the RPV and, therefore, helps to maintain the cooldown rate. The vessel head spray nozzle is mounted to a short length of pipe and a flange, which is bolted to a mating flange on the RPV head nozzle (Section 5.4.7).

Core Differential Pressure Line

This component is not a core support structure. It is included here to describe a safety class component in the RPV. The core differential pressure line enters the vessel through a bottom head penetration and serves to sense the differential pressure across the core support plate (Section 5.4). One part of the line terminates near the lower shroud below the core support plate. It is used to sense the pressure below the core support plate during normal operation. The other line terminates immediately above the core support plate and senses the pressure in the region outside the fuel assemblies.

In-core Flux Monitor Guide Tubes

These components are not core support structures. They are a safety class feature and provide a means of positioning fixed detectors in the core, as well as provide a path for calibration monitors (TIP system).

The in-core flux monitor guide tubes extend from the top of the in-core flux monitor housing (Section 5.3.3.1.4) in the lower plenum to the top of the core support plate. The power range detectors for the power range monitoring units and the dry tubes for the SRM and IRM detectors are inserted through the guide tubes. A latticework of clamps, tie bars, and spacers give lateral support and rigidity to the guide tubes. The bolts and clamps are welded, after assembly, to prevent loosening during reactor operation.

Surveillance Sample Holders

This component is not a core support structure or a safety class component. The surveillance sample holders are welded baskets containing impact and tensile specimen capsules (Section 5.3.1.6.4). The baskets hang from the brackets that are attached to the inside wall of the RPV and extend to mid-height of the active core. The radial positions are chosen to expose the specimens to the same environment and maximum neutron fluxes experienced by the RPV itself, while avoiding jet pump removal interference or damage.

Low-Pressure Coolant Injection Lines Penetrations

This component is a safety class feature, not a core support structure, but is discussed here to describe the coolant flow paths in the RPV. Three LPCI lines penetrate the core shroud through separate LPCI nozzles. Coolant is discharged inside the core shroud immediately below the top guide to restore and maintain the water level in the vessel required after a LOCA.

3.9B.5.2 Design Loading Conditions

3.9B.5.2.1 Events to Be Evaluated

Examination of the spectrum of conditions for which the safety design basis must be satisfied by core support structures and ESF components reveals the following significant faulted events:

1. Recirculation Line Break A break in a recirculation line between the RPV and the recirculation pump suction.

2. Steam Line Break Accident A break in one MSL between the RPV and the flow restrictor. The accident results in significant pressure differentials across some of the structures within the reactor.

3. Earthquake Subjects the core support structures and reactor internals to significant forces as a result of ground motion.

4. SRV discharge in combination with a SSE.

Analysis of other conditions existing during normal operation, abnormal operational transients, and accidents shows that the loads affecting the core support structures and other ESF reactor internals are less severe than these four postulated events. The faulted conditions for the RPV internals are discussed in Section 3.9B.1.4. Load combinations and analysis for the RPV internals are discussed in Section 3.9B.3.1 and Tables 3.9B-2h and 3.9B-2i. The stress deformation and fatigue limits are discussed in Sections 3.9B.5.3.5 and 3.9B.5.3.6.

3.9B.5.2.2 Pressure Differential During Rapid Depressurization

A digital computer code is used to analyze the transient conditions within the RPV following the recirculation line break accident and the steam line break accident. The analytical model of the vessel consists of nine nodes that are connected to the necessary adjoining nodes by flow paths having the required resistance and inertial characteristics. The program solves the energy and mass conservation equations for each node to give the depressurization rates and pressure in the various regions of the reactor. Figure 3.9B-5 shows the nine reactor nodes. The computer code used is the GE Short-Term Thermal-Hydraulic Model[12]. This model has been approved for use in ECCS conformance evaluation under 10CFR50 Appendix K. In order to adequately describe the blowdown pressure effect on the individual assembly components, three features are included in the model that are not applicable to the ECCS analysis and are therefore not described in NEDE-20566[12].

These additional features are discussed as follows:

1. The liquid level in the steam separator region and in the annulus between the dryer skirt and the pressure vessel is tracked to more accurately determine the flow and mixture quality in the steam dryer and in the steam line.

2. The flow path between the bypass region and the shroud head is more accurately modeled since the fuel assembly pressure differential P is influenced by flashing in the guide tubes and bypass region for a steam line break. In the ECCS analysis, the momentum equation is solved in this flow path, but its irreversible loss coefficient is conservatively set at an arbitrary low value.

3. The enthalpies in the guide tubes and the bypass are calculated separately, since the fuel assembly P is influenced by flashing in these regions. In the ECCS analysis, these regions are lumped.

3.9B.5.2.3 Recirculation Line and Steam Line Break

Accident Definition

Both a recirculation line break (the largest liquid break) and a steam line break inside containment (the largest steam break) are considered in determining the DBA for the ESF reactor internals. The recirculation line break is the same as the design basis LOCA (Section 6.3). A sudden, complete circumferential break is assumed to occur in one recirculation loop. The pressure differentials on the reactor internals and core support structures are in all cases lower than those for the MSL break.

The analysis of the steam line break assumes a sudden, complete circumferential break of one MSL between the RPV and the MSL restrictor. A steam line break upstream of the flow restrictors produces a larger blowdown area and thus a faster depressurization rate than a break downstream of the restrictors. The larger blowdown area results in greater pressure differentials across the reactor internal structures.

The steam line break accident produces significantly higher pressure differentials across the reactor internal structures than does the recirculation line break. This results from the higher reactor depressurization rate associated with the steam line break. Therefore, the steam line break is the DBA for internal pressure differentials.

Effects of Initial Reactor Power and Core Flow

The maximum internal pressure loads can be considered to be composed of two parts: steady-state and transient pressure differentials. For a given plant, the core flow and power are the two major factors that influence the reactor internal pressure differentials. The core flow essentially affects only the steady-state differential pressure. For a fixed power, the greater the core flow, the larger will be the steady-state pressure differentials. The core power affects both the steady-state and the transient differential pressure. As the power is decreased, there is less voiding in the core and, consequently, the steady-state core pressure differential is less. However, less voiding in the core also means that less steam is generated in the RPV and thus the depressurization rate and the transient part of the maximum pressure load is increased. As a result, the total loads on some components are higher at low power.

To ensure that the calculated pressure differences bound those that could be expected if a steam line break should occur, an analysis is conducted at a low power, high recirculation flow condition in addition to the standard safety analysis condition at high power, rated recirculation flow. The power chosen for analysis is the minimum value permitted by the recirculation system controls at rated recirculation drive flow (rated recirculation drive flow is the drive flow used to achieve rated core flow. This condition maximizes those loads that are inversely proportional to power.

Seismic and Hydrodynamic Events

The seismic and hydrodynamic loads acting on the structures within the RPV are based on a dynamic analysis as described in Sections 3.9B and 3.9B.2.5. Dynamic analysis is performed by coupling the lumped mass model of the RPV and internals with the building model to determine the forces, acceleration, and moment time-history in the reactor vessel and internals. This is done using the modal superposition method. ARS are also generated for subsystem analyses of selected components.

3.9B.5.3 Design Bases

3.9B.5.3.1 Safety Design Bases

The reactor core support structures and internals meet the following safety design bases:

1. They are arranged to provide a floodable volume in which the core can be adequately cooled in the event of a breach in the nuclear system process barrier external to the RPV.

2. Deformation is limited to assure that the control rods and core standby cooling systems can perform their safety functions.

3. Mechanical design of applicable structures assures that safety design bases 1 and 2 are satisfied so that the safe shutdown of the plant and removal of decay heat are not impaired.

3.9B.5.3.2 Power Generation Design Bases

The reactor core support structures and internals are designed to the following power generation design bases:

1. They provide the proper coolant distribution during all anticipated normal operating conditions up to full power operation of the core without fuel damage.

2. They are arranged to facilitate refueling operations.

3. They are designed to facilitate inspection.

3.9B.5.3.3 Design Loading Categories

The basis for determining faulted loads on the reactor internals is shown for seismic and hydrodynamic loads in Sections 3.7B, 3.8B, and 3.9B.2.5, and for pipe rupture loads in Sections 3.9B.5.2.3 and 3.9B.5.3.4. Loading conditions for shroud support, core support structures, CRD housing, jet pumps, LPCI coupling, and control rod guide tubes are given in Table 3.9B-2 under the respective equipment table.

Core support structure and safety class internals stress limits are consistent with ASME Section III, Paragraph NA-2140, and associated stress limits contained in Addenda dated through Summer 1976. Level A, B, C, and D service limits defined in Winter 1976 Addenda which replace normal, upset, emergency, and faulted condition limits are not reflected in design documents for core support structures and other safety class internals for this reactor. However, for these components, Level A, B, C, and D service limits are judged to be equivalent to the normal, upset, emergency, and faulted loading condition limits and, therefore, for clarity, both sets of nomenclature are retained herein.

Stress intensity and other design limits are discussed in Section 3.9B.5.3.5. The core support structures that are fabricated as part of the RPV assembly are discussed in Section 3.9B.1.3.

The design requirements for equipment classified as "other internals" (e.g., steam dryers and shroud heads) were specified by the designer with appropriate consideration of the intended service of the equipment and expected plant and environmental conditions under which it is to operate. Where possible, design requirements are based on applicable industry codes and standards. If these are not available, the designer relies on accepted industry or engineering practices.

<u>Core Shroud IGSCC Cracking</u>

The core shroud welds are susceptible to intergranular stress corrosion cracking (IGSCC) as discussed in BWRVIP-01 (Reference 15) and NRC Generic Letter 94-03. The core shroud welds have been inspected and some of the welds have been determined to have IGSCC cracking in and near the HAZ. The structural evaluation methodology used in the evaluation of the cracked shroud is consistent with methodologies described in ASME Section XI and BWRVIP-01 documents.

The analysis demonstrates that shroud structural margins and all design basis requirements are satisfied. The required ISI inspection interval for the cracked welds is defined based on the guidance provided in BWRVIP Core Shroud Inspection and Evaluation Guidelines (BWRVIP-01) and the Guidelines for Reinspection of BWR Core Shrouds (BWRVIP-07). The specific interval is defined by engineering analysis of the as-found cracking and consideration for potential crack growth and inspection uncertainty.

3.9B.5.3.4 Response of Internals Due to Inside Steam Break Accident

The maximum pressure loads acting on the reactor internal components result from an inside steam line break, and on some components the loads are maximum when operating at the minimum power associated with the maximum core flow. This has been substantiated by the analytical comparison of liquid versus steam breaks and by the investigation of the effects of core power and core flow.

It has also been pointed out that it is possible but not probable that the reactor would be operating at the rather abnormal condition of minimum power and maximum core flow. More realistically, the reactor would be at or near a full power condition and thus the maximum pressure loads would act on the internal components.

3.9B.5.3.5 Stress, Deformation, and Fatigue Limits for Engineered Safety Feature Reactor Internals (Except Core Support Structure)

The stress deformation and fatigue criteria listed in Tables 3.9B-5 through 3.9B-8 are used, or the criteria are based on the criteria established in applicable codes and standards for similar equipment, by manufacturers' standards, or by empirical methods based on field experience and testing. For the quantity SF_{min} (minimum safety factor) appearing in those tables, the following values were used.

Service Level	Design Condition	SF_{min}
A	Normal	2.25
B	Upset	2.25
C	Emergency	1.5
D	Faulted	1.125

Components inside the RPV, such as control rods that must move during accident conditions, have been examined for adequate clearances during emergency and faulted conditions. No mechanical clearance problems have been identified. The forcing functions applicable to the reactor internals are discussed in Section 3.9B.2.5.

3.9B.5.3.6 Stress, Deformation, and Fatigue Limits for Core Support Structures

The stress, deformation, and fatigue criteria presented in Tables 3.9B-9 through 3.9B-11 are used. These criteria are supplemented, where applicable, by the criteria for the reactor internals in the previous section.

3.9B.6 References

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TABLE 3.9B-1
(Sheet 1 of 2)

PLANT EVENTS

Normal, Upset, and Testing Condition	No. of Cycles
1. Boltup[1]	123
2. Design hydrostatic test[5]	130
3. Startup (100°F/hr heatup rate)[2] and cooldown (100°F/hr cooldown rate)[2][5]	120
4. Daily reduction to 75% power[1]	10,000
5. Weekly reduction 50% power[1]	2,000
6. Control rod pattern change[1]	400
7. Loss of feedwater heaters (80 cycles total)[5]	80
8. 50% SSE event at rated operating conditions (OBE)	10/50[3]
9. Scram:[5]	
a. Turbine generator trip, feedwater on, isolation valves stay open	40
b. Other scrams	140
c. Loss of feedwater pumps, isolation valves closed	10
d. Single safety or relief valve blowdown	8
10. Reduction to 0% power, hot standby, shutdown (100°F/hr cooldown rate)[2]	111
11. Unbolt	123
Emergency Condition	
12. Scram:	
a. Reactor overpressure with delayed scram, feedwater stays on, isolation valves stay open	1[4]

TABLE 3.9B-1
(Sheet 2 of 2)

PLANT EVENTS

Emergency Condition	No. of Cycles
b. Automatic blowdown	1[4]
13. Improper start of cold recirculation loop	1[4]
14. Sudden start of pump in cold recirculation loop	1[4]
15. Hot standby, RPV drain shutoff, recirculation pumps restart	1[4]
Faulted Condition	
16. Pipe rupture and blowdown	1[4]
17. Safe shutdown earthquake at rated operating conditions	1[4]

(1) Applies to reactor pressure vessel only.
(2) Bulk average vessel coolant temperature change in any 1-hr period.
(3) 50 peak OBE cycles for NSSS piping; 10 peak OBE cycles for other NSSS equipment and components.
(4) Annual encounter probability of the one-cycle events is $<10^{-2}$ for emergency and $<10^{-4}$ for faulted events.
(5) Monitor these events per Technical Specifications Section 5.5.5. Item 2 has a design cycle pressurization of ≥930 psig and ≤1250 psig; item 3 has a design cycle of 70°F to 565°F to 70°F; and item 9 has a transient of 100% to 0% of rated thermal power.

TABLE 3.9B-2
(Sheet 1 of 4)

LOAD COMBINATIONS, STRESS LIMITS,AND ALLOWABLE STRESSES

Load Combinations for ASME
Safety Class 1, 2, and 3 NSSS Components

INTRODUCTION

This table lists the major safety-related and selected non-safety related (NSR) components in the plant, and both calculated and allowable stresses. Various parts of the table are referenced in Section 3.9B. The formats in various parts of the table are not consistent since variation in analytical method and depth of detail, necessary to demonstrate the safety aspects of various components, differs.

INDEX

a. Control Rod Drive

b. Control Rod Guide Tube

c. In-core Housing

d. Jet Pumps

e. Highest Stressed Region on the LPCI Coupling (Attachment Ring)

f. Reactor Vessel Support Equipment

g. Control Rod Drive Housing

h. Reactor Pressure Vessel and Shroud Support Assembly

i. Reactor Vessel Internals and Associated Equipment

j. Acting Type Safety/Relief Valves Spring-Loaded Direct

k. Reactor Recirculation System Gate Valves

l. Recirculation Flow Control Valve

TABLE 3.9B-2
(Sheet 2 of 4)

LOAD COMBINATIONS, STRESS LIMITS,AND ALLOWABLE STRESSES

Load Combinations for ASME
Safety Class 1, 2, and 3 NSSS Components

m. ASME Safety Class 1 Recirculation Loop Piping and Pipe-Mounted Equipment (Class 1)

n. Reactor Refueling and Servicing Equipment

o. Fuel Assembly (including Channel)

p. Recirculation Pump

q. Standby Liquid Control Tank

r. Residual Heat Removal Heat Exchanger

s. RCIC Turbine

t. RCIC Pump

u. ECCS Pumps

v. Standby Liquid Control Pump

w. Reactor Water Cleanup System Pump

x. Reactor Water Cleanup Heat Exchangers

y. Control Rod Drive Housing Supports

z. Main Steam Isolation Valve

TABLE 3.9B-2
(Sheet 3 of 4)

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA
FOR ASME SAFETY CLASS 1, 2, AND 3
NSSS PIPING AND EQUIPMENT

Design Load Combination	Evaluation Basis	Service Basis	Level
N + SRV_{ALL}	Upset	Upset	B
N + OBE	Upset	Upset	B
N + OBE + SRV_{ALL}	Emergency	Upset	B
N + SSE + SRV_{ALL}	Faulted	Faulted(1)	D
N + SBA + SRV	Emergency	Emergency(1)	C
N + IBA + SRV	Faulted	Faulted(1)	D
N + SBA + SRV_{ADS}	Emergency	Emergency(1)	C
N + SBA + OBE + SRV_{ADS}	Faulted	Faulted(1)	D
N + IBA + OBE + SRV_{ADS}	Faulted	Faulted(1)	D
N + SBA/IBA + SSE + SRV_{ADS}	Faulted	Faulted(1)	D
N + LOCA(2) + SSE	Faulted	Faulted(1)	D

LOAD DEFINITION KEY:

N = Normal and/or abnormal loads depending on acceptance criteria
OBE = Operating basis earthquake loads
SSE = Safe shutdown earthquake loads
SRV = Safety/relief valve discharge-induced loads from two adjacent valves (one valve actuated when adjacent valve is cycling)
SRV_{ALL} = Loads induced by actuation of all safety/relief valves that activate within milliseconds of each other (e.g., turbine trip operational transient)
SRV_{ADS} = Loads induced by actuation of safety/relief valves associated with the automatic depressurization system that actuate within milliseconds of each other during the postulated small or intermediate size pipe rupture

TABLE 3.9B-2
(Sheet 4 of 4)

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA
FOR ASME SAFETY CLASS 1, 2, AND 3
NSSS PIPING AND EQUIPMENT

LOCA	=	Loss-of-coolant accident associated with the postulated pipe rupture of large pipes (e.g., main steam, feedwater, recirculation piping)
$LOCA_1$	=	Pool swell drag/fallout loads on piping and components located between the main vent discharge outlet and the suppression pool water upper surface
$LOCA_2$	=	Pool swell impact loads on piping and components located above the suppression pool water upper surface
$LOCA_3$	=	Oscillating pressure-induced loads on submerged piping and components during condensation oscillations
$LOCA_4$	=	Building motion-induced loads from chugging
$LOCA_5$	=	Building motion-induced loads from main vent air clearing
$LOCA_6$	=	Vertical and horizontal loads on main vent piping
$LOCA_7$	=	Annulus pressurization loads
SBA	=	Abnormal transients associated with small break accident
IBA	=	Abnormal transients associated with intermediate break accident

(1) All ASME Safety Class 1, 2, and 3 piping systems that are required to function for safe shutdown under the postulated events are designed to meet the functional capability criteria in accordance with NEDO-21985.

(2) The most limiting case of load combination among $LOCA_1$ through $LOCA_7$.

TABLE 3.9B-2a
(Sheet 1 of 2)

CONTROL ROD DRIVE

Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated** Stress (psi)
Main Flange				
Allowable primary membrane stress plus bending stress is based on ASME Section III for Type F304 stainless steel @ 575°F S_m = 16,700 psi				
For normal and upset condition: S_{allow} = 1.5 x S_m	For normal and upset condition: 1. Normal loads* 2. Scram with OBE 3. Scram with no buffer	General membrane plus bending	25,000	5,813
For emergency condition: S_{allow} = 1.8 x S_m	For emergency condition: 1. Normal loads* 2. Scram at emergency 3. Scram with accumulator at overpressure	General membrane plus bending	30,000	4,283
For faulted condition: S_{allow} = 3.6 x S_m	For faulted condition: 1. Normal loads* 2. Scram with SSE 3. Scram with stuck rod	General membrane plus bending	60,000	7,186
Indicator Tube				
Allowable primary membrane stress plus bending stress is based on ASME Section III for Type 316 stainless steel @ 250°F S_m = 20,000 psi				
For normal and upset condition: S_{allow} = 1.5 x S_m	For normal and upset condition: 1. Normal loads* 2. Scram with OBE and no buffer	General membrane plus bending	30,000	15,242

TABLE 3.9B-2a
(Sheet 2 of 2)

CONTROL ROD DRIVE

Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated** Stress (psi)
For emergency condition: $S_{allow} = 1.8 \times S_m$	For emergency condition: 1. Normal loads* 2. Failure of pressure - regulating system 3. Scram with accumulator at overpressure	General membrane plus bending	31,028	20,795
For faulted condition: $S_{allow} = 2.4 \times S_m$	For faulted condition: 1. Normal loads* 2. Scram with SSE 3. LOCA 4. SRV	General membrane plus bending	48,000	25,700
Ring Flange				
Allowable primary membrane stress plus bending stress is based on ASME Section III for Type F304 stainless steel @ 250°F S_m = 20,000 psi				
For normal and upset condition: $S_{allow} = 1.5 \times S_m$	For normal and upset condition: 1. Normal loads* 2. Scram with OBE and no buffer	General membrane plus bending	30,000	8,285
For emergency condition: $S_{allow} = 1.8 \times S_m$	For emergency condition: 1. Normal loads* 2. Scram at emergency 3. Scram with accumulator at overpressure	General membrane plus bending	36,000	1,370
For faulted condition: $S_{allow} = 3.6 \times S_m$	For faulted condition: 1. Normal loads* 2. Scram with SSE 3. Scram with stuck rod	General membrane plus bending	71,925	3,563

* Normal loads include pressure, temperature, weight, and mechanical loads.
** The New Loads Adequacy Evaluation has concluded that the listed limiting design basis loads envelope new loads.

TABLE 3.9B-2b
(Sheet 1 of 1)

CONTROL ROD GUIDE TUBE

Criteria	Loading	Primary Stress Type	Allowable* Stress (psi)	Calculated* Stress (psi)
Primary Stress Limit The allowable primary membrane stress plus bending stress is based on ASME Section III for Type 304 stainless steel tubing and SA351 Type CF8 casting (base)				
For Service Levels A & B (normal and upset) conditions: $1.5\ S_m = 1.5 \times 16{,}000$ $= 24{,}000$ psi	1. Deadweight 2. External pressure 3. Lateral flow impingement 4. OBE + SRV	Primary membrane plus bending	24,000	15,056
For Service Level C (emergency) condition: $S_{limit} = 2.25\ S_m$ $= 2.25 \times 16{,}000$ $= 36{,}000$ psi	1. Deadweight 2. External pressure 3. Lateral flow impingement 4. OBE + SRV	Primary membrane plus bending	36,000	15,056
For Service Level D (faulted) condition: $S_{limit} = 3.6\ S_m$ $= 3.6 \times 16{,}000$ $= 57{,}600$ psi	1. Deadweight 2. External pressure 3. Lateral flow impingement 4. SSE 5. Annulus pressurization	Primary membrane plus bending	57,600	27,770

* For extended power uprate (EPU) conditions, see GEH 0000-0072-9332; for GE 14 fuel introduction, see GE-NE-0000-0016-5640-00; and for GNF2 fuel introduction, see 003N2003.

TABLE 3.9B-2c
(Sheet 1 of 1)

IN-CORE HOUSING

Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress (psi)*
Primary Stress Limit The allowable primary membrane stress is based on ASME Section III for Class I vessels for Type 304 stainless steel				
For Service Levels A, B & C* (normal, upset, and emergency) conditions: $S_{limit} = S_m = 16{,}660$ psi	1. Pressure 2. OBE 3. SRV	Primary membrane	16,660	16,575
Faulted condition: $S_{faulted} = 2.4\ S_m$ $= 39{,}984$ psi	1. Pressure 2. LOCA 3. Annulus pressurization 4. SSE	Maximum membrane stress intensity occurs at the outer surface of the vessel penetration	39,984	24,972

* Service Level C (emergency) allowables are less than Service Level A and B (normal and upset) allowables, and Service Level A and B loads (normal and upset) calculated are less than Service Level C (emergency) calculated loads, so no additional information is presented.

TABLE 3.9B-2d
(Sheet 1 of 1)

JET PUMPS

Criteria	Load Combinations	Stress Type	Allowable* Stress (psi)	Calculated* Stress (psi)
Primary membrane plus bending stress based on ASME Section III				
For Service Levels A and B (normal and upset) condition: For Type 304 @ 550°F S_m = 16,900 psi S_{limit} = 1.5 S_m psi	1. Deadweight 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	25,350	19,346
For Service Level C (emergency) condition: For Type 304 @ 550°F S_m = 16,900 psi S_{limit} = 1.8 S_m psi	1. Deadweight 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	30,420	19,346
For Service Level D (faulted) condition: For Type 304 @ 550°F S_m = 16,900 psi S_{limit} = 3.6 S_m psi	1. Deadweight 2. Pressure 3. Chugging 4. SRV 5. SSE	Primary membrane plus bending	60,840	34,417

* The New Loads Adequacy Evaluation has concluded that the listed limiting design basis loads envelope new loads. For EPU conditions, see GEH 0000-0072-9332; for GE 14 fuel introduction, see GE-NE-0000-0016-5640-00; and for GNF2 fuel introduction, see 003N2003. For the replacement inlet mixers and main wedges installed in year 2012, LTR-MODS-11-4 analyzes the stresses on the jet pump components and concludes that the content of this table is unaffected by this modification.

TABLE 3.9B-2e
(Sheet 1 of 1)

HIGHEST STRESSED REGION ON THE LPCI COUPLING (ATTACHMENT RING)

(Bellow-Type Design)

Criteria	Load Combinations	Stress Type	Allowable Stress (psi)	Calculated* Stress (psi)
Primary membrane plus bending stress based on ASME Section III for Type 304L				
For Service Levels A and B (normal and upset) condition: S_{limit} = 1.5 S_m = 20,925 psi	1. Normal loads 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	20,925	18,900
For Service Level C (emergency) condition: S_{limit} = 2.25 S_m = 31,400 psi	1. Normal loads 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	31,400	18,900
For Service Level D (faulted) condition: S_{limit} = 3.6 S_m = 50,220 psi	1. Normal Loads 2. Pressure 3. Annulus pressurization 4. SSE	Primary membrane plus bending	50,220	35,700

* The New Loads Adequacy Evaluation has concluded that the listed design basis loads envelope new loads.

TABLE 3.9B-2f
(Sheet 1 of 4)

REACTOR PRESSURE VESSEL SUPPORT EQUIPMENT

RPV Support (Bearing Plate)

Criteria	Loading	Location	Allowable Stress (psi)	Calculated[4] Stress (psi)
Primary Stress Limit: AISC specification for the design, fabrication, and erection of structural steel for buildings				
For normal and upset condition: AISC allowable stresses, but without the usual increases for earthquake loads	Normal and upset condition: 1. Deadweight 2. OBE 3. Scram	Bearing plate	F_b (bearing) 22,000	f_b = 3,680
For emergency condition: 1.5 x AISC allowable stresses	Emergency condition: 1. Deadweight 2. OBE 3. Scram	Bearing plate	F_b (bearing) 33,000	f_b = 7,360
For faulted condition: 1.67 x AISC allowable stresses for structural steel members	Faulted condition: 1. Deadweight 2. SSE 3. Jet reaction load	Bearing plate	F_b (bearing) 36,000	f_b = 9,080

TABLE 3.9B-2f
(Sheet 2 of 4)

REACTOR PRESSURE VESSEL SUPPORT EQUIPMENT

RPV Stabilizer

Criteria	Loading	Location[1]	Allowable Stress (psi)	Calculated[4] Stress (psi)
Primary Stress Limit: ASME Section III, Subsection NF-Linear type support Material: Bracket and yoke: SA-516, Gr. 70 Rod: SA-540, B24, C1.2				
For normal and upset conditions: Subsection NF allowables	Upset condition: 1. Spring preload 2. OBE	Bracket Yoke Rod	[2]	[2]
For emergency conditions: 1.33 x normal/upset allowables	Emergency condition: 1. Spring preload 2. SSE	Bracket Bracket Yoke Yoke	F_b = 29,000 F_v = 19,300 F_b = 34,600 F_t = 27,610	f_b = 16,430 f_v = 4,390 f_b = 26,550 f_t = 19,000
For faulted conditions: (0.7 S/ft) x normal/upset allowables	Faulted condition: 1. Spring preload 2. SSE 3. Jet reaction load	Rod	F_t = 104,490	f_t = 84,220

TABLE 3.9B-2f
(Sheet 3 of 4)

REACTOR PRESSURE VESSEL SUPPORT EQUIPMENT

Stabilizer Bracket-Adjacent Shell

Criteria	Loading	Location	Allowable Stress (psi)	Calculated[4] Stress (psi)
ASME Section III primary local membrane plus primary bending limit for SA 533 Grade B, Class I:				
For normal and upset condition: $S_{limit} = 1.5 \times S_m$	Normal and upset condition loads: 1. OBE 2. Pressure	Local membrane plus bending	40,050	38,895
For emergency condition: $S_{limit} = 1.5 \times S_y$	Emergency condition loads: 1. SSE 2. Pressure	Local membrane plus bending	[3]	[3]
For faulted condition: $S_{limit} = 1.5 \times S_y$	Faulted condition loads: 1. SSE 2. Jet reaction 3. Pressure	Local membrane plus bending	63,450	56,604

TABLE 3.9B-2f
(Sheet 4 of 4)

REACTOR PRESSURE VESSEL SUPPORT EQUIPMENT

Orificed Fuel Supports

Criteria	Loading	Direction	Allowable Loads (LBF)	Calculated Loads (LBF)
Based on ASME Subsection NG-3228.4				
For normal, upset, and emergency conditions: $L_{limit} = 0.44\ L_u$ [5]	Normal, upset, and emergency loads: Horizontal: Normal operating loads: OBE SRV	Horizontal	4,495	2,109
	Vertical: Normal operating loads: SRV SCRAM	Vertical	49,632	4,028
For faulted condition: $L_{limit} = 0.80\ L_u$ [5]	Faulted loads: Horizontal: Normal operating loads Jet Reaction AP SSE	Horizontal	8,172	3,075
	Vertical: Normal operating loads: SRV SSE SCRAM	Vertical	90,240	8,044
Cumulative usage factor Limit = 0.047				

[1] Bracket and yoke have least stress margin in emergency condition, and rod in faulted condition.
[2] For the three locations, normal and upset condition has higher stress margins as compared to other conditions.
[3] Faulted category loads are evaluated with emergency allowable stresses; hence, emergency condition is not evaluated.
[4] The New Loads Adequacy Evaluation has concluded that the listed design basis loads envelope the new loads.
[5] Ultimate test load.

TABLE 3.9B-2g
(Sheet 1 of 1)

CONTROL ROD DRIVE HOUSING

Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Primary Stress Limit The allowable primary membrane stress is based on ASME Section III for Safety Class 1 vessels for Type 304 stainless steel				
For normal and upset condition: S_{limit} = 1.0 S_m = 16,660 psi @ 575°F	Normal and upset condition: 1. Pressure 2. Stuck rod scram 3. OBE 4. SRV 5. Hydraulic line loads	Maximum membrane stress intensity occurs at the tube-to-tube weld near the center of the housing for normal, upset, emergency, and faulted conditions	16,660	13,993
For faulted conditions: S_{limit} = 1.2 S_m	Faulted conditions: 1. Pressure 2. Stuck rod scram 3. SSE 4. Annulus pressurization 5. LOCA 6. Hydraulic line loads		20,000*	15,419

* Faulted category loads are evaluated with emergency allowable stresses; hence, the emergency condition is not evaluated.

TABLE 3.9B-2h
(Sheet 1 of 4)

REACTOR PRESSURE VESSEL AND SHROUD SUPPORT ASSEMBLY

I. Vessel Support Skirt

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress* (psi)
Material: SA-533 Gr. B Class I				
A. Normal and Upset Conditions:				
$P_m \leq S_m$	1. Deadweight	Primary membrane	26,700	21,900
S_m = 26,700 @ 575°F	2. Pressure loads			
$P_L + P_b \leq 1.5\ S_m$	3. OBE	Primary membrane	40,050	30,910
S_m = 26,700 @ 575°F	4. SRV	plus bending		
B. Emergency Condition:				
$P_m \leq 1.2\ S_m$	1. Deadweight	Primary membrane	32,040	26,930
S_m = 26,700 @ 575°F	2. Pressure loads			
$P_L + P_b \leq 1.8\ S_m$	3. OBE	Primary membrane	48,060	47,960
S_m = 26,700 @ 575°F	4. SRV	plus bending		
C. Faulted Condition:				
$P_m \leq 0.7\ S_m$	1. Deadweight	Primary membrane	56,000	26,930
S_y = 80,000 @ 575°F	2. Pressure			
$P_L + P_b \leq 1.05\ S_y$	3. Jet reaction	Primary membrane	84,000	47,960
S_y = 80,000 @ 575°F	4. Annulus pressurization	plus bending		
	5. SSE			
D. Maximum Cumulative Usage Factor:	0.248 at knuckle			

TABLE 3.9B-2h
(Sheet 2 of 4)

REACTOR PRESSURE VESSEL AND SHROUD SUPPORT ASSEMBLY

II. Shroud Support

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress*,** (psi)	Calculated Stress*,** (psi)
Material: SB-168				
A. Normal and Upset Conditions:				
$P_m \leq S_m$ S_m = 23,300 psi @ 575°F	1. Deadweight 2. Pressure	Primary membrane	23,300	11,820
$P_L + P_b \leq S_y$ S_y = 28,125 psi @ 575°F	3. OBE 4. SRV	Primary membrane plus bending	28,125	28,030
B. Emergency Condition:				
$P_m \leq S_y$ S_y = 28,548 @ 528°F	1. Deadweight 2. Pressure	Primary membrane	28,548	17,990
$P_L + P_b \leq 1.5\ S_y$ S_y = 28,548 psi @ 528°F	3. Chugging 4. SRV	Primary membrane plus bending	42,822	40,040
C. Faulted Condition:				
$P_m \leq S_y$ S_y = 28,548 psi @ 528°F	1. Deadweight 2. Pressure	Primary membrane	28,548	21,420
$P_L + P_b \leq 1.5\ S_y$ S_y = 28,548 @ 528°F	3. Chugging 4. SRV 5. SSE	Primary membrane plus bending	42,822	40,040
D. Maximum Cumulative Usage Factor:	0.047 at Inconel section 0.053 at low alloy steel section			

TABLE 3.9B-2h
(Sheet 3 of 4)

REACTOR PRESSURE VESSEL AND SHROUD SUPPORT ASSEMBLY

III. RPV Feedwater Nozzle

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress* (psi)
Material: SA-508 Class I safe end SRSS values only				
A. Normal and Upset Conditions:				
$P_m \leq$ 17,700 psi S_m = 17,700 @ 575°F	1. Deadweight 2. Pressure loads	Primary membrane	17,700	16,220
$P_L + P_b \leq$ 26,550 psi 1.5 S_m = 26,550 @ 575°F	3. OBE 4. SRV	Primary membrane plus bending	26,550	22,930
B. Emergency Condition:				
$P_m \leq$ 25,900 psi S_y = 25,900 @ 594°F	1. Deadweight 2. Pressure loads	Primary membrane	25,900	21,420
$P_L + P_b \leq$ 38,850 psi 1.5 S_y = 38,850 @ 594°F	3. SRV 4. SBA	Primary membrane plus bending	38,850	22,400
C. Faulted Condition:				
$P_m \leq$ 53,100 psi 3 S_m = 53,100 @ 575°F	1. Deadweight 2. Pressure loads	Primary membrane	53,100	28,300
$P_L + P_b \leq$ 38,850 psi 1.5 S_m = 38,850 @ 594°F	3. SSE 4. SRV 5. IBA	Primary membrane plus bending	38,850	33,740
D. Maximum Cumulative Usage Factor:	0.965 at safe end			

TABLE 3.9B-2h
(Sheet 4 of 4)

REACTOR PRESSURE VESSEL AND SHROUD SUPPORT ASSEMBLY

IV. CRD Penetration

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress* (psi)	Calculated Stress* (psi)
Material: SB 167 (Inconel stub tube)				
A. Normal and Upset Conditions:				
$P_m \leq S_m$ $S_m = 20,000$ @ 575°F	1. Normal loads 2. Pressure	Primary membrane	20,000	8,250
$P_L + P_b \leq 1.5\ S_m$ $S_m = 20,000$ @ 575°F	3. OBE 4. SRV	Primary membrane plus bending	30,000	27,051
B. Emergency Condition:				
$P_m \leq S_y$ $S_y = 24,100$ @ 575°F	1. Normal loads 2. Pressure	Primary membrane	24,100	8,250
$P_L + P_b \leq 1.5\ S_y$ $S_y = 24,100$ @ 575°F	3. OBE 4. SRV	Primary membrane plus bending	36,150	27,051
C. Faulted Condition:				
$P_m \leq 2.4\ S_m$ $S_m = 20,000$ @ 575°F	1. Normal loads 2. Pressure	Primary membrane	48,000	9,760
$P_L + P_b \leq 3.6\ S_m$ $S_m = 20,000$ @ 575°F	3. Jet reaction 4. Vent clearing 5. SSE 6. Scram	Primary membrane plus bending	72,000	31,900
D. Maximum Cumulative Usage Factor:	0.645 at stub tube			

* The New Loads Adequacy Evaluation has concluded that the listed design basis loads envelope new loads.
** For EPU conditions, see GEH 0000-0072-9332; for GE 14 fuel introduction, see GE-NE-0000-0016-5640-00; and for GNF2 fuel introduction, see 003N2003.

TABLE 3.9B-2i
(Sheet 1 of 5)

REACTOR VESSEL INTERNALS AND ASSOCIATED EQUIPMENT

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Maximum Calculated Stress (psi)
I. Top Guide - Beam with Highest Stress[2]				
Material: 304 stainless steel				
A. Normal and Upset Conditions:				
$P_m \le S_m$	1. Normal loads	Primary membrane	16,900	2,416
S_m = 16,900 @ 550°F	2. Pressure			
$P_L + P_b \le 1.5\ S_m$	3. OBE	Primary membrane plus bending	25,350	23,724
S_m = 16,900 @ 550°F	4. SRV			
B. Emergency Condition:				
$P_m \le 1.5\ S_m$	1. Normal loads	Primary membrane	25,350	2,416
S_m = 16,900 @ 550°F	2. Pressure			
$P_L + P_b \le 2.25\ S_m$	3. OBE	Primary membrane plus bending	38,030	23,724
S_m = 16,900 @ 550°F	4. SRV			
C. Faulted Condition:				
$P_m \le 2.4\ S_m$	1. Normal loads	Primary membrane	40,560	3,550
S_m = 16,900 @ 550°F	2. Pressure			
$P_L + P_b \le 3.0\ S_m$	3. SSE	Primary membrane plus bending	50,700	42,806
S_m = 16,900 @ 550°F	4. SRV			
D. Maximum Cumulative Usage Factor:				
0.17 at beam slot				

TABLE 3.9B-2i
(Sheet 2 of 5)

REACTOR VESSEL INTERNALS AND ASSOCIATED EQUIPMENT

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Maximum Calculated Stress (psi)
II. Core Plate (Ligament in Top Plate)(2)				
Material: 304 stainless steel				
A. Normal and Upset Conditions:				
$P_m \leq S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. OBE 4. SRV	Primary membrane	16,900	9,400
$P_L + P_b \leq 1.5\ S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	25,350	18,550
B. Emergency Condition:				
$P_m \leq 1.5\ S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. Chugging 4. SRV ADS	Primary membrane	25,350	380
$P_m + P_b \leq 2.25\ S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. Chugging 4. SRV ADS	Primary membrane plus bending	38,030	9,540

TABLE 3.9B-2i
(Sheet 3 of 5)

REACTOR VESSEL INTERNALS AND ASSOCIATED EQUIPMENT

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Maximum Calculated Stress (psi)
C. Faulted Condition:				
$P_m \leq 2.4\ S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. Annulus pressurization 4. SSE 5. Jet reaction	Primary membrane	40,560	14,370
$P_L + P_b \leq 3.0\ S_m$ S_m = 16,900 @ 550°F	1. Normal loads 2. Pressure 3. Jet reaction 4. SRV ADS 5. SSE	Primary membrane plus bending	50,700	26,960
D. Maximum Cumulative Usage Factor: 0.93 at core plate studs				
III. Differential Pressure Line[1]				
Material: 304 stainless steel				
A. Normal and Upset Conditions:				
$P_L + P_b \geq 3\ S_m$ S_m = 16,400 @ 600°F	1. Deadweight 2. Pressure 3. SRV_{ALL}	Primary membrane plus bending	49,200	<46,320
B. Emergency Condition:				
$P_L + P_b \geq 2.25\ S_m$ S_m = 16,400 @ 600°F	1. Deadweight 2. Pressure 3. OBE 4. SRV	Primary membrane plus bending	36,900	<13,570

TABLE 3.9B-2i
(Sheet 4 of 5)

REACTOR VESSEL INTERNALS AND ASSOCIATED EQUIPMENT

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Maximum Calculated Stress (psi)
C. Faulted Condition: $P_L + P_b \geq 3.6\ S_m$ S_m = 16,400 @ 600°F	1. Deadweight 2. Pressure 3. Jet reaction 4. Vent clearing 5. SSE	Primary membrane plus bending	59,040	<35,750
D. Maximum Cumulative Usage Factor: u < 0.02 maximum				
IV. Head Cooling Spray Nozzle				
Material: Pipe, carbon steel SA-106B				
A. Normal and Upset Conditions: $P_L + P_b \geq$ S_m = 17,700 psi @ 575°F 3.0 S_m = 53,100 psi	1. Pressure 2. Weight 3. Thermal 4. OBE	Primary membrane plus bending plus secondary membrane	53,100	31,360
B. Emergency Condition: $P_L + P_b \geq$ S_m = 17,700 psi @ 575°F 1.8 S_m = 31,900 psi	1. Pressure 2. Weight 3. OBE 4. SRV	Primary membrane plus bending	31,900	17,710
C. Faulted Condition: $P_L + P_b \geq$ S_u = 60,000 psi @ 575°F 1.5 (0.7 S_u = 63,000 psi	1. Pressure 2. Weight 3. Annulus pressurization 4. SSE	Primary membrane plus bending	63,000	27,870

TABLE 3.9B-2i
(Sheet 5 of 5)

REACTOR VESSEL INTERNALS AND ASSOCIATED EQUIPMENT

ASME Section III Primary Stress Limit Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Maximum Calculated Stress (psi)
D. Maximum Fatigue Usage Factor: 0.91 at pipe-to-flange weld				

(1) Calculated stresses envelop current configuration without the standby liquid control loadings applied.
(2) For EPU conditions, see GEH 0000-0072-9332; for GE 14 fuel introduction, see GE-NE-0000-0016-5640-00; and for GNF2 fuel introduction, see 003N2003.

TABLE 3.9B-2j
(Sheet 1 of 6)

SAFETY/RELIEF VALVES SPRING-LOADED DIRECT-ACTING TYPE[1]

Topic	Method of Analysis	Dikkers Analysis	Allowable Value	Calculated Value
1. Body inlet and outlet flange stresses[2]	$S_H = \frac{fMo}{Lg_1^2 B} + \frac{PB}{4g_o} < 1.5\,S_m$ $S_R = \frac{(4te/3+1)\,Mo}{Lt^2 B} < 1.5\,S_m$ $S_T = \frac{YMo}{t^2 B} - ZS_R < 1.5\,S_m$ Where: S_H = Longitudinal "hub" wall stress, psi S_R = Radial "flange" (body base, inlet) stress, psi S_T = Tangential "flange" stress, psi	$\begin{bmatrix} (Uses\ same \\ notation \\ as\ codes) \end{bmatrix}$ Body material: ASME SA352 LCB Inlet: S_m at 585°F = 17,540 psi Outlet: S_m at 500°F = 18,900 psi	1.5 S_m = 26,310 psi (inlet) and = 28,350 psi (outlet)	Inlet: S_H = 1.15 S_m = 0.77 (allowable) S_R = 0.25 S_m = 0.17 (allowable) S_T = 1.08 S_m = 0.72 (allowable) Outlet: S_H = 1.21 S_m = 0.81 (allowable) S_R = 0.79 S_m = 0.53 (allowable) S_T = 0.49 S_m = 0.33 (allowable)
2. Inlet and outlet stud area requirements[2]	Total cross-sectional area shall exceed the greater of: $Am1 = \frac{Wm1}{Sb}$ or $Am2 = \frac{Wm2}{Sa}$	$\begin{bmatrix} (Uses\ same \\ notation \\ as\ codes) \end{bmatrix}$	Inlet: Am_1 (>Am_2) = 12.45 in^2 Outlet: Am_1 (>Am_2) = 4.65 in^2	Inlet: Ab(actual area) = 1.52 Am (required min) Outlet: Am(actual area) = 1.84 Am (required min)

TABLE 3.9B-2j
(Sheet 2 of 6)

SAFETY/RELIEF VALVES SPRING-LOADED DIRECT-ACTING TYPE[1]

Topic	Method of Analysis	Dikkers Analysis	Allowable Value	Calculated Value
	Where: Am_1 = Total required bolt (stud) area for condition Am_2 = Total required bolt (stud) area for gasket seating	Bolting material: ASME SA193 Gr. B7		
3. Nozzle wall thickness	1. Minimum wall thickness criterion: $t_{min} < t$ [3] Where: t_{min} = Minimum calculated thickness requirement, including corrosion allowance t_A = Actual nozzle wall thickness	Section near nozzle base: $t_{me} < t_{me}(actual)$ Nozzle midsection: $t_{mc} < t_{mc}(actual)$ Thin section near valve seat: $t_{mb} < t_{mb}(actual)$ Thinnest section at nozzle tip - just below valve seat: $t_{ma} < t_{ma}(actual)$ Nozzle Material: ASME SA350 LF2	$t_{me} = 0.84\ inch$ $t_{mc} = 0.81\ inch$ $t_{mb} = 0.79\ inch$ $t_{ma} = 0.206\ inch$ Actual thickness greater than t_m at the section under consideration	$t_{me}(actual) = 1.58\ t_{me}$ $t_{mc}(actual) = 1.54\ t_{mc}$ $t_{mb}(actual) = 1.012\ t_{mb}$ $t_{ma}(actual) = 1.68\ t_{ma}$

TABLE 3.9B-2j
(Sheet 3 of 6)

SAFETY/RELIEF VALVES SPRING-LOADED DIRECT-ACTING TYPE[1]

Topic	Method of Analysis	Dikkers Analysis	Allowable Value	Calculated Value
(Refer to Section 3.9B.1.1.9 for thermal transients information.)	2. Cyclic Rating: Thermal: $It = \sum \frac{Nri}{Ni}$	$It = \sum \frac{Nri}{Ni} \left(i = 1,2,3,4,5 \right)$	It (max) ≤ 1.0	It=0.0014
	Fatigue: $N_a \geq 2{,}000$ cycles, as based on Sa, where Sa is defined as the larger of: $Sp_1 = (2/3)Qp + \frac{Peb}{2} + Q_{T3} + 1.3\,Q_{T1}$ or $Sp_2 = 0.4\,Q_p + \frac{K}{2}(Peb + 2\,Q_{T3})$ Where: Sp_1 = Fatigue stress intensity at inside surface of crotch, psi Sp_2 = Fatigue stress intensity at inside surface of crotch, psi	$N_a \geq 2{,}000$ cycles, as based on Sa, where $Sa=Sp_1 (>Sp_2)$ $\left[\text{(Uses same notation as codes)} \right]$	$N_a \geq 2{,}000$ cycles	N_a (based on $Sa=Sp_2$) = 400,000 cycles, therefore satisfies criterion

TABLE 3.9B-2j
(Sheet 4 of 6)

SAFETY/RELIEF VALVES SPRING-LOADED DIRECT-ACTING TYPE[1]

Topic	Method of Analysis	Dikkers Analysis	Allowable Value	Calculated Value
4. Bonnet flange strength	Flange treated as a loose type flange without hub: $S_R = \pm \frac{6\,M\,P}{t^2 (3.14C - nD)}$ $S_T = \pm \frac{5.46\,M\,P}{BT^2} \left[0.318 \left[\frac{C - B}{C + B} + \frac{2\,h_C}{C + A}\right] + r_B\right] - \frac{E\,\theta_A\,t}{B}$ Where: S_R = Radial "flange" stress, psi S_T = Tangential "flange" stress, psi	$\left[\begin{matrix}(Uses\ same\\ notation\\ as\ codes)\end{matrix}\right]$ Bonnet Material: ASME SA-352LCB S_m at 500°F = 18,900 psi	1.5 S_m (for max S_H, S_R, and S_T), = 28,350 psi	S_R = .6 S_m = .4 (allowable) S_T = .14 S_m = .09 (allowable) (max S_T at back face of flange)
5. Bonnet bolting area requirements	Total cross-sectional area shall exceed the greater of: $AM_1 = \frac{Wm_1}{Sb}$ or $Am_2 = \frac{Wm_2}{Sa}$ Where: Am_1= Total required bolt (stud) area for operating condition	$Am_1 = \frac{Wm_1}{Sb}$ $Am_2 = \frac{Wm_2}{Sa}$ Where: Am (required minimum) is the greater of Am_1 and Am_2; and	Am_1(>Am_2) = 7.995 in^2	A_b (actual area) = 1.34 Am (required min)

TABLE 3.9B-2j
(Sheet 6 of 6)

SAFETY/RELIEF VALVES SPRING-LOADED DIRECT-ACTING TYPE[1]

Topic	Method of Analysis	Dikkers Analysis	Allowable Value	Calculated Value
	Am_2 = Total required bolt (stud) area for gasket seating	Ab (actual bolt area) must exceed Am. Body to bonnet bolting material: ASME SA-193 Gr. B7		
6. Disc	The disc stress is calculated by treating the disc as a flat circular plate, edges supported, uniform load over area with radius r_o; reference Bach's Formulas, Machinery's Handbook, 15th Ed., p 414. From the reference: $t = 1.2\left[W\left(\frac{1-2r_o}{\frac{3R}{S}}\right)\right]^{1/2}$ W is based on p=1,375 psi under the disc	w = 27,432 lb r_o = 0.785 in R = 2.48 in Disc material: ASME SA351 CF3A Temperature: 585°F S_m (585°F) = 18,235 psi. Allowable stress is 1.5 S_m. This is the value S in the above formula. (1.5 S_m = 27,353 psi)	t (min allowable) = 1.067 in	Actual t_{min} = 1.068 in = 1.0009 (required min)
7. Seismic capability	Stress analysis uses $F_{vertical}$ = (mass of valve) x (4.5 g), and $F_{horizontal}$ = (mass of valve) x (6.5 g), with 800,000 in-lb and 300,000 in-lb applied at the inlet and outlet, respectively. Actual capability verifiable by test (with the moments concurrently applied) and exceeds these values.			

(1) ASME Section III, July 1974, including addenda through summer 1976.

(2) Design pressures:
P_b = 1,375 psig (inlet)
P_b = 625 psig (outlet)
These are the maximum anticipated pressures under all operating conditions. Analyses include applied moments of: M=800,000 in-lb (inlet) and M=300,000 in-lb (outlet). The analyses also include consideration of seismic, operational, and flow reaction forces. Since these SRVs are pipe-mounted equipment, refer to the piping analysis for verification that the moments are not exceeded.

(3) This t_{min} is t_m in accordance with notation of the codes.

TABLE 3.9B-2k
(Sheet 1 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Suction Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
1.0	<u>Body and Bonnet</u>				
1.1	Loads: Design pressure Design temperature	 System requirement System requirement	 1,250 psi 575°F	 1,250 psi 575°F	 N/A N/A
1.2	Pressure rating	ASME Section III[(1)], Figure NB-3545.1-2	P_r = 734.96 psi	P_r = 734.96 psi	N/A
1.3	Minimum wall thickness	ASME Section III[(1)], Paragraph NB-3542	t_{min} = 1.931 in	t_{min} = 1.931 min	N/A
1.4	Primary membrane stress	ASME Section III[(1)], Paragraph NB-3545.1	$P_m \leq S$ (500°F) = 19,600 psi	P_m = 8,087 psi	0.54
1.5	Secondary stress due to pipe reaction	ASME Section III[(1)], Paragraph NB-3545.2(b)(i)	P_e = greatest value of p	P_{ed} = 6,300 psi P_{ed} = 19,643 psi	0.21 0.67
			P_{eb} and $P_{et} \leq 1.5$ S (500°F) (1.5) (19,600) = 29,400 psi	P_{et} = 19,643 psi	0.67
1.6	Primary plus secondary stress due to internal pressure	ASME Section III[(1)], Paragraph NB-3545.2(a)(1)	See Paragraph 1.8	Q_p = 20,632 psi	
1.7	Thermal secondary stress	ASME Section III[(1)], Paragraph NB-3545.2(c)	See Paragraph 1.8	Q_{T_2} = 998 psi	
1.8	Range of primary plus secondary stress at crotch region	ASME Section III[(1)], Paragraph NB-3545.2	$S_n \leq 3\ S_m$ (500°F) = 58,800 psi	$S_n = Q_p + P_e + 2Q_t$ = 36,970 psi	0.63
1.9	Cycle requirements for fatigue analysis	ASME Section III[(1)], Paragraph NB-3545.3	$N_a \geq 2,000$ cycles	$N\delta = 1 \times 10^6$ cycles	N/A
1.10	Usage factor requirements for fatigue analysis	ASME Section III[(1)], Paragraph NB-3550	$I_t \leq 1.0$	I_t = 0.0025	

TABLE 3.9B-2k
(Sheet 2 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Suction Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
2.0	Body to Bonnet Bolting				
2.1	Loads: design pressure and temperature, gasket loads, stem operational load, seismic load (SSE)				
2.2	Bolt area	ASME Section III[1], Paragraph NB-3647.1	$A_b \geq 28.96$ in^2 S_b = 28.675 psi	A_b = 29.70 in^2 S_b = 28.675 psi	N/A N/A
2.3	Body Flange Stresses	ASME Section III[1], Paragraph NB-3647.1	--	--	--
2.3.1	Operating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \leq 1.5$ S (575°F) = 28,832 psi $S_r \leq 1.5\ S_m$ (575°F) = 28,837 psi $S_t \leq 1.5\ S_m$ (575°F) = 28,837 psi	S_h = 14,293 psi S_r = 11,568 psi S_t = 3,914 psi	0.50 0.40 0.14
2.3.2	Gasket seating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \leq 1.5\ S_m$ (100°F) = 30,000 psi $S_r \leq 1.5\ S_m$ (100°F) = 30,000 psi $S_t \leq 1.5\ S_m$ (100°F) = 30,000 psi	S_h = 18,437 psi S_r = 16,242 psi S_t = 5,498 psi	0.61 0.54 0.18
2.4	Bonnet Flange Stresses	ASME Section III[1], Paragraph NB-3647.1	--	--	--
2.4.1	Operating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \leq 1.5\ S_m$ (575°F) = 28,837 psi $S_r \leq 1.5\ S_m$ (575°F) = 28,837 psi $S_t \leq 1.5\ S_m$ (575°F) = 28,837 psi	S_h = 18,783 psi S_r = 14,968 psi S_t = 4,691 psi	0.65 0.52 0.16

TABLE 3.9B-2k
(Sheet 3 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Suction Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
2.4.2	Gasket seating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \leq 1.5\ S_m$ (100°F) = 30,000 psi $S_r \leq 1.5\ S_m$ (100°F) = 30,000 psi $S_t \leq 1.5\ S_m$ (100°F) = 30,000 psi	S_h = 18,214 psi S_r = 14,391 psi S_t = 4,507 psi	0.61 0.48 0.15
3.0	<u>Stresses in Stem</u>				
3.1	Loads: operator thrust and torque	--	--	--	--
3.2	Stem thrust stress	Calculate stress due to operator thrust in critical cross section	$S_t \leq S_m$ = 42,275 psi	S_t = 3,347 psi	0.08
3.3	Stem shear stress	Calculate shear stress due to operator torque in critical cross section	$S_s \leq 0.6\ S_m$ = 25,365 psi	S_s = 2,288 psi	0.09
3.4	Buckling on stem	Calculate slenderness ratio. If greater than 30 calculate allowable load from Rankine's formula using safety factor of 4.	Max. allowable load = 34,284 lb	Slenderness ratio = 115 Actual load on stem = 15,115 lb (therefore, no buckling)	N/A 0.44
4.0	<u>Disc Analysis</u>				
4.1	Loads: maximum differential pressure[2]	--	--	--	--
4.2	Maximum stress in disc	ASME Section III[1], Paragraphs NB-3215 and NB-3221.3	$S_{max} \leq 1.5\ S_m$ (575°F) = 27,487 psi	Max stress = 20,225 psi	0.74

TABLE 3.9B-2k
(Sheet 4 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Suction Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
5.0	Yoke and Yoke Connections				
5.1	Loads: stem operational loads	Calculate stresses in the yoke and yoke connections to acceptable structural analysis methods	--	--	--
5.2	Tensile stress in yoke leg bolts	--	$S_{max} \leq S_m$ (100°F) = 35,000 psi	S_{max} = 8,718 psi	0.25
5.3	Bending stress of yoke legs	--	$S_b \leq 1.5\ S_m$ (185°F) = 33,165 psi	S_b = 14,011 psi	0.42

TABLE 3.9B-2k
(Sheet 5 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Discharge Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
1.0	Body and Bonnet				
1.1	Loads:				
	Design pressure	System requirement	1,650 psi	N/A	N/A
	Design temperature	System requirement	575°F	N/A	N/A
	Pipe reaction	Not specified	N/A	N/A	N/A
	Thermal effects	Not specified	N/A	N/A	N/A
1.2	Pressure rating	ASME Section III(1), Figure NB-3545.1-2	P_r = 969.68 psi	P_r = 969.68 psi	N/A
1.3	Minimum wall thickness	ASME Section III(1), Paragraph NB-3542	t (nominal) = 2.432 in	t_m = 2.432 min, in	N/A
1.4	Primary membrane stress	ASME Section III(1), Paragraph NB-3545.1	$P_m \leq S_m$ (500°F) = 19,600 psi	P_m = 9,831 psi	0.50
1.5	Secondary stress due to pipe reaction	ASME Section III(1), Paragraph NB-3545.2	P_e = greatest value of P_{ed}	P_{ed} = 5,917 psi P_{ed} = 19,643 psi	0.20 0.67
			P_{eb} and $P_{et} \leq 1.5\ S_m$ (500°F) 1.5 (19,600) = 29,400 psi	P_{et} = 19,643 psi $P_e = P_{et}$ = 19,643 psi	0.67
1.6	Primary plus secondary stress due to internal pressure	ASME Section III(1), Paragraph NB-3545.2(a)(1)	$S_h \leq 3\ S_m$ (500°F) = 58,800 psi	Q_p = 23,264 psi	--
1.7	Thermal secondary stress	ASME Section III(1), Paragraph NB-3545.2(c)	$S_h \leq 3\ S_m$ (500°F) = 58,800 psi	Q_t = 1,020 psi	--
1.8	Sum of primary plus secondary stress	ASME Section III(1), Paragraph NB-3545.2	$S_h \leq 3\ S_m$ (500°F) = 58,800 psi	$S_h = Q + P_e + 2Q_t$ = 36,970 psi	0.63
1.9	Fatigue requirements	ASME Section III(1), Paragraph NB-3545.3	$N_a \geq$ 2,000 cycles	$N\delta = 4 \times 10^5$ cycles	N/A
1.10	Cyclic rating	ASME Section III(1), Paragraph NB-3550	$I_t \leq 1.0$	I_t = 0.0032	N/A

TABLE 3.9B-2k
(Sheet 6 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Discharge Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
2.0	Body to Bonnet Bolting				
2.1	Loads: design pressure and temperature, gasket loads, stem operational load, seismic load (design basis earthquake)	ASME Section III[1], Paragraph NB-3647.1	--	--	--
2.2	Bolt area	ASME Section III[1], Paragraph NB-3647.1	$A_b \le 41.23$ in^2 $S_b \le 28{,}675$ psi	$A_b \ge 47.52$ in^2 $S_b = 28{,}675$ psi	N/A N/A
2.3	Body Flange Stresses	ASME Section III[1], Paragraph NB-3647.1	--	--	--
2.3.1	Operating conditions	ASME Section III[1], Paragraph NB-3647.1	$S_h \le 1.5\ S_m$ (575°F) = 28,837 psi $S_r \le 1.5\ S_m$ (575°F) = 28,837 psi $S_t \le 1.5\ S_m$ (575°F) = 28,837 psi	S_h = 14,682 psi S_r = 18,889 psi S_t = 4,815 psi	0.51 0.65 0.17
2.3.2	Gasket seating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \le 1.5\ S_m$ (100°F) = 30,000 psi $S_r \le 1.5\ S_m$ (100°F) = 30,000 psi $S_t \le 1.5\ S_m$ (100°F) = 30,000 psi	S_h = 19,884 psi S_r = 28,378 psi S_t = 7,235 psi	0.66 0.94 0.24
2.4	Bonnet Flange Stresses				
2.4.1	Operating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \le 1.5\ S_m$ (575°F) = 28,837 psi $S_r \le 1.5\ S_m$ (575°F) = 28,837 psi $S_t \le 1.5\ S_m$ (575°F) = 28,837 psi	S_h = 18,352 psi S_r = 24,546 psi S_t = 6,400 psi	0.64 0.85 0.22
2.4.2	Gasket seating condition	ASME Section III[1], Paragraph NB-3647.1	$S_h \le 1.5\ S_m$ (100°F) = 30,000 psi $S_r \le 1.5\ S_m$ (100°F) = 30,000 psi $S_t \le 1.5\ S_m$ (100°F) = 30,000 psi	S_h = 18,540 psi S_r = 24,875 psi S_t = 6,485 psi	0.62 0.83 0.22

TABLE 3.9B-2k
(Sheet 7 of 7)

REACTOR RECIRCULATION SYSTEM GATE VALVES

Discharge Valves

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value	Ratio Calculated/ Allowed
3.0	Stresses in Stem				
3.1	Load: operator thrust and torque	--	--	--	--
3.2	Stem thrust stress	Calculate stress due to operator thrust in critical cross section	$S_t \leq S_m$ = 42,275 psi	S_t = 7,295 psi	0.17
3.3	Stem torque stress	Calculate shear stress due to operator torque in critical cross section	$S_s \leq 0.6\ S_m$ = 25,365 psi	S_s = 4,986 psi	0.20
3.4	Buckling on stem	Calculate slenderness ratio. If greater than 30, calculate allowable load from Rankine's formula using safety factor of 4.	Max allowable load = 44,322 lb	Slenderness ratio = 96.5 Actual load on stem = 32,944 lb (therefore, no buckling)	N/A 0.74
4.0	Disc Analysis				
4.1	Loads: maximum differential pressure[3]	--	--	--	--
4.2	Maximum stress in disc	ASME Section III[1], Paragraphs NB-3215 and NB-3221.3	$S_{max} \leq 1.5\ S_m$ (575°F) = 27,487 psi	Max stress = 26,179 psi	0.95
5.0	Yoke and Yoke Connections				
5.1	Loads: stem operational load	Calculate stresses in yoke and yoke connections to acceptable structural analysis methods	--	--	--
≤5.2	Tensile stress in yoke leg bolts	--	$S_{max} \leq S_m$ (100°F) = 35,000 psi	S_{max} = 14,654 psi	0.42
5.3	Bending stress of yoke legs	--	$S_b \leq 1.5\ S$ (185°F) = 33,165 psi	S_b = 19,988 psi	0.60

(1) ASME Section III, 1971 Edition.
(2) Valve differential pressure is 50 psig.
(3) Valve differential pressure is 450 psig.

TABLE 3.9B-2ℓ
(Sheet 1 of 2)

RECIRCULATION FLOW CONTROL VALVE 24-IN SIZE (FISHER)
(ASME Section III 1971 Edition, with Winter 1973 Addenda)

Item No.	Component/Stress/Loading	Design Procedure	Allowable Limit	Calculated or Actual Value	Ratio Calc/ Allowed
1.0	Body, housing, bonnet and covers				
1.1	Loads - Design pressure Design temperature	System requirement System requirement		1675 psi 575°F	
1.2	Body pressure rating	ASME Section III NB-3545.1-2		985 psi	
1.3	Body minimum wall thickness	ASME Section III NB-3541	t_m = 2.614 in	t_m = 2.710 in	1.036
1.4	Maximum primary body membrane stress	ASME Section III NB-3545.1	$P_m \leq S_m$ (575°) = 19,600 psi	P_m = 10,265 psi	0.523
1.5	Maximum primary plus secondary body stress	ASME Section III NB-3545.2	$S_m \leq 3\ S_m \leq$ 58,800 psi	S_m = 25,315 psi	0.43
1.6	Housing minimum wall thickness	ASME Section III NB-3541	t_m = 2.549 in	t_m = 2.710 in	1.063
1.7	Maximum primary housing membrane stress	ASME Section III NB-3545.1	$P_m \leq S_m$ (575°) $\leq$ 19,600 psi	P_m = 8,400 psi	0.428
1.8	Maximum primary plus secondary housing stress	ASME Section III NB-3545.2	$S_m \leq 3\ S_m$ (575°) $\leq$ 58,800 psi	S_m = 23,100 psi	0.392
1.9	Cyclic requirements	ASME Section III NB-3545.3	$N_a \leq$ 2,000 cyc	$N_a = 10^6$ cyc	
1.10	Fatigue analysis usage factor	ASME Section III NB-3550	$I_t \leq 1.0$	I_t = 0.0006	
1.11	Body-to-housing flange maximum stress	ASME Section III NB-3647.1	S_m = 29,400 psi (1.5 x 19,600)	S_m = 28,832 psi	0.981
1.12	Body-to-housing studs - area Body-to-housing primary stress Body-to-housing maximum stress	ASME Section III NB-3647.1	$A_6 \geq 31.67\ in^2$ S_m = 27,000 psi 3 S_m = 81,000 psi	$A_6 = 31.68\ in^2$ S_6 = 26,992 psi S_6 = 68,100 psi	1.0 0.999 0.841
1.13	Top housing cover - thickness	ASME Section III NB-3646 and ASME Section VIII, UG-34	$t_m \geq$ 3.23 in	t_m = 4.63 in	1.433

TABLE 3.9B-2ℓ
(Sheet 2 of 2)

RECIRCULATION FLOW CONTROL VALVE 24-IN SIZE (FISHER)
(ASME Section III 1971 Edition, with Winter 1973 Addenda)

Item No.	Component/Stress/Loading	Design Procedure	Allowable Limit	Calculated or Actual Value	Ratio Calc/ Allowed
1.14	Top housing cover studs - area Top housing primary stud stress Top housing maximum stud stress	ASME Section III NB-3647.1	$A_6 \geq 31.75$ in^2 S_m = 27,000 psi 3 S_m = 81,000 psi	A_6 = 33.60 in^2 S_6 = 25,900 psi S_6 = 45,100 psi	1.058 0.959 0.556
1.15	Bottom cover - thickness	NB-3646 and Section VIII, UG-34	$t_m \geq 1.85$ in	t_m = 3.56 in	1.924
1.16	Bottom cover primary stud stress Bottom cover maximum stud stress Bottom cover studs - area	ASME Section III NB-3647.1	S_m = 27,000 psi 3 S_m = 81,000 psi $A_6 \geq 11.09$ in^2	S_6 = 22,277 psi S_6 = 52,400 psi A_6 = 13.44 in^2	0.825 0.647 1.211
1.17	Bonnet cartridge - thickness	NB-3646 and Section VIII, UG-34	$t_m \geq 1.82$ in	t_m = 3.125 in	1.717
1.18	Bonnet cartridge studs - area Bonnet cartridge primary stud stress Bonnet cartridge maximum stud stress	ASME Section III NB-3647.1	$A_6 \geq 12.07$ in^2 S_m = 27,000 psi 3 S_m = 81,000 psi	A_6 = 18.48 in^2 S_6 = 17,630 psi S_6 = 56,500 psi	1.531 0.652 0.698

NOTE: The recirculation flow control valves are passive components and therefore are not required to operate in emergency or faulted conditions. The valves have been designed for 6 g vertical and 9 g horizontal, which exceeds any load condition from Table 3.9B-2h. The valves will maintain pressure integrity during and after events imposing these accelerations. The valve internals (ball shaft, linkage, bearings, etc.) have also been designed for faulted, large pipe break conditions. Qualification method is by analysis only.

TABLE 3.9B-2m
(Sheet 1 of 2)

ASME SAFETY CLASS 1 RECIRCULATION PIPING AND PIPE MOUNTED EQUIPMENT
HIGHEST STRESS SUMMARY

Acceptance Criteria	Limiting Stress Type	Calculated Stress[1] or Usage Factor	Allowable Limits	Ratio Actual/ Allowable	Loading	Identification[2] of Locations of Highest Stress Points
ASME Section III, NB-3600 Design Condition: Eq. 9 $\leq$ 1.5 S_m	Primary	15,846 psi	25,875 psi	0.61	1. Pressure 2. Weight	Hanger lug (Loop B)
Service Levels A and B (normal & upset) condition: Eq. 12 $\leq$ 3.0 S_m	Secondary	30,015 psi	51,750 psi	0.58	1. Thermal	Header sweepolet (Loop B)
Service Levels A and B (normal & upset) condition: Eq. 13 $\leq$ 3.0 S_m	Primary plus secondary (except thermal expansion)	40,978 psi	51,750 psi	0.79	1. Pressure 2. Weight 3. OBE 4. Operating transients 5. SRV	RHS return sweepolet (Loop B)
Service Levels A and B (normal and upset) condition: Cumulative usage factor	N/A	0.56	1.0	0.56		Header sweepolet (Loop B)
Service Level B (upset) condition: Eq. 9 $\leq$ 1.8 S_m & 1.5 S_y	Primary	29,239 psi	29,388 psi	0.99	1. Pressure 2. Weight 3. OBE 4. SRV	RHS return sweepolet (Loop B)
Service Level C (emergency) condition: Eq. 9 < 2.25 S_m & 1.8 S_y	Primary	18,540 psi	35,266 psi	0.53	1. Pressure 2. Weight 3. Chugging 4. SRV	Hanger lug (Loop B)
Service Level D (faulted) condition: Eq. 9 < 3.0 S_m + 2.0 S_y	Primary	34,058 psi	39,184 psi	0.87	1. Pressure 2. Weight 3. SSE 4. AP	RHS return sweepolet (Loop B)

TABLE 3.9B-2m
(Sheet 2 of 2)

ASME SAFETY CLASS 1 RECIRCULATION PIPING AND PIPE MOUNTED EQUIPMENT
HIGHEST STRESS SUMMARY

Component/Load Type	Highest Calculated Load	Allowable Load	Ratio Calculated/ Allowable	Loading	Identification of Equipment with Highest Loads
Snubber Load (lb)					
Service Level B	53,924	100,000	0.54	1. OBE 2. SRV	Snubber SB10
Service Level C	20,774	133,000	0.16	1. Chugging 2. SRV	Snubber SB10
Service Level D	72,271	150,000	0.48	1. SSE 2. AP	Snubber SB10
Flange Moment (in-lb)					
Level B	1,164,538	1,527,140	0.76	1. Weight 2. Thermal 3. OBE 4. SRV	Discharge valve (Loop B)
Level C	471,382	1,527,140	0.31	1. Weight 2. Thermal 3. Chugging 4. SRV	Discharge valve (Loop B)
Level D	1,374,232	1,527,140	0.90	1. Weight 2. Thermal 3. SSE 4. AP	Discharge valve (Loop B)
Acceleration (g)					
Horizontal	1.58	9.0	0.18	1. SSE 2. Chugging 3. SRV	Flow control valve (Loop A)
Vertical	1.40	6.0	0.23	1. SSE 2. AP	Flow control valve (Loop B)

TABLE 3.9B-2n
(Sheet 1 of 3)

REACTOR REFUELING AND SERVICING EQUIPMENT

Equipment Storage Racks

Acceptance Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
The allowable primary bending stress is based on ASME Section III for type ASTM B221 or 308 6061T6 aluminum alloy F_u = 38,000 psi F_y = 35,000 psi				
For normal condition: S_{limit} = 0.66 F_y	For normal condition: 1. Normal operating loads	Bending	23,100	16,887
For emergency condition: S_{limit} = 0.88 F_y	For emergency condition: 1. Normal operating loads 2. OBE 3. SRV discharge 4. LOCA*	Bending	30,800	26,130
For faulted condition: S_{limit} = 0.88 F_y	For faulted condition: 1. Normal operating loads 2. SSE 3. SRV discharge 4. LOCA	Bending	30,800	26,415

* Used for conservatism.

TABLE 3.9B-2n
(Sheet 2 of 3)

REACTOR REFUELING AND SERVICING EQUIPMENT

Fuel Preparation Machine

Acceptance Criteria	Loading	Primary Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Material: Aluminum 6061-T6, T651 welded using ASTM 5356 filler wire				
F_y = 20,000 psi				
F_u = 24,000 psi				
For normal condition:	For normal condition:	$P_m + P_b$	13,100	4,500
S_{limit} = 0.65 F_y	1. Static			
For upset condition:	For upset condition:	$P_m + P_b$	17,600	14,800
S_{limit} = 0.88 F_y	1. Normal operating loads 2. OBE 3. SRV			
For faulted condition:	For faulted condition:	$P_m + P_b$	24,000	22,400
S_{limit} = F_u	1. Normal operating loads 2. SSE 3. SRV 4. LOCA			

TABLE 3.9B-2n
(Sheet 3 of 3)

REACTOR REFUELING AND SERVICING EQUIPMENT

Refueling Platform With Service Pole Caddy, NF500 Round Mast, Gleason Dual Air Hose and Reels

Acceptance Criteria	Loading	Load Type	Allowable Stress (psi)	Calculated Stress (psi)
The allowable stresses are based on AISC Part 5, Sections 1.5 and 1.6				
For normal condition:	1. Operating	Axial load and bending	30,360	15,813
For upset condition:	1. Operating 2. OBE 3. SRV 4. LOCA*	Shear load (weld)	16,000	15,075
For faulted condition:	1. Operating 2. SSE 3. SRV 4. LOCA	Shear load (weld)	16,000	15,857

* Used for conservatism.

TABLE 3.9B-2o
(Sheet 1 of 1)

FUEL ASSEMBLY (INCLUDING CHANNEL)[2][3]

Acceptance Criteria	Loading	Primary Load Type	Calculated Peak Acceleration	Evaluation Basis Acceleration
Acceleration envelope	Horizontal direction Peak pressure Safe shutdown earthquake Annulus pressurization	Horizontal acceleration	2.5 G	[1]
	Vertical direction Peak pressure Safe shutdown earthquake Safety relief valve Chugging	Vertical accelerations	3.1 G[4]	[1]

[1] Evaluation basis accelerations and evaluations are contained in NEDE-21175-3-P-A; for GE 11 fuel, NEDE-31917P; for GE 14 fuel, NEDC-32868P, NEDE-31152P, and GE-NE-0000-0016-5640-00; and for GNF2 fuel, 003N2003 and NEDC-33270P.

[2] The calculated maximum fuel assembly gap opening for the most limiting load combination is 0.01 in based on the methodology contained in NEDE-21175-3-P. This is much less than the gap required to start the disengagement of the lower tie-plate from the fuel support casting.

[3] The fatigue analysis indicates that the fuel assembly has adequate fatigue capability to withstand loadings resulting from multiple SRV actuations and the OBE + SRV event.

[4] These values are determined using methodology contained in NEDE-21175-3-P-A.

TABLE 3.9B-2p
(Sheet 1 of 1)

RECIRCULATION PUMP

Summary of Load Classification
High Stress Locations and Limit Criteria Pump Case

Loading Condition ASME Section III	Load Combination		Criteria (ASME Section III NB-3220)	Location	Highest Calc. Stress (psi)/ Usage Factor	Allowable Value	Ratio Act./ All.
	Pressure (psig)	Mechanical Loads					
Design (NB-3112)	Design pressure = 1,650	1. OBE 2. Pump thrust 3. Deadweight 4. Nozzle loads 5. Gasket seating	Figure NB-3221-1 $P_m \leq 1.0\ S_m$ $P_L + P_b \leq 1.5\ S_m$	Pump case	28,449 psi	28,838 psi	0.99
Normal (NB-3113.1) and upset (NB-3113.2)	Most severe normal/ upset pressure = 1,313	1. Deadweight 2. Nozzle loads 3. Thermal transient 4. OBE 5. Upset	Figure NB-3222-1 $P_L + P_b + P_e + Q \leq 3.0\ S_m$ $P_e \leq 3.0\ S_m$	Discharge transition Bolts	48,449 psi u=0.29	58,020 psi 1.0	0.84 0.29
Emergency (NB-3113.3)	Most severe emergency pressure = 1,796	1. Deadweight 2. Nozzle loads 3. Pump thrust 4. Gasket seating 5. OBE	Figure NB-3224-1 $P_m \leq (1.2\ S_m$ or $S_y)$ $P_L \leq (1.8\ S_m$ or $1.5\ S_y)$ $P_L + P_b \leq (1.8\ S_m$ or $1.5\ S_y)$	Crotch	32,317 psi	34,812 psi	0.93
Faulted (NB-3113.4)	Most severe faulted pressure = 1,313	1. Deadweight 2. Nozzle loads 3. SSE 4. Pump thrust 5. Gasket seating	Table F-1322.2-1 $P_m \leq 2.4\ S_m$ or $0.7\ S_u$ $+ P \leq 1.5\ (2.4\ S_m$ or $0.7\ S_u)$ $P_L + P_b \leq 1.5\ (2.4\ S_m$ or $0.75\ S_u)$	Discharge transition	52,563 psi	66,845 psi	0.79

TABLE 3.9B-2q
(Sheet 1 of 1)

STANDBY LIQUID CONTROL TANK

Criteria	Method of Analysis	Allowable Stress or Minimum Thickness Required or Load	Actual Stress or Thickness or Load	
1. Shell thickness				
Loads: Normal and upset design pressure and temperature	Brownell & Young "Process Equipment Design"	0.010 in	0.25 in	
Stress limit	ASME Section III	30,000 psi	1,203 psi	
2. Nozzle loads				
Loads: Normal and upset design pressure and temperature	The maximum moments due to pipe reaction and maximum forces shall not exceed the allowable limits.			
Overflow nozzle		Fo = 450 lb Mo = 310 ft-lb	98 lb 195 ft-lb	
			<u>Nozzle 1</u>	<u>Nozzle 2</u>
Discharge nozzle		Fo = 450 lb Mo = 310 ft-lb	287 lb 289 ft-lb	350 lb 191 ft-lb
Loads: Faulted deadweight, thermal expansion, and SSE	The maximum moments due to pipe reaction and maximum forces shall not exceed the allowable limits.			
Overflow nozzle		Fo = 540 lb Mo = 372 ft-lb	109 lb 209 ft-lb	
			<u>Nozzle 1</u>	<u>Nozzle 2</u>
Discharge nozzle		Fo = 540 lb Mo = 372 ft-lb	298 lb 315 ft-lb	441 lb 234 ft-lb
3. Anchor bolts	ASME Section III	10,000 psi	8,104 psi	
4. Dynamic loads a. SSE b. SRV all c. LOCA	Equivalent static	1.75 g horizontal 1.75 g vertical	1.046 g horizontal 0.71 g vertical	

TABLE 3.9B-2r
(Sheet 1 of 4)

RESIDUAL HEAT REMOVAL HEAT EXCHANGER

Loading	Criteria/Location	Allowable Stress or Minimum Thickness Required	Calculated Stress or Actual Thickness
1. Closure Bolting Loads: Normal Design pressure and temperature Design gasket load	Bolting loads and stresses calculated in accordance with Rules for Bolted Flange Connections, ASME Section III, Appendix XI a. Shell-to-tube sheet bolts b. Channel cover bolts	 25,000 psi 25,000 psi	 22,009 psi 18,626 psi
2. Wall Thickness Loads: Normal Design pressure and temperature	Shell side ASME Section III, Safety Class 2 and TEMA, Class C Tube side ASME Section III, Safety Class 3 and TEMA, Class C a. Shell b. Shell cover c. Channel d. Tubes e. Channel cover f. Tube sheet	 0.78 in 0.77 in 0.808 in 0.0515 in 6.77 in 6.22 in	 0.875 in 0.81 in min 0.875 in 0.054 in min 6.82 in 6.25 in

TABLE 3.9B-2r
(Sheet 2 of 4)

RESIDUAL HEAT REMOVAL HEAT EXCHANGER

Loading	Criteria	Allowable Nozzle Forces and Moments	Calculated Nozzle Loads
3. Nozzle Loads: Faulted Design pressure and temperature Deadweight SSE SRV LOCA	The maximum moments due to pipe reaction and the maximum forces shall not exceed the allowable limits. Primary stress smaller of 0.7 Su or 2.4 S in accordance with ASME Section III allowable.	(1,2)	(3)
4. Support Brackets and Attachment Welds Loads: Faulted Design pressure and temperature Deadweight Nozzle loads SSE SRV LOCA	Stress allowables in accordance with ASME Section III, Subsection NT (upset condition). a. Lower bracket welds Bending stress Shear stress b. Upper bracket welds Bending stress Shear stress	 14,438 21,000 14,438 21,000	 2,169 3,646 1,983 853
5. Anchor Bolts Loads: Faulted Design pressure and temperature Deadweight Nozzle loads SSE SRV LOCA	Stress allowable in accordance with ASME Section III, Appendix XVII Lower support bolting Tension Shear	 29,000 11,990	 6,919 3,771

TABLE 3.9B-2r
(Sheet 3 of 4)

RESIDUAL HEAT REMOVAL HEAT EXCHANGER

Loading	Criteria/Location	Allowable Stress (psi) or Minimum Thickness Required	Calculated Stress or Actual Thickness
6. Shell Adjacent to Support Brackets Loads: Faulted Design pressure and temperature Deadweight Nozzle loads SSE SRV LOCA	Shell stress allowables in accordance with ASME Section III Subsection NC (upset condition) a. Maximum principal stress adjacent to upper support b. Maximum principal stress adjacent to lower support	 28,875 28,875	 18,864 23,097
7. Shell Away from Discontinuities Loads: Faulted Design pressure and temperature Deadweight Nozzle loads SSE SRV LOCA	Stress allowable in accordance with ASME Section III Subsection NC (upset condition) Principal stress	 19,250	 17,838

(1) Maximum allowable piping load combinations for faulted conditions (including DBE) shall not exceed the following relationship for each nozzle:

$$\frac{|Fi|}{|Fo|} + \frac{|Mi|}{|Mo|} \leq 1$$

Fo

Fi

Mi Mo

Where:

Fi = Largest of the three actual external orthogonal forces (Fx, Fy, and Fz)
Mi = Largest of the three actual external orthogonal moments (Mx, My, and Mz) for the same reference coordinates
Fo = Allowable value of Fi when all moments are zero
Mo = Allowable value of Mi when all forces are zero

One coordinate axis must be the nozzle centerline. Another coordinate axis must be parallel to the heat exchanger centerline except where the heat exchanger centerline is parallel to the nozzle centerline. In this case, the coordinate axis must be orthogonal to the nozzle centerline and at 0°-180° or 90°-270° azimuths.

TABLE 3.9B-2r
(Sheet 4 of 4)

RESIDUAL HEAT REMOVAL HEAT EXCHANGER

(2) Allowable limits (design basis):

		N1	N2	N3	N4
Fx	=	13,000 lb	13,000 lb	15,500 lb	15,500 lb
Fy	=	13,000 lb	13,000 lb	15,500 lb	15,500 lb
Fz	=	13,000 lb	13,000 lb	15,500 lb	15,500 lb
Mx	=	46,000 ft-lb	46,000 ft-lb	60,000 ft-lb	60,000 ft-lb
My	=	46,000 ft-lb	46,000 ft-lb	60,000 ft-lb	60,000 ft-lb
Mz	=	46,000 ft-lb	46,000 ft-lb	60,000 ft-lb	60,000 ft-lb

(3) See as shown:

Faulted

Heat Exch	Nozzle No.	Fi	Mi	Fo	Mo	$\frac{\lvert Fi\rvert}{\lvert Fo\rvert} + \frac{\lvert Mi\rvert}{\lvert Mo\rvert}$
2RMS	N1	6,520	20,611	13,000	46,000	0.95
*E1A	N2	3,751	10,622	13,000	46,000	0.52
	N3	NA	NA	NA	NA	NA
	N4	NA	NA	NA	NA	NA
2RMS	N1	4,444	10,976	13,000	46,000	0.58
*E1B	N2	3,517	13,437	13,000	46,000	0.563
	N3	7,179	31,363	15,500	60,000	0.986
	N4	3,987	18,051	15,500	60,000	0.56

TABLE 3.9B-2s
(Sheet 1 of 2)

RCIC TURBINE

Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
The highest stressed sections of the various components of the RCIC turbine assembly are identified. Allowable stresses are based on ASME Section III for normal conditions: Pressure boundary castings SA-216-WCB: S = 17,500 psi Pressure boundary boltings, SA-193-B7: S = 25,000 psi Alignment dowel pins: AISI4037, Rc28-35 τ_a = 61,000 psi S_y = 106,000 psi				
Normal Condition Loads: 1. Design pressure 2. Design temperature 3. Inlet nozzle loads 4. Exhaust nozzle loads	Castings: a. Stop valve b. Governor valve c. Turbine inlet d. Turbine case Pressure-containing bolts Structure alignment pins	General membrane General membrane Local bending Local bending Tensile Shear	17,500 17,500 21,000 21,000 25,000 61,000	(1)
Upset, Emergency, or Faulted Condition[2]: 1. Design pressure 2. Design temperature 3. SSE or OBE (horizontal and vertical, see Figures 3.9-1 and 3.9-2) 4. Inlet nozzle loads 5. Exhaust nozzle loads 6. SRV 7. LOCA	Castings: a. Stop valve b. Governor valve c. Turbine inlet d. Turbine case Pressure-containing bolts Structure alignment pins	General membrane General membrane Local bending Local bending Tensile Shear	19,250 19,250 25,200 25,200 25,000 61,000	13,860 15,300 15,300 18,000 20,100 53,080

TABLE 3.9B-2s
(Sheet 2 of 2)

RCIC TURBINE

Criteria/Loading	Component	Limiting Stress Type	Allowable Load Criteria	Load Calculated
Nozzle Load Definition: Turbine vendor has defined allowable nozzle loads for the turbine assembly. The above calculated stresses assume these allowable nozzle loads have been satisfied.			Inlet: $F \leq \frac{(2,620-M)}{3}$ Exhaust: $F \leq \frac{(6,000-M)}{3}$	 F_R = 590.0 lb M_R = 837.0 ft-lb F_R = 1085.0 lb M_R = 2503.0 ft-lb
Normal Condition Loads: 1. Design pressure 2. Design temperature 3. Weight of structure 4. Thermal expansion			F = Resultant force (lb) M = Resultant moment (ft-lb)	
Upset, Emergency, and Faulted Condition Loads: 1. Design pressure 2. Design temperature 3. Weight of structure 4. Thermal expansion 5. SSE or OBE 6. SRV 7. LOCA			Inlet: $F \leq \frac{(7,000-M)}{7}$ Exhaust: $F \leq \frac{(8,500-M)}{0.34}$ but <7,000 F = resultant force (lb) M = resultant moment (ft-lb)	 F_R = 605.0 lb M_R = 893.0 ft-lb F_R = 1361.0 lb M_R = 3114.0 ft=lb

(1) Calculated stresses for the upset, emergency, or faulted condition are lower than the allowable stresses for the normal condition; therefore, normal condition does not need to be evaluated.
(2) Analysis indicates that shaft deflection with faulted loads is 0.014 in, which is fully acceptable, and maximum bearing load with faulted condition is 80% of allowable.

TABLE 3.9B-2t
(Sheet 1 of 3)

RCIC PUMP

Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Pressure boundary stress limits of the various components for the RCIC pump assembly are based on ASME Section III for pressure boundary parts at 140°F. 1. Forged barrel SA-105 Gr. II — S_y = 36,000 psi 2. End cover plates SA-105 Gr. II — S_y = 36,000 psi 3. Nozzle connections SA-105 Gr. II — S_y = 36,000 psi 4. Aligning pin SA-515 Gr. 60 — S_y = 36,000 psi 5. Closure bolting SA-193-87 — S_y = 105,000 psi 6. Pump holddown bolting SA-325 — S_y = 77,000 psi 7. Taper pins SA-108 Gr. B1112 — S_y = 75,000 psi				
Normal and Upset Condition Loads: 1. Design pressure 2. Design temperature 3. OBE 4. Suction nozzle loads 5. Discharge nozzle loads	 1. Forged barrel 2. Nozzle reinforcement 3. Alignment pin 4. Taper pins 5. Pump holddown bolts	 General membrane General membrane Shear Shear Tensile	 17,500 17,500 15,000 15,000 40,000	
Emergency or Faulted Condition Loads[1]: 1. Design pressure 2. Design temperature 3. SSE 4. Suction nozzle loads 5. Discharge nozzle loads	 1. Forged barrel 2. Nozzle reinforcement at barrel discharge 3. Alignment pin 4. Taper pins (bearing housing) 5. Pump holddown bolts	 General membrane General membrane Shear Tension	 17,500 26,250 18,000 15,000 48,000	 7,052 7,855 2,230 2,280 33,662

TABLE 3.9B-2t
(Sheet 2 of 3)

RCIC PUMP

Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Nozzle Load Definition: Units: Forces - lb Moments - ft-lb The allowable combinations of forces and moments are as follows: Fo $\frac{Fi}{Fo} + \frac{Mi}{Mo} \leq 1$ Fi Mi Mo Where: Fi = Largest absolute value of the three actual external orthogonal forces (Fx, Fy, Fz) that may be imposed by the interface pipe. Mi = Largest absolute value of the three actual external orthogonal moments (Mx, My, Mz) permitted from the interface pipe when they are combined simultaneously for a specific condition.				

TABLE 3.9B-2t
(Sheet 3 of 3)

RCIC PUMP

Criteria/Loading	Component	Limiting Stress Type	Allowable Loads (Ft-ft/lb)	Calculated Loads (Ft-ft/lb)
Normal and Upset Condition Loads: 1. Design pressure 2. Design temperature 3. Weight of structure 4. Thermal expansion 5. OBE		Fo - Allowable value of Fi when all moments are zero Mo - Allowable value of Mi when all forces are zero	Suction: Fo ≤ 1,940 Mo ≤ 2,460 Discharge: Fo ≤ 3,715 Mo ≤ 4,330	Fi = 842 Mi = 1,224 Fi = 1,767 Mi = 2,012
Emergency or Faulted Condition Loads: 1. Design pressure 2. Design temperature 3. Weight of structure 4. Thermal expansion 5. SSE			Suction: Fo ≤ 2,325 Mo ≤ 2,950 Discharge: Fo ≤ 4,450 Mo ≤ 5,200	Fi = 860 Mi = 1,248 (emergency) Fi = 1,799 Mi = 2,126 (faulted)

(1) Operability: state analysis for emergency or faulted condition shows that the maximum shaft deflection is 0.004 in (with 0.0055 in allowable), shaft stresses are 5,975 psi with 32,000 psi allowable, and bearing loads of, drive end 376 lb, with 7,670 lb allowable and thrust end 1,323 lb with 17,200 lb allowable.

TABLE 3.9B-2u
(Sheet 1 of 2)

ECCS PUMPS

Location	Loading Condition	Criterion	Calculated Stress or Actual Thickness	Allowable Stress or Min Thickness
(i) Residual Heat Removal Pump				
Discharge head shell	Design pressure, Nozzle loads, SRV, Seismic loads, LOCA	ASME Section VIII, Division 1, Para. UG-27	24,253 psi	34,650 psi
Discharge head cover	Design pressure	ASME Section VIII, Division 1, Para. UG-34, UG-39, UG-40	3.00 in	2.63 in
Nozzle shell intersection	Faulted Condition Design pressure, Nozzle loads, SRV, Seismic load, LOCA	ASME Section VIII, Division 1, Para. UG-37	34,518 psi (suction) 28,905 psi (discharge)	34,650 psi
Discharge pipe	Faulted Condition Design pressure, Nozzle loads	ASME Section VIII, Division 1, Para. UG-27	14,791 psi	18,000 psi
Discharge head bolting	Faulted Condition Design pressure, Nozzle loads, Seismic, LOCA, SRV	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	35,030 psi	45,000 psi
Motor bolting	Faulted Condition Seismic load, SRV, LOCA	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	10,741 psi	25,000 psi
(ii) Low-Pressure Core Spray Pump				
Discharge head shell	Faulted Condition Design pressure, Nozzle loads, SRV, Seismic, LOCA	ASME Section VIII, Division 1, Para. UG-27	9,173 psi	34,650 psi
Discharge head cover	Design pressure	ASME Section VIII, Division 1, Para. UG-34, UG-39, UG-40	3.0 in	2.37 in
Nozzle shell intersection	Faulted Condition Design pressure, Nozzle loads, SRV, Seismic, LOCA	ASME Section VIII, Division 1, Para. UG-37	14,794 psi (suction) 16,929 psi (discharge)	34,650 psi
Discharge pipe	Faulted Condition Design pressure, Nozzle loads	ASME Section VIII, Division 1, Para. UG-27	17,920 psi	18,000 psi
Discharge head bolting	Faulted Condition Design pressure, Nozzle loads, SRV, Seismic, LOCA	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	17,281 psi	45,000 psi

TABLE 3.9B-2u
(Sheet 2 of 2)

ECCS PUMPS

Location	Loading Condition	Criterion	Calculated Stress or Actual Thickness	Allowable Stress or Min Thickness
Motor bolting	Faulted Condition Seismic load, SRV, LOCA	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	3,159 psi	25,000 psi
(iii) High-Pressure Core Spray Pump				
Discharge head shell	Faulted Condition Design pressure, Nozzle loads, Seismic load	ASME Section VIII, Division 1, Para. UG-27	8,904 psi	34,650 psi
Discharge head cover	Design pressure	ASME Section VIII, Division 1, Para. UG-34, UG-39, UG-40	3.25 in	2.75 in
Nozzle shell intersection	Faulted Condition Design pressure, Nozzle loads, Seismic load	ASME Section VIII, Division 1, Para. UG-37	10,534 psi (suction) 15,611 psi (discharge)	34,650 psi
Discharge pipe	Faulted Condition Design pressure, Nozzle loads	ASME Section VIII, Division 1, Para. UG-27	10,175 psi	21,000 psi
Discharge head bolting	Faulted Condition Design pressure, Nozzle loads, Seismic load	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	18,796 psi	45,000 psi
Motor bolting	Faulted Condition Seismic load	Bolting loads and stresses in Rules for Bolted Flange Connections, ASME Section VIII, App. II	5,878 psi	25,000 psi

TABLE 3.9B-2v
(Sheet 1 of 4)

STANDBY LIQUID CONTROL PUMP

Criteria/Loading		Component	Limiting Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Pressure boundary parts[1]:					
1. Fluid cylinder - SA-182-F304	S_y = 30,000 psi				
2. Discharge valve stop and cylinder head extension SA-479-304	S_y = 30,000 psi				
3. Discharge valve cover, cylinder head SA-240-304	S_y = 30,000 psi				
Stuffing box flange plate SA-564-630 cond H-1100	S_y = 115,000 psi				
4. Stuffing box gland, SA-564-630	S_y = 115,000 psi				
5. Studs, SA-540-B22 Cl. 1	S_y = 150,000 psi				
6. Dowel pins[2] alignment, SAE-4140	S_A = 23,400 psi				
7. Studs, cylinder tie, SA-193-B7	S_A = 25,000 psi				
8. Pump holddown bolts, SAE Gr. 8	T_A = 30,000 psi				
	Q_A = 37,500 psi				
9. Power frame, foot area, cast iron	S_A = 15,000 psi				
10. Motor holddown bolts, SAE Gr. 1	T_A = 12,000 psi				
	Q_A = 15,000 psi				
11. Motor frame foot area, cast iron	S_A = 7,500 psi				

TABLE 3.9B-2v
(Sheet 2 of 4)

STANDBY LIQUID CONTROL PUMP

Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Calculated Stress (psi)
Normal and Upset Condition Loads:				
1. Design pressure	1. Fluid cylinder	General membrane	17,800	
2. Design temperature	2. Discharge valve stop	General membrane	17,800	(4)
3. OBE	3. Cylinder head extension	General membrane	17,800	
4. Nozzle loads(3)	4. Discharge valve cover	General membrane	17,800	
5. SRV discharge	5. Cylinder head	General membrane	17,800	
6. Deadweight	6. Stuffing box flange plate	General membrane	17,800	
7. Thermal expansion	7. Stuffing box gland	General membrane	35,000	
Emergency Condition:				
1. Design pressure	1. Fluid cylinder	General membrane	21,360	4,450
2. Design temperature	2. Discharge valve stop	General membrane	21,360	13,600
3. Deadweight	3. Cylinder head extension	General membrane	21,360	13,600
4. Thermal expansion	4. Discharge valve cover	General membrane	21,360	8,150
5. Nozzle loads	5. Cylinder head	General membrane	21,360	8,150
6. Safety relief valve discharge	6. Stuffing box flange plate	General membrane	21,360	10,390
7. LOCA	7. Stuffing box gland	General membrane	42,000	11,420
Faulted Condition:				
1. Design pressure	1. Cylinder head studs	Tensile	25,000	18,820
2. Design temperature	2. Stuffing box studs	Tensile	25,000	24,750
3. Nozzle loads	3. Dowel pins(2)	Shear only(2)	23,400	19,430
4. Safety relief valve discharge	4. Studs, cylinder tie	Tensile(2)	25,000	8,685
5. LOCA	5. Pump holddown bolts	Shear	30,000	11,350
6. SSE	6. Pump holddown bolts	Tensile	37,500	17,680
	7. Power frame-foot area	Shear	15,000	1,850
	8. Power frame-foot area	Tensile	15,000	11,390
	9. Motor holddown bolts	Shear	12,000	3,470
	10. Motor holddown bolts	Tensile	15,000	5,660
	11. Motor frame-foot area	Shear	7,500	2,550
	12. Motor frame-foot area	Tensile	7,500	5,100

Note: Pump stresses have been re-evaluated to account for the increase in design pressure and rated flow of the SLC system. The stresses have been determined to be less than code allowable stresses.

TABLE 3.9B-2v
(Sheet 3 of 4)

STANDBY LIQUID CONTROL PUMP

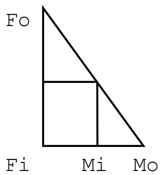
Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Actual Loads
Nozzle Load Definition: Units: Forces - lb Moments - ft-lb Allowable combination of forces and moments is as follows:  $\frac{Fi}{Fo} + \frac{Mi}{Mo}$ Where: Fi = The largest absolute value of the three actual external orthogonal forces (Fx, Fy, Fz) that may be imposed by the interface pipe, and M = The largest absolute value of the three actual internal orthogonal moments (Mx, My, Mz) permitted from the pipe when they are combined simultaneously for a specific condition.				
Normal and Upset Condition Loads: 1. Design pressure 2. Design temperature 3. OBE 4. Nozzle loads 5. SPV discharge 6. Deadweight 7. Thermal expansion		Fo = Allowable value of Fi when all moments are zero. Mo = Allowable value of Mi when all forces are zero.	Suction: Fo = 750 Mo = 500 Discharge: Fo = 360 Mo = 150	Suction: 2SLS*P1A Fi = 350 Mi = 182 2SLS*P1B Fi = 390 Mi - 231 Discharge: 2SLS*P1A Fi = 95 Mi = 70 2SLS*P1B Fi = 95 Mi = 70

TABLE 3.9B-2v
(Sheet 4 of 4)

STANDBY LIQUID CONTROL PUMP

Criteria/Loading	Component	Limiting Stress Type	Allowable Stress (psi)	Actual Loads
Emergency or Faulted Condition Loads: 1. Design pressure 2. Design temperature 3. Nozzle loads 4. SRV discharge 5. LOCA 6. SSE			Suction: Fo = 750 Mo = 500 Discharge: Fo = 360 Mo = 150	Suction: 2SLS*P1A Fi = 479 Mi = 249 2SLS*P1B Fi = 491 Mi = 212 Discharge: 2SLS*P1A Fi = 97 Mi = 75 2SLS*P1B Fi = 97 Mi = 75

(1) Based on ASME Boiler & Pressure Vessel Code Section III.
(2) Dowel pins take all shear.
(3) Nozzle loads produce shear loads only.
(4) Calculated stresses for emergency or faulted condition are less than the allowable stresses for the normal and upset condition loads; therefore, the normal and upset condition is not evaluated.
(5) Will be provided in a future amendment.

NOTE: Operability: The sum of the plunges and rod assembly (pounds mass times 1.75) acceleration is much less than the thrust loads encountered during normal operation conditions. Therefore, the loads during the faulted condition have no significant effect on pump operability.

TABLE 3.9B-2w
(Sheet 1 of 2)

REACTOR WATER CLEANUP SYSTEM PUMP

Component	Load Combination	Stress Criteria	Stress Type	Allowable Stress (S_a) or Deflection	Calculated Stress (S) or Deflection
Motor holddown bolts (shear)	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	$S \leq S_a$	General membrane	31,000 psi	11,026 psi
Motor holddown bolts (tensile)	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	$S \leq S_a$	General membrane	75,000 psi	10,124 psi
Foundation bolts (tensile)	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	$S \leq S_a$	General membrane	62,500 psi	11,114 psi
Foundation bolts (shear)	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	$S \leq S_a$	General membrane	25,833 psi	11,705 psi
Shaft deflection at pump wear ring	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	NA	NA	9 mil	3.10 mil
Shaft deflection at pump coupling	Pressure loads Thermal loads Seismic loads Deadweight Torsional loads	NA	NA	28 mil	13.7 mil

TABLE 3.9B-2w
(Sheet 2 of 2)

REACTOR WATER CLEANUP SYSTEM PUMP

Component	Loading Condition	Stress Criteria	Stress Type	Allowable Stress (psi)	Calculated Stress (psi)	Allowable Thickness (t) (in)	Actual Thickness (t_a) (in)
Suction nozzle	Design pressure and temperature	$S \leq S_a$	General membrane	21,000	4,548	0.309	0.75
Discharge nozzle	Design pressure and temperature	$S \leq S_a$	General membrane	21,000	8,998	0.248	0.75
Cover bolting	Design pressure and temperature	$S \leq S_a$	General membrane	25,000	19,932	NA	NA
Seal gland bolting	Design pressure and temperature	$S \leq S_a$	General membrane	33,000	26,298	NA	NA
Seal gland	Design pressure and temperature	$S \leq S_a$	General membrane	23,850	5,497	0.604	2.25
Pump cover	Design pressure and temperature	$S \leq S_a$	General membrane	26,250	24,124	0.236	0.625
Pedestal bolts (tensile)	Pressure loads Thermal loads Nozzle loads Seismic loads Deadweight Torsional loads	$S \leq S_a$	General membrane	62,500	13,459	NA	NA
Pedestal bolts	Pressure loads Thermal loads Nozzle loads Seismic loads Torsional loads	$S \leq S_a$	Shear	25,830	3,834	NA	NA
Pedestal bolts	Preload	$S \leq 0.9\ S_y$	Shear	94,500	37,258	NA	NA

KEY: S_a = Allowable general membrane stress (ASME Section III)
S_y = Calculated stress
t = Allowable thickness
t_a = Actual thickness

TABLE 3.9B-2x
(Sheet 1 of 4)

REACTOR WATER CLEANUP

Regenerative Heat Exchanger

Criteria	Loading	Component	Minimum Thickness Required (in)	Actual Thickness (in)
Closure Bolting Bolting requirements are calculated in accordance with rules of ASME Section III. Primary stress limit for SA-193-B7: S = 25,000 psi	Design basis loads consisting of: 1. Design pressure 2. Design temperature 3. Design gasket load	Bolting - channel-to-shell flange	1.25 dia	1.25 dia
Wall Thickness Wall thickness requirements are calculated in accordance with rules of ASME Section III, Class 3 components and TEMA Class C. Primary stress limit for: SA-515 Gr 70, SA-516 Gr 70, and SA-105 carbon steel S = 17,500 psi SA-106 Gr B carbon steel S = 15,000 psi SA-182 F304 austenitic stainless steel S = 15,900 psi SA-249 Type 304L austenitic stainless steel S = 11,900 psi	1. Design pressure 2. Design temperature	Shell Shell end tee Shell end cover Channel shell Channel cover Tube sheet Tubes (#BWG)	0.817 0.968 4.46 0.394 4.241 2.379 0.044	1.012 1.50 4.75 1.012 4.375 3.00 0.049

TABLE 3.9B-2x
(Sheet 2 of 4)

REACTOR WATER CLEANUP

Regenerative Heat Exchanger

Criteria	Loading	Component	Allowable Nozzle Loads*	Actual Nozzle Loads
Nozzle Loads Maximum forces and moments due to pipe reactions shall not exceed the allowable limits.	1. Design pressure 2. Design temperature 3. Deadweight 4. Thermal expansion 5. Seismic (Class II basis)	Nozzle N1 (tube inlet)	Fo = 4,428 lb Mo = 7,083 ft-lb	Fi = 4,150 lb Mi = 5,452 ft-lb
		Nozzle N2 (tube outlet)	Fo = 4,428 lb Mo = 7,083 ft-lb	Fi = 2,333 lb Mi = 2,477 ft-lb
		Nozzle N3 (shell inlet)	Fo = 6,676 lb Mo = 16,386 ft-lb	Fi = 4,038 lb Mi = 4,345 ft-lb
		Nozzle N4 (shell outlet)	Fo = 6,676 lb Mo = 16,386 ft-lb	Fi = 3,210 lb Mi = 6,034 ft-lb

TABLE 3.9B-2x
(Sheet 3 of 4)

REACTOR WATER CLEANUP

Nonregenerative Heat Exchanger

Criteria	Loading	Component	Minimum Thickness Required (in)	Actual Thickness (in)
Closure Bolting Bolting requirements are calculated in accordance with rules of ASME Section III, primary stress limit for SA-193-B7 S = 25,000 psi	Design basis loads consisting of: 1. Design pressure 2. Design temperature 3. Design gasket load	Bolting - channel-to-shell flange	1.375 dia	1.375 dia
Wall Thickness Wall thickness requirements are calculated in accordance with rules of ASME Section III, Class 3 components and TEMA Class C. Primary stress limit for: SA-515 Gr 70 and SA-516 Gr 70 carbon steel S = 17,500 psi SA-106 Gr B carbon steel S = 15,000 psi SA-182 F304 austenitic stainless steel S = 15,900 psi SA-249 Type 304L austenitic stainless steel S = 11,900 psi	1. Design pressure 2. Design temperature	Shell Shell end tee Shell end cover Channel shell Channel cover Tube sheet Tubes (#BWG)	0.144 0.130 1.552 0.872 4.949 2.986 0.027	0.328 0.375 2.50 1.125 5.125 3.00 0.49

TABLE 3.9B-2x
(Sheet 4 of 4)

REACTOR WATER CLEANUP

Nonregenerative Heat Exchanger

Criteria	Loading	Components	Allowable Nozzle Loads*	Actual Nozzle Loads
Nozzle Loads The maximum forces and moments due to pipe reactions shall not exceed the allowable limits.	1. Design pressure 2. Design temperature 3. Deadweight 4. Thermal expansion 5. Seismic (Class II basis)	Nozzle N1 (tube outlet)	Fo = 4,428 lb Mo = 7,083 ft-lb	Fi = 1,072 lb Mi = 2,825 ft-lb
		Nozzle N2 (tube inlet)	Fo = 4,428 lb Mo = 7,083 ft-lb	Fi = 1,510 lb Mi = 4,694 ft-lb
		Nozzle N3 (shell outlet)	Fo = 5,569 lb Mo = 15,375 ft-lb	Fi = 2,080 lb Mi = 3,337 ft-lb
		Nozzle N4 (shell inlet)	Fo = 5,569 lb Mo = 15,325 ft-lb	Fi = 1,657 lb Mi = 6,594 ft-lb

* Maximum allowable piping loads shall not exceed the following relationship for each nozzle unless analysis is performed to meet the applicable ASME III design requirements for the component.

$|Fi/Fo| + |Mi/Mo| \leq 1$

Where: Fi (lb)=Maximum of three orthogonal forces (Fx, Fy, Fz)
Mi (ft-lb)=Maximum of three orthogonal moments (Mx, My, Mz)
Fo (lb) = The allowable value of Fi when all moments are zero
Mo (ft-lb)=The allowable value of Mi when all forces are zero

TABLE 3.9B-2y
(Sheet 1 of 2)

CRD HOUSING SUPPORTS

Criteria	Loading	Allowable Stress (psi)	Calculated Stress (psi)
Beams Allowable stresses based on AISC specification for the design, fabrication and erection of structural steel for buildings. F_y @ 150°F = 36,000 psi[1]			
For normal and upset conditions: $F_a = 0.60\ F_y$ (tension) $F_b = 0.66\ F_y$ (bending) $F_v = 0.40\ F_y$ (shear)	Normal and upset loads:[2] (Negligible)		
For emergency condition:	Emergency loads:[2] (Negligible)		
For faulted condition: $F_a = 1.50 \times 0.60 \times F_y$ (tension) $F_b = 1.5 \times 0.60 \times F_y$ (bending) $F_v = 1.5 \times 0.40 \times F_y$ (shear)	Faulted loads: 1. Deadweight 2. Impact force from blow-out of CRD housing	F_b = 33,000 (top chord) F_b = 33,000 (bottom chord)	f_b = 28,700 f_b = 22,000
Grid Structure Allowable stresses based on AISC specification for the design, fabrication and erection of structural steel for buildings. F_y @ 150°F = 46,000 psi[1]			
For normal and upset conditions: $F_a = 0.60\ F_y$ (tension) $F_b = 0.66\ F_y$ (bending) $F_v = 0.40\ F_y$ (shear)	Normal and upset loads:[2] (Negligible)		

TABLE 3.9B-2y
(Sheet 2 of 2)

CRD HOUSING SUPPORTS

Criteria	Loading	Allowable Stress (psi)	Calculated Stress (psi)
For emergency condition:	Emergency loads:[2]		
	(Negligible)		
For faulted condition:	Faulted loads:		
F_a = 1.50 x 0.60 x F_y (tension)	1. Deadweight	F_b = 41,500 (top chord)	f_b = 40,700
F_b = 1.5 x 0.60 x F_y (bending)	2. Impact force from blow-out of CRD housing	F_b = 27,500 (bottom chord)	f_b = 12,500
F_v = 1.5 x 0.40 x F_y (shear)			

NOTE: Cumulative usage factor is not significant because only one loading cycle (blow-out of CRD housing) is applied in the design life of the equipment.

(1) F_y = Material yield strength.
(2) Deadweights and earthquake loads are very small compared to impact force.

TABLE 3.9B-2z
(Sheet 1 of 3)

MAIN STEAM ISOLATION VALVES

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value
1.0	Body and Bonnet			
1.1	Loads: Design pressure Design temperature Pipe reaction Thermal effects	 System requirement System requirement Not specified Not specified	 1,375 psig 586°F N/A N/A	 N/A N/A N/A N/A
1.2	Pressure rating	ASME Section III[1] Paragraph NB-3543c	P_r = 575 psig	P_r = 575 psig
1.3	Minimum wall thickness	ASME Section III[1] Paragraph NB-3542.1	t (nominal) = 2.05 in	t_m = 1.76 min, in
1.4	Primary membrane stress	ASME Section III[1] Paragraph NB-3545.1	$P_m \leq S_m$ (500°F) = 21,600 psi	P_m = 7,840 psi
1.5	Secondary stress due to pipe reaction	ASME Section III[1] Paragraph NB-3545.2	P_e = greatest value of P_{ed} P_{eb} and $P_{et} \leq$ 1.5 S_m (500°F) 1.5 (21,600) = 32,400 psi	P_{ed} = 4,150 psi P_{eb} = 9,570 psi P_{et} = 7,040 psi $P_e = P_{eb}$ = 9,570 psi
1.6	Primary plus secondary stress due to internal pressure	ASME Section III[1] Paragraph NB-3545.2 (a) (1)	$S_n \leq 3 S_m$ (500°F) = 64,800 psi	Q_p = 24,700 psi
1.7	Thermal secondary stress	ASME Section III[1] Paragraph NB-3545.2 (c)	$S_n \leq 3 S_m$ (500°F) = 64,800 psi	Q_t = 4,130 psi
1.8	Sum of primary plus secondary stress	ASME Section III[1] Paragraph NB-3545.2	$S_n \leq 3 S_m$ (500°F) = 64,800 psi	$S_n = Q_p + P_e\ 2Q_t$ = 42,500 psi
1.9	Fatigue requirements	ASME Section III[1] Paragraph NB-3545.3	$N_a \geq$ 2,000 cycles	N_δ = 30,000 cycles
1.10	Cyclic rating	ASME Section III[1] Paragraph NB-3550	$I_t \leq$ 1.0	I_t = 0.0054

TABLE 3.9B-2z
(Sheet 2 of 3)

MAIN STEAM ISOLATION VALVES

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value
2.0	<u>Body to Bonnet Bolting</u>			
2.1	Loads: design pressure and temperature, gasket loads, stem operational load, seismic load (design basis earthquake)	ASME Section III[(1)] Paragraph NB-3647.1	--	--
2.2	Bolt area	ASME Section III[(1)] Paragraph NB-3647.1	$A_b \leq 53.40\ in^2$ $S \leq 34,700$ psi	$A_b = 53.40\ in^2$ $S = S_b + S_{te} + S_{tv} = 22,700$ psi
2.3	<u>Body Flange Stresses</u>			
2.3.1	Operating conditions	ASME Section III[(1)] Paragraph NB-3647.1, XI-3240	$S_H \leq 1.5\ S_m$ (500°F) = 26,200 psi $S_R \leq S_m$ (500°F) = 17,500 psi $S_T \leq S_m$ (500°F) = 17,500 psi $(S_H + S_R)/2 \leq S_m = 17,500$ $(S_H + S_T)/2 \leq S_m = 17,500$	$S_H = 15,100$ psi $S_R = 9,800$ psi $S_T = 8,900$ psi $(S_H + S_R)/2 = 12,500$ psi $(S_H + S_T)/2 = 12,000$ psi
2.3.2	Gasket seating condition	ASME Section III[(1)] Paragraph NB-3647.1	$S_H \leq 1.5\ S_m$ (100°F) = 26,200 psi $S_R \leq S_m$ (100°F) = 17,500 psi $S_T \leq S_m$ (100°F) = 17,500 psi $(S_H + S_R)/2 \leq S_m$ (100°F) = 17,500 psi $(S_H + S_T)/2 \leq S_m$ (100°F) = 17,500 psi	$S_H = 17,600$ psi $S_R = 11,400$ psi $S_T = 10,300$ psi $(S_H + S_R)/2 = 14,500$ psi $(S_H + S_T)/2 = 14,000$ psi
3.0	<u>Stresses in Stem</u>			
3.1	Loads: operator thrust	--	--	--
3.2	Stem tensile stress	Calculate stress due to operator thrust in critical cross section	$S_t \leq S_m$ (500°F)[(2)] = 23,400 psi	$S_t = 19,200$ psi, max.
3.3	Stem thread stress	Calculate shear stress due to maximum stem load on thread stress area	$S \leq 0.6\ S_m$ (500°F)[(2)] = 14,000 psi	S = 7,500 psi

TABLE 3.9B-2z
(Sheet 3 of 3)

MAIN STEAM ISOLATION VALVES

Item No.	Component/Load/Stress Type	Design Procedure	Allowable Limit	Design/ Calculated Value
3.4	Buckling on stem	Calculate critical load, P_{cr} Actual stem load should be less than P_{cr}	P_{cr} = 99,136 lb	Actual stem load = 39,450 lb; therefore, no buckling
4.0	<u>Disk Analysis</u>			
4.1	Maximum stress in disk	The disk stress intensity is calculated using a finite element computer program, which iterates disk thickness until the stress in the plate is less than that allowed by code	S_m (500°F) = 19,400 psi	Max. stress = 13,000 psi

(1) ASME Section III, 1977 Edition through Summer 1977 Addenda.
(2) Valve stem material ASTM A-182, Gr F6A, Cl 3 in accordance with ASME Section III, 1980 Edition through Summer 1981 Addenda.

TABLE 3.9B-3
(Sheet 1 of 4)

NSSS ASSESSMENT AGAINST REGULATORY GUIDE 1.48[1]

Component	Plant Condition	Load Combination 1/	Design Limit	Regulatory Guide Paragraph
Class 1 vessels	Upset (U) Emergency (E) Faulted (F)	[NPC or UPC] + 0.5 SSE[2] EPC NPC + SSE + DSL	NB-3223} NB-3224} 2/ NB-3225}	1.a 1.b 1.c
Class 1 piping	U E F	[NPC + UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3654} NB-3655} 2/ NB-3656}	1.a 1.b 1.c
Class 1 pumps (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3223 5/} NB-3224 } 1/ NB-3225 }	2.a 2.b 2.c
Class 1 pumps (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3222 5/ NB-3222 6/ NB-3222 7/, 8/ 8/	4.a 4.a 4.a
Class 1 valves (inactive) by analysis	U E	[NPC or UPC] + 0.5 SSE EPC	NB-3223 5/ NB-3224 2/ 4/	2.a 2.b
Class 1 valves (inactive) Designed by either std. or alternative design rules	F U E F	NPC + SSE + DSL [NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3225 1.1 Pr 1.2 Pr 1.5 Pr	2.c 3.a 3.b 3.c
Class 1 valves (active) by analysis	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3222} 5/ NB-3222} 6/ NB-3222} 7/, 8/	4.a 4.b 4.c
Class 1 valves (active) Designed by std. or alternative design rules	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.0 Pr} 1.0 Pr} 6/ 1.0 Pr}	5.a 5.b 5.c

TABLE 3.9B-3
(Sheet 2 of 4)

NSSS ASSESSMENT AGAINST REGULATORY GUIDE 1.48[1]

Component	Plant Condition	Load Combination[1/]	Code Allowable Stresses	ASME Section III Reference	Comparison with NRC Regulatory Guide 1.48
Class 1 vessels	U E F	[NPC or UPC] + 0.5 SSE[2] EPC NPC + SSE + DSL	3.0 S_m (includes secondary stresses) 1.8 S_m or 1.5 S_y App. F - Sect. III	NB-3223 NB-3224 NB-3225	Agree
Class 1 piping	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	3.0 S_m (includes secondary stresses) 2.25 S_m 3.0 S_m	NB-3654 NB-3655 NB-3656	Agree
Class 1 pumps (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.65 S_m (excludes secondary stresses) 1.8 S_m App. F - Sect. III	NB-3223 NB-3224	Agree
Class 1 pumps (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	N/A	N/A	N/A
Class 1 valves (inactive) by analysis	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	N/A	N/A	N/A
Class 1 valves (inactive) Designed by either std. or alternative design rules	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.1 Pr 1.2 Pr 1.5 Pr	NB-3525 NB-3526 NB-3527	Agree
Class 1 valves (active) by analysis	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	N/A	N/A	N/A
Class 1 valves (active) Designed by std. or alternative design rules	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.0 Pr} 1.0 Pr} [3] 1.0 Pr}	NB-3525 NB-3526 NB-3527	Agree

TABLE 3.9B-3
(Sheet 3 of 4)

NSSS ASSESSMENT AGAINST REGULATORY GUIDE 1.48(1)

Component	Plant Condition	Load Combination 1/	Design Limit	Regulatory Guide Paragraph
Class 2 & 3 vessels (Division 1) of ASME Section III	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.1 S} 1.1 S} 9/ 1.5 S}	6.a 6.b 6.c
Class 2 vessels (Division 2) of ASME Section VIII	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NB-3223} NB-3224} 2/ NB-3225}	7.a 7.b 7.c
Class 2 & 3 piping	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	NC-3611.1(b)(4)} (c)(b)(1) } NC-3611.1(b)(4)} 10/ (c)(b)(1) } NC-3611.1(b)(4)} (c)(b)(2) }	8.a 8.a 8.b
Class 2 & 3 pumps (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m \leq 1.1\ S \geq (\sigma_m + \sigma_b)$ /1.5 $\sigma_m \leq 1.1\ S \geq (\sigma_m + \sigma_b)$ /1.5 $\sigma_m \leq 1.2\ S \geq (\sigma_m + \sigma_b)$ /1.5	9.a 9.a 9.b
Class 2 & 3 pumps (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m \leq 1.0\ S \geq (\sigma_m + \sigma_b)$ /1.5} $\sigma_m \leq 1.0\ S \geq (\sigma_m + \sigma_b)$ /1.5} 11/ $\sigma_m \leq 1.0\ S \geq (\sigma_m + \sigma_b)$ /1.5)	10.a 10.a 10.a
Class 2 & 3 valves (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.1 Pr 1.1 Pr 1.2 Pr	11.a 11.a 11.b
Class 2 & 3 valves (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.0 Pr} 1.0 Pr} 11/ 1.0 Pr}	12.a 12.a 12.a

TABLE 3.9B-3
(Sheet 4 of 4)

NSSS ASSESSMENT AGAINST REGULATORY GUIDE 1.48[1]

Component	Plant Condition	Load Combination 1/	Code Allowable Stresses	ASME Section III Reference	Comparison with NRC Regulatory Guide 1.48
Class 2 & 3 vessels (Division 1) of ASME Section III	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m = 1.1\ S$ } (4) $\sigma_m = 2.0\ S$ }	Code case 1607, NC/ND-3300	Agree except for faulted condition. NRC more conservative
Class 2 vessels (Division 2) of ASME Section VIII	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	N/A	N/A	N/A
Class 2 & 3 piping	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	1.2 S_h 1.8 S_h 2.4 S_h	NC/ND-3611.3(b) NC/ND-3611.3(c) Code case 1606	NRC more conservative. GE reflects industry position
Class 2 & 3 pumps (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	N/A	N/A	N/A
Class 2 & 3 pumps (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m = 1.1\ S$ } (3) $\sigma_m = 1.2\ S$ } (4)	Code case 1636, NC/ND-3423	Agree (3)
Class 2 & 3 valves (inactive)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m = 1.1\ S$ } (4) $\sigma_m = 2.0\ S$ }	Code case 1635, NC/ND-3521	Equally conservative
Class 2 & 3 valves (active)	U E F	[NPC or UPC] + 0.5 SSE EPC NPC + SSE + DSL	$\sigma_m = 1.1\ S$ } (3) $\sigma_m = 1.2\ S$ } (4)	Code case 1635, NC/ ND-3521	Equally conservative (4)

(1) Numerical indicators (i.e., 1/, 2/, etc.) correspond to the footnotes of Regulatory Guide 1.48.
(2) An OBE or 0.5 SSE intensity is classified as an emergency event. However, for design purposes it is treated as an upset condition as shown in Table 3.9B-2h.
(3) In addition to compliance with the design limits specified, assurance of operability under all design loading combinations shall be in accordance with Section 3.9B.3.2.
(4) The design limit for local intensity or primary membrane plus primary bending stress intensity is 150% of that allowed for general membrane (except as limited to 2.4 S for inactive components under faulted condition). Refer to Section 3.9B.3.1.

TABLE 3.9B-4
(Sheet 1 of 2)

GE-SUPPLIED SEISMIC ACTIVE PUMPS AND VALVES

Component	Master Parts List No.	Standards[1]
Main steam isolation valve	B22-F022 B22-F028	IEEE-323-1974 IEEE-344-1975 IEEE-382-1980 NUREG-0588, Cat. 1 ASME Section III, 1977 Edition, S77 Addenda
Main steam SRV	B22-F013	IEEE-323-1974 IEEE-344-1975 IEEE-382-1980 NUREG-0588, Cat. 1 ASME Section III, 1974 Edition, S76 Addenda
Standby liquid control (explosive) valve	C41-F004	IEEE-323-1974 IEEE-344-1975 NUREG-0588, Cat. 1 ASME Section III, 1977 Edition, S77 Addenda
CRD solenoid valve	C12-F009 C12-F110 C12-F160 C12-F162 C12-F163 C12-F182	IEEE-323-1974 IEEE-344-1975 IEEE-382-1980 NUREG-0588, Cat. 1
CRD globe valve	C12-F010 C12-F011	IEEE-344-1975 ASME Section III, 1971 Edition, S73 Addenda
	C12-F180 C12-F181	IEEE-344-1975 IEEE-382-1980 ASME Section III, 1977 Edition, S77 Addenda
HPCS gate valves	E22-F001 E22-F004 E22-F010 E22-F011	IEEE-323-1974 IEEE-344-1975 IEEE-382-1980 NUREG-0588, Cat. 1

TABLE 3.9B-4
(Sheet 2 of 2)

GE-SUPPLIED SEISMIC ACTIVE PUMPS AND VALVES

Component	Master Parts List No.	Standards[1]
	E22-F012 E22-F015 E22-F023	ASME Section III, 1971 Edition, W73 Addenda
RCIC turbine	E51-C002	a, b
RCIC pump	E51-C001	d,e,f,h,j
SLC pump and motor	C41-C001	Pump: d,e,f,h,i Motor: a,b,c,d,e, f,g,h,i,j
RHR pump and motor	E12-C002	Pump: d,e,f,h,i Motor: a,b,c,d,e, f,g,h,i,j
LPCS pump and motor	E21-C001	Pump: d,e,f,h,i Motor: a,b,c,d,e, f,g,h,i,j
HPCS pump and motor	E22-C001	Pump: d,e,f,h,i Motor: a,b,c,d,e, f,g,h,i,j

[1] a: IEEE-323-74
b: IEEE-344-75
c: IEEE-334-74
d: RG 1.48
e: RG 1.60
f: RG 1.61
g: RG 1.89
h: RG 1.92
i: RG 1.100
j: RG 1.122

TABLE 3.9B-5
(Sheet 1 of 1

DEFORMATION LIMIT
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

Either one of (not both): General Limit

1. $$\left[\frac{\text{Permissible deformation, } DP}{\begin{array}{c}\text{Analyzed deformation}\\ \text{causing loss of function, } DL\end{array}}\right] \leq \frac{0.9}{SF_{\min}}$$

2. $$\left[\frac{\text{Permissible deformation, } DP}{\begin{array}{c}\text{Experiment deformation}\\ \text{causing loss of function, } DE\end{array}}\right]^{(1)} \leq \frac{1.0}{SF_{\min}}$$

Where:

DP = Permissible deformation under stated conditions of Service Levels A, B, C, or D (normal, upset, emergency, or faulted)

DL = Analyzed deformation that could cause a system loss of function[(2)]

DE = Experimentally determined deformation that could cause a system loss of function

(1) Equation 2 is not used unless supporting data is provided to the NRC by GE.

(2) "Loss of function" can only be defined quite generally until attention is focused on the component of interest. In cases of interest, where deformation limits can affect the function of equipment and components, they are specifically delineated. From a practical viewpoint, it is convenient to interchange some deformation condition at which function is assured with the loss of function condition if the required safety margins from the functioning conditions can be achieved. Therefore, it is often unnecessary to determine the actual loss of function condition because this interchange procedure produces conservative and safe designs. Examples where deformation limits apply are: CRD alignment and clearances for proper insertion, core support deformation causing fuel disarrangement or excess leakage of any component.

TABLE 3.9B-6
(Sheet 1 of 3)

PRIMARY STRESS LIMIT
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

Any one of (no more than one required):		General Limit
1.	$\left\lvert \dfrac{\text{Elastic evaluated primary stresses, PE}}{\text{Permissible primary stresses, PN}} \right\rvert$	$\le \dfrac{2.25}{SF_{min}}$
2.	$\left\lvert \dfrac{\text{Permissible load, LP}}{\text{Largest lower bound limit load, CL}} \right\rvert$	$\le \dfrac{1.5}{SF_{min}}$
3.	$\left\lvert \dfrac{\text{Elastic evaluated primary stress, PE}}{\text{Conventional ultimate strength at temperature, US}} \right\rvert$	$\le \dfrac{0.75}{SF_{min}}$
4.	$\left\lvert \dfrac{\text{Elastic-plastic evaluated nominal primary stress, EP}}{\text{Conventional ultimate strength at temperature, US}} \right\rvert$	$\le \dfrac{0.9}{SF_{min}}$
5. *	$\left\lvert \dfrac{\text{Permissible load, LP}}{\text{Plastic instability load, PL}} \right\rvert$	$\le \dfrac{0.9}{SF_{min}}$
6. *	$\left\lvert \dfrac{\text{Permissible load, LP}}{\text{Ultimate load from fracture analysis, UF}} \right\rvert$	$\le \dfrac{0.9}{SF_{min}}$
7. *	$\left\lvert \dfrac{\text{Permissible load, LP}}{\text{Ultimate load or loss of function load from test, LP}} \right\rvert$	$\le \dfrac{1.0}{SF_{min}}$

Where:

PE = Primary stresses evaluated on an elastic basis. The effective membrane stresses are to be averaged through the load-carrying section of interest. The simplest average bending, shear, or torsion stress distribution that supports the external loading is added to the membrane stresses at the section of interest.

PN = Permissible primary stress levels under Service Levels A or B (normal or upset) conditions under ASME Section III.*

TABLE 3.9B-6
(Sheet 2 of 3)

PRIMARY STRESS LIMIT
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

LP = Permissible load under stated conditions of Service Levels A, B, C, or D (normal, upset, emergency, or faulted).

CL = Lower bound limit load with yield point equal to 1.5 S_m where S_m is the tabulated value of allowable stress at temperature of ASME Section III or its equivalent. The "lower bound limit load" is here defined as that produced from the analysis of an ideally plastic (nonstrain hardening) material where deformations increase with no further increase in applied load. The lower bound load is one in which the material everywhere satisfies equilibrium and nowhere exceeds the defined material yield strength using either a shear theory or a strain energy of distortion theory to relate multiaxial yield to the uniaxial case.

US = Conventional ultimate strength at temperature or loading that would cause a system malfunction, whichever is more limiting.

EP = Elastic-plastic evaluated nominal primary stress. Strain hardening of the material may be used for the actual monotonic stress strain curve at the temperature of loading or any approximation to the actual stress strain curve that everywhere has a lower stress for the same strain as the actual monotonic curve may be used. Either the shear or strain energy of distortion flow rule may be used.

PL = Plastic instability load defined here as the load at which any load-bearing section begins to diminish its cross-sectional area at a faster rate than the strain hardening can accommodate the loss in area. This type analysis requires a true stress-true strain curve or a close approximation based on monotonic loading at the temperature of loading.

TABLE 3.9B-6
(Sheet 3 of 3)

PRIMARY STRESS LIMIT
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

UF = Ultimate load from fracture analyses. For components that involve sharp discontinuities (local theoretical stress concentration <3), the use of a fracture mechanics analysis where applicable utilizing measurements of plane strain fracture toughness may be applied to compute fracture loads. Correction for finite plastic zones and thickness effects as well as gross yielding may be necessary. The methods of linear elastic stress analysis may be used in the fracture analysis where its use is clearly conservative or supported by experimental evidence. Examples where fracture mechanics may be applied are for fillet welds or end-of-fatigue-life crack propagation.

LE = Ultimate load or loss of function load as determined from experiment. In using this method, account will be taken of the dimensional tolerances that may exist between the actual part and the tested part or parts as well as differences that may exist in the ultimate tensile strength of the actual part and the tested parts. The guide to be used in each of these areas is that the experimentally determined load is adjusted to account for material property and dimension variations, each of which has no greater probability than 0.1 of being exceeded in the actual part.

* Not used unless supporting data are provided.

TABLE 3.9B-7
(Sheet 1 of 1)

BUCKLING STABILITY LIMIT
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

Any one of (no more than one required):	General Limit
1. $\left\| \dfrac{\text{Permissible load, LP}}{\text{Service Level A (normal) permissible load, PN}} \right\|$	$\dfrac{2.25}{\le SF_{min}}$
2. $\left\| \dfrac{\text{Permissible load, LP}}{\text{Stability analysis load, SL}} \right\|$	$\dfrac{0.9}{\le SF_{min}}$
3. *$\left\| \dfrac{\text{Permissible load, LP}}{\text{Ultimate buckling collapse load from test, SE}} \right\|$	$\dfrac{*1.0}{\le SF_{min}}$

Where:

LP = Permissible load under stated conditions of Service Levels A, B, C, or D (normal, upset, emergency, or faulted).

PN = Applicable Service Level A (normal) permissible load.

SL = Stability analysis load. The ideal buckling analysis is often sensitive to otherwise minor deviations from ideal geometry and boundary conditions. These effects will be accounted for in the analysis of the buckling stability loads. Examples of this are ovality in externally pressurized shells or eccentricity on column members.

SE = Ultimate buckling collapse load as determined from experiment. In using this method, account will be taken of the dimensional tolerances that may exist between the actual part and the tested part. The guide to be used in each of these areas is that the experimentally determined load will be adjusted to account for material property and dimension variations, each of which has no greater probability than 0.1 of being exceeded in the actual part.

*Not used unless supporting data are provided.

TABLE 3.9B-8
(Sheet 1 of 1)

FATIGUE LIMIT*
(FOR SAFETY CLASS REACTOR INTERNAL STRUCTURES ONLY)

Cumulative Damage in Fatigue	Limit for Service Levels A and B (normal and upset) Design Conditions
Design fatigue cycle usage from analysis using the method of ASME Code	≤1.0

* Summation of fatigue damage usage with design and operation loads following Miner hypotheses.

SOURCE: Miner, M. A. Cumulative Damage in Fatigue, Journal of Applied Mechanics, Vol. 12, ASME Vol. 67, pp A159-A164, September 1945.

TABLE 3.9B-9
(Sheet 1 of 4)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVELS A AND B (NORMAL AND UPSET) CONDITIONS

Stress Category	Primary Stresses		Secondary Stresses[1]	Peak Stresses
	Membrane P_m [2-4]	Bending P_b [2-4]	Membrane and Bending Secondary, Q[2,5]	Peak, F[2,6]
Service Levels A and B (normal and upset)	P_m S_m or Elastic analysis[7] 0.67 L_L or Limit analysis[11] 0.44 L_u Test[12]	$P_m + P_b$ 1.5 S_m or Elastic analysis[7] 0.67 L_L or Limit analysis[11] 0.44 L_u Test[12]	$P_m + P_b + Q$ 3 S_m S_L[10] For cycles less than 1,000, use peak[5]	$P_m + P_b + Q + F$ Elastic fatigue[8,9] S_a $P_m + P_b + Q + F$ S_a Elastic plastic fatigue[5,8,9]

TABLE 3.9B-9
(Sheet 2 of 4)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVELS A AND B (NORMAL AND UPSET) CONDITIONS

(1) This limitation applies to the range of stress intensity. When the secondary stress is due to a temperature excursion at the point at which the stresses are being analyzed, the value of S_m will be taken as the average of the S_m values tabulated in Tables I-1.1, I-1.2, and I-1.3 of ASME Section III for the highest and lowest temperature of the metal during the transient. When part of the secondary stress is due to mechanical load, the value of S_m will be taken as the S_m value for the highest temperature of the metal during the transient.

(2) The symbols P_m, P_b, Q and F do not represent single quantities, but rather sets of six quantities representing the six stress components: $\sigma_t, \sigma_i, \sigma_r, \tau tl, \tau lr, \tau rt$.

(3) For configurations where compressive stresses occur, the stress limits will be revised to take into account critical buckling stresses (Subparagraph NB-3211(c) of ASME Section III). For external pressure, the permissible equivalent static external pressure will be as specified by the rules of Paragraph NB-3133 of ASME Section III. Where dynamic pressures are involved, the permissible external pressure will be limited to 25 percent of the dynamic instability pressure.

(4) When loads are transiently applied, consideration should be given to the use of dynamic load amplification and possible change in modulus of elasticity.

(5) The allowable value for the maximum range of this stress intensity is 3 S_m, except for cyclic events that occur less than 1,000 times during the design life of the plant. For this exception, in lieu of meeting the 3 S_m limit, an elastic-plastic fatigue analysis, in accordance with ASME Section III, may be performed to demonstrate that the cumulative fatigue usage attributable to the combination of these low events, plus all other cyclic events, does not exceed a fatigue usage value of 1.0.

TABLE 3.9B-9
(Sheet 3 of 4)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVELS A AND B (NORMAL AND UPSET) CONDITIONS

(6) The stresses in Category Q are those parts of the total stress that are produced by thermal gradients, structural discontinuities, etc., and do not include primary stresses that may also exist at the same point. It should be noted, however, that a detailed stress analysis frequently gives the combination of primary and secondary stresses directly, and when appropriate, this calculated value represents the total of $P_m + P_b + Q$ and not Q alone. Similarly, if the stress in Category F is produced by a stress concentration, the quantity F is the additional stress produced by the notch, over and above the nominal stress. For example, if a plate has a nominal stress intensity, $P_m = S$, $P_b = O$, $Q = O$ and a notch with a stress concentration K is introduced, then $F = P_m (K-1)$ and the peak stress intensity equals $P_m + P_m (K-1) = KP_m$.

(7) The triaxial stresses represent the algebraic sum of the three primary principal stresses $(\sigma_1 + \sigma_2 + \sigma_3)$ for the combination of stress components. Where uniform tension loading is present, triaxial stresses are limited to 4 S_m.

(8) S_a is obtained from the fatigue curves, Figures I-9.1 and I-9.2 of ASME Section III. The allowable stress intensity for the full range of fluctuation is 2 S_a.

(9) In the fatigue data curves, where the number of operating cycles is less than 10, use the S_a value for 10 cycles; where the number of operating cycles is greater than 106, use the S_a value for 106 cycles.

(10) S_L denotes the structural action of shakedown load, as defined in Subparagraph NB-3213.18 of ASME Section III, calculated on a plastic basis as applied to a specific location on the structure.

(11) L_L is the lower bound limit load with yield point equal to 1.5 S_m (where S_m is the tabulated value of allowable stress at temperature as contained in ASME Section III). The lower

TABLE 3.9B-9
(Sheet 4 of 4)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVELS A AND B (NORMAL AND UPSET) CONDITIONS

bound limit load is here defined as that produced from the analysis of an ideally plastic (nonstrain hardening) material where deformations increase with no further increase in applied load. The lower bound load is one in which the material everywhere satisfies equilibrium, and nowhere exceeds the defined material yield strength using either a shear theory or a strain energy of distortion theory to relate multiaxial yielding to the uniaxial case.

(12) For Service Levels A and B (normal and upset) conditions, the limits on primary membrane plus primary bending need not be satisfied in a component if it can be shown from the test of a prototype or model that the specified loads (dynamic or static equivalent) do not exceed L_u, where L_u is the ultimate load or the maximum load or load combination used in the test. In using this method, account will be taken of the size effect and dimensional tolerances that may exist between the actual part and the test part, or parts, as well as differences that may exist in the ultimate strength or other governing material properties of the actual part and the tested part to assure that the loads obtained from the test are a conservative representation of the load-carrying capability of the actual component under the postulated loading for Service Levels A and B (normal and upset) conditions.

TABLE 3.9B-10
(Sheet 1 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVEL C (EMERGENCY) CONDITIONS

Stress Category	Primary Stresses		Secondary Stresses	Peak Stresses
	Membrane P_b[1-3]	Bending P_m[1-3]	Membrane and Bending Secondary, Q	Peak, F
Service Level C (emergency)[6]	P_m — 1.5 S_m Elastic analysis[4] or — L_L Limit analysis[5] or — 1.5 S_m Plastic analysis[7] or — 0.6 L_e Tests[9] or — S_F Stress-ratio analysis[10]	$P_m + P_b$ — 2.25 S_m Elastic analysis[4] or — L_L Limit analysis[5] or — 2.25 S_m Plastic analysis[7,8] or — 0.5 S_u[8] or — 0.6 L_e Test[9] — KS_E Stress-ratio analysis[10]	Evaluation not required	Evaluation not required

TABLE 3.9B-10
(Sheet 2 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVEL C (EMERGENCY) CONDITIONS

(1) The symbols P_m, P_b, Q, and F do not represent single quantities but rather sets of six quantities representing the six stress components: $\sigma_t, \sigma_i, \sigma_r, \tau tl, \tau lr, \tau rt$.

(2) For configurations where compressive stresses occur, stress limits will be revised to take into account critical buckling stresses. For external pressure, the permissible equivalent static external pressure will be taken as 150% of that permitted by the rules of Paragraph NB-3133 of ASME Section III. Where dynamic pressures are involved, the permissible external pressure will satisfy the preceding requirements or be limited to 50% of the dynamic instability pressure.

(3) When loads are transiently applied, consideration should be given to the use of dynamic load amplification and possible change in modulus of elasticity.

(4) The triaxial stresses represent the algebraic sum of the three primary principal stresses $(\sigma_1 + \sigma_2 + \sigma_3)$ for the combination of stress components. Where uniform tension loading is present, triaxial stresses should be limited to 6 S_m.

(5) L_L is the lower bound limit load with yield point equal to 1.5 S_m (where S_m is the tabulated value of allowable stress at temperature as contained in ASME Section III). The lower bound limit load is here defined as that produced from the analysis of an ideally plastic (nonstrain hardening) material where deformations increase with no further increase in applied load. The lower bound load is one in which the material everywhere satisfies equilibrium and nowhere exceeds the defined material yield strength using either a shear theory or a strain energy of distortion theory to relate multiaxial yielding to the uniaxial case.

(6) Where deformation is of concern in a component, the deformation will be limited to two-thirds the value given for Service Level C (emergency) conditions in the design specification.

TABLE 3.9B-10
(Sheet 3 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY
FOR SERVICE LEVEL C (EMERGENCY) CONDITIONS

(7) This plastic analysis uses an elastic-plastic evaluated nominal primary stress. Strain hardening of the material may be used for the actual monotonic stress-strain curve at the temperature of loading, or any approximation to the actual stress-strain curve which everywhere has a lower stress for the same strain as the actual monotonic curve may be used. Either the shear or strain energy of distortion flow rule will be used to account for multiaxial effects.

(8) S_u is the ultimate strength at temperature. Multiaxial effects on ultimate strength will be considered.

(9) For Service Level C (emergency) conditions, the stress limits need not be satisfied if it can be shown from the test of a prototype or model that the specified loads (dynamic or static equivalent) do not exceed 60% of L_e, where L_e is the ultimate load or the maximum load or load combination used in the test. In using this method, account will be taken of the size effect and dimensional tolerances that may exist between the actual part and the tested part or parts, as well as differences that may exist in the ultimate strength or other governing material properties of the actual part and the tested parts, to assure that the loads obtained from the test are a conservative representation of the load carrying capability of the actual component under postulated loading for Service Level C (emergency) conditions.

(10) Stress ratio is a method of plastic analysis that uses the stress ratio combinations (combination of stresses that consider the ratio of the actual stress to be the allowable plastic or elastic stress) to compute the maximum load a strain hardening material can carry. K is defined as the section factor ($S_F \leq 2\ S_m$) for primary membrane loading.

TABLE 3.9B-11
(Sheet 1 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY FOR SERVICE LEVEL D (FAULT) CONDITION

Stress Category	Primary Stresses: Membrane P_m [4,7,8]	Primary Stresses: Bending P_b [4,7,8]	Secondary Stresses: Membrane and Bending Secondary, Q [2,4]	Peak Stress: Peak, F [2,4]
Service Level D (fault) [9]	P_m — $2.4\ S_m$ Elastic analysis or — $0.75\ S_u$ [5] or — $1.33\ L_L$ Limit analysis [4] or — $0.67\ S_u$ Plastic analysis [5,6] or — $0.8\ L_F$ Test [7] or — S_F Stress-ratio analysis [8]	$P_m + P_b$ — $3.0\ S_m$ Elastic analysis or — $1.33\ L_L$ Limit analysis [4] or — $0.75\ S_u$ Plastic analysis [5,6] or — $0.8\ L_F$ Test [7] or — KS_F Stress-ratio analysis [3]	Evaluation not required	Evaluation not required

TABLE 3.9B-11
(Sheet 2 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY FOR
SERVICE LEVEL D (FAULT) CONDITION

(1) The symbols P_m, P_b, Q, and F do not represent single quantities but rather sets of six quantities representing the six stress components: $\sigma_t, \sigma_i, \sigma_r, \tau tl, \tau lr, \tau rt$.

(2) When loads are transiently applied, consideration should be given to the use of dynamic load amplification and possible changes in modulus of elasticity.

(3) For configurations where compressive stresses occur, stress limits take into account critical buckling stresses. For external pressure, the permissible equivalent static external pressure will be taken as 2.5 times that given by the rules of Paragraph NB-3133 of ASME Section III. Where dynamic pressures are involved, the permissible external pressure will satisfy the preceding requirements or be limited to 75% of the dynamic instability pressure.

(4) L_L is the lower bound limit load with yield point equal to 1.5 S_m (where S_m is the tabulated value of allowable stress at temperature as contained in ASME Section III). The lower bound limit load is here defined as that produced from the analysis of an ideally plastic (nonstrain hardening) material where deformations increase with no further increase in applied load. The lower bound load is one in which the material everywhere satisfies equilibrium and nowhere exceeds the defined material yield strength using either a shear theory or a strain energy of distortion theory to relate multiaxial yielding to the uniaxial case.

(5) S_u is the ultimate strength at temperature. Multiaxial effects on ultimate strength will be considered.

(6) This plastic analysis uses an elastic-plastic evaluated nominal primary stress. Strain hardening of the material may be used for the actual monotonic stress-strain curve at the temperature of loading, or any approximation to the

TABLE 3.9B-11
(Sheet 3 of 3)

CORE SUPPORT STRUCTURES
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY FOR
SERVICE LEVEL D (FAULT) CONDITION

actual stress-strain curve which everywhere has a lower stress for the same strain as the actual monotonic curve may be used. Either the maximum stress or strain energy of distortion flow rule will be used to account for multiaxial effects.

(7) For Service Level D (faulted) conditions, the stress limits need not be satisfied if it can be shown from the test of a prototype or model that the specified loads (dynamic or static equivalent) do not exceed 80% of L_F, where L_F is the ultimate load or load combination used in the test. In using this method, account will be taken of the size effect and dimensional tolerances, as well as differences that may exist in the ultimate strength or other governing material properties of the actual part and the tested parts, to assure that the loads obtained from the test are a conservative representation of the load carrying capability of the actual component under postulated loading for Service Level D (faulted) condition.

(8) Stress ratio is a method of plastic analysis that uses the stress ratio combinations (combination of stresses that consider the ratio of the actual stress to the allowable plastic or elastic stress) to compute the maximum load a strain hardening material can carry. K is defined as the section factor; S_F is the lesser of 2.4 S_m or 0.75 S_u for primary membrane loading.

(9) Where deformation is of concern in a component, the deformation will be limited to 80% of the value given for Service Level D (faulted) conditions in the Design Specifications.

3.10 SEISMIC QUALIFICATION OF CATEGORY I INSTRUMENTATION AND ELECTRICAL EQUIPMENT

Two inputs are provided for Section 3.10: Section 3.10A applies to the SWEC scope of supply, and Section 3.10B applies to the GE scope of supply.

3.10A SEISMIC QUALIFICATION OF CATEGORY I INSTRUMENTATION AND ELECTRICAL EQUIPMENT (SWEC SCOPE OF SUPPLY)

This section provides the qualification methods for equipment affected by seismic loads. The methods for the qualification of equipment affected by hydrodynamic loads associated with SRV discharge and the postulated LOCA are provided in the DAR, Appendix 6A, Subsection 6A.9.

3.10A.1 Seismic Qualification Criteria

Table 3.10A-1 provides a listing of Category I instrumentation and electrical equipment requiring seismic qualification. Parameters used to develop seismic loadings and criteria for Category I structures, systems, and components are described in Section 3.7A. From the ground input data, a series of response spectrum curves at various building elevations was developed. The magnitude and frequency of the SSE loadings for which each component is qualified vary, depending on their locations within the plant. These seismic data were included in the purchase specifications for Category I equipment and systems. For equipment located at various areas throughout the plant, the purchase specification includes response spectrum curves that envelop the response spectra at all locations where the equipment is used.

For equipment subject to hydrodynamic loads, see the DAR for Hydrodynamic Loads (Appendix 6A) for details.

Seismic qualification and documentation procedures used for Class 1E equipment and/or systems meet the provisions of IEEE-344-1975, as supplemented by RG 1.100.

Category I equipment is divided into two classifications: 1) equipment designed to maintain its functional capability during and after a SSE, and 2) equipment that, although not required to maintain its functional capability, is designed to maintain the pressure boundary integrity of the system of which it is a part, during and after a SSE. The requirements for instrumentation, equipment, and systems required to maintain pressure boundary integrity are in accordance with ASME Section III, 1974 or later, depending on time of purchase of equipment. The performance requirements of Category I electrical and instrumentation items and their respective supports may be structural as well as functional. The structural design is in accordance with applicable codes, as listed in the equipment specification.

It should be noted that certain non-Category I equipment is reviewed for maintenance of structural integrity to ensure that failure of these items or their supports will not jeopardize adjacent Category I equipment.

If no codes are applicable, the stress level for the OBE combined with operating loads is limited to 75 percent of the minimum yield for the material in accordance with the ASTM specification. For the SSE combined with operating loads, the stress level does not exceed the smaller of:

1. 100 percent of the minimum yield strength, or

2. 70 percent of the minimum ultimate tensile strength of the material (at design temperature), in accordance with the ASTM specification.

Seismic analysis, without testing, is performed on equipment whose functional operability is assured by its structural integrity alone. When complete seismic testing is impractical, a combination of tests and analyses is performed. See Table 3.10A-1 for the seismic qualification methods applicable to specific equipment.

3.10A.2 Methods and Procedures for Qualifying Electrical Equipment and Instrumentation

The methods by which the supplier can qualify equipment for compliance with seismic requirements are as follows:

1. Testing.

2. Type-testing (prototype).

3. Analysis.

4. Combination of 1 or 2 and 3.

These methods, including the factors for selection of an analytical or test option, test objectives, and acceptability criteria, are described in Section 3.7A.3.1.1. Qualification and documentation procedures used for Category I equipment and/or systems meet the provisions of IEEE-344-1975, as supplemented by the requirements of RG 1.100.

3.10A.2.1 Testing

Seismic tests are performed by subjecting equipment to vibratory motion that conservatively simulates the seismic loading at the equipment mounting. Such tests are conducted over the range of 1 to 33 Hz. For components susceptible to environmental aging (temperature, humidity, radiation, etc.), seismic testing is performed on environmentally preaged components, following the requirements of IEEE-323-1974.

For equipment subject to hydrodynamic loads, see the DAR for Hydrodynamic Loads (Appendix 6A) for details.

Whenever feasible, seismic qualification tests on equipment are performed while the equipment is subjected to normal operating loads. However, occasionally an operational configuration is difficult to simulate correctly, and where it can be demonstrated that operating loads such as pressure, torque, flow, voltage, current, or temperature do not cause significant stress loads within the equipment, or where such operating loads are not significant to a determination of equipment operability, operation under load is not specified. The equipment is monitored and evaluated during and after the test for malfunction or failure and, upon completion of the test, is tested for proper operation.

In seismic qualification testing, equipment auxiliary components such as relays, switches, and instruments necessary for proper operation are mounted similarly to the manner in which they are to be installed, and then tested and qualified along with the equipment. For multicabinet assemblies, the tested prototype unit occasionally consists of a smaller number of frames than the frames in the assembly being provided. In such cases, an evaluation of the responses due to the front-to-back, side-to-side, vertical, and torsional modes of the multicabinet assemblies, with respect to those of the tested unit, are made. This evaluation ensures the adequacy of the qualification of the multicabinet assemblies and of the electrical components located within them.

The input motion is applied to the vertical axis, combined with each one of the principal horizontal axes, unless it can be demonstrated that the equipment response along the vertical direction is not sensitive (coupled) to the vibration motion along the horizontal direction and vice versa. Refer to Section 3.7A.3.1.1 for complete details of testing. The maximum input motion acceleration is equal to, or is in excess of, the maximum seismic acceleration expected at the equipment mounting location. Following the requirements of RG 1.100, it is specified that the TRS closely envelop applicable portions of the RRS in verifying the adequacy of test input motion.

3.10A.2.2 Prototype Testing

In some cases where groups of equipment have similar characteristics, the test program is based upon testing of a prototype item of equipment. The test reports furnished by the equipment supplier are reviewed for assurance that the group of components qualified by the prototype is dynamically similar. If any extrapolation as to dimension or mass is used, the vendor is required to justify similarity of the dynamic characteristics.

3.10A.2.3 Analysis

Analysis without testing is acceptable only if structural integrity alone could assure the design-intended function. Responses are calculated for the three-directional seismic loadings individually and combined by the SRSS method. The seismic response is added to the operating load response on an absolute basis to establish the combined effects, and compared with allowable stress, strain, or deflections, as the basis for acceptable qualification.

3.10A.2.4 Combined Analysis and Testing

When the equipment cannot be practically qualified by analysis or testing alone because of its complexity or size, combined analysis and testing is used. When this procedure is employed, the major component is qualified by analysis, and the motors, operators, and appurtenances necessary for operation are qualified by testing. The auxiliary equipment is tested and qualified to the acceleration level at its mounted location, and its equivalent seismic loading is applied to the major component being analyzed.

3.10A.3 Methods and Procedures of Analysis or Testing of Supports of Electrical Equipment and Instrumentation

A design objective, when feasible, is to provide supports for electrical equipment, instrumentation, and control systems with fundamental natural frequencies above the cutoff frequency of the relevant ARS curves. This ensures that amplification of floor accelerations through supporting members to mounted equipment is minimized.

The response of racks, panels, cabinets, and consoles is considered in assessing the capability of instrumentation and electrical equipment. Items of electrical equipment and instrumentation are tested, wherever feasible, with their supporting structures in their installed configurations. Intermediate support structures are designed to be rigid to preclude dynamic interaction. When it is impractical to design rigid structures, qualification analysis will include the mass and stiffness characteristics of the support. Mounted components are therefore qualified to acceleration levels consistent with those transmitted by their supporting structures.

Determination of amplification and seismic adequacy of instrumentation and electrical equipment is implemented by the analysis and testing methods outlined in Section 3.7A.3.

The Category I cable tray support systems are analyzed using a modal analysis/response spectra method. Mathematical models include both two- and three-dimensional lumped mass models that are subjected to a support excitation generated by applying the ARS for that structure for the seismic and/or the hydrodynamic loads events. These conditions were considered in designing the cable tray support system in accordance with the applicable loading combinations described in Section 3.8.4. The boundary conditions used in the analysis assume that the system is fixed (i.e., rigidly attached) or pinned depending on the connection to the main structural steel and concrete members at its support points. The procurement and testing requirements for structural steel tray supports are discussed in Section 3.8.4.2.

3.10A.4 Operating License Review

The results of all seismic tests and analyses performed by outside vendors are reviewed and approved. These results become a permanent onsite record. A summary of seismic test and/or analysis results is given in Table 3.10A-1.

TABLE 3.10A-1
(Sheet 1 of 19)

CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Hydrogen/Oxygen Gas Analyzers	The equipment, which consists of two sets of two panels, was qualified by a combination of analysis and test. The applicable code, standards, and guidelines are the AISC Code, IEEE-323-1974, IEEE-344-1975, and RG 1.61, 1.89, 1.92, and 1.100.	The equipment is affected by seismic loads only. Each analyzer set is comprised of one remote control panel and one analyzer panel. Vibration tests of the panels used to house the remote control modules demonstrated that the cabinets have a natural frequency of 26 Hz in the horizontal direction and are rigid (i.e., greater than 33 Hz) in the vertical direction. Static analysis verified that stresses in the panels are below the allowable limits. The internal subassemblies in the remote cabinets were qualified separately by a combination of dynamic testing and analysis. The tested components were mounted on a rigid fixture, or to a test panel, to simulate the normal installation, and subjected to biaxial random multifrequency seismic input. The tests were performed in two orientations to subject the equipment to loading in all three axes. The duration of each test was 30 sec and the TRS enveloped the RRS in the applicable frequency range by a minimum margin of 10 percent. The analyzer panels were qualified by similarity to a prototype assembly that was qualified by dynamic testing. The test panel was mounted on a rigid fixture and subjected to random multifrequency biaxial input. Differences in the method of attachment were reconciled by analysis. The specimens were instrumented to record accelerations and monitor equipment operability. A resonance search was performed at specified locations in all three axes in the range from 1 to 50 Hz. The resonance search provided transmissibility curves at component locations. The tests were performed in two orientations to subject the equipment to loading in all three axes. The duration of each test was 30 sec and the TRS enveloped the RRS in the applicable frequency range by a minimum margin of 10 percent. Internal subassemblies not addressed in the prototype test were qualified separately by a combination of dynamic testing and analysis. The components were generally mounted on rigid fixtures to simulate the normal installation and subjected to random multifrequency seismic input. The dynamic input accounted for amplification in the analyzer panel structure, and the TRS enveloped the RRS in the applicable frequency range by a minimum margin of 10 percent.
Ac and Dc Panelboards	The ac and dc panelboards are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The panelboards are affected by seismic loads only. The dynamic testing was performed as follows: Representative test specimens were mounted on the vibration test table using specially designed test fixtures such that actual in-service conditions were simulated. The specimens were instrumented to record accelerations and monitor operability. A resonance search was performed from 1 to 35 Hz in each of the three orthogonal axes. The seismic simulation vibration tests consisted of triaxial random multifrequency tests for five OBEs and one SSE. The TRS enveloped the RRS within the applicable frequency range with at least a 10-percent margin. The test specimens did not exhibit any malfunction as a result of the seismic simulation tests.

TABLE 3.10A-1
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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Motor Operators Limitorque Model SMB-000 SMB-00 SMB-0 SMB-1 SMB-2 SMB-3 SMB-4 SB-00 SB-0 SB-1 SB-2 SB-3	The motor operators are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, IEEE-382-1972, and NRC RG 1.73, 1.89, and 1.100.	Some of the motor operators are affected by seismic loads only. Others are affected by both seismic and hydrodynamic loads. The test program for the motor operators consists of testing a selected group of parent actuators, which are then used to dynamically qualify the entire line of Limitorque motor operators in the plant using direct comparison and similarity. For motor operators affected by seismic loads, dynamic testing is performed as follows: A number of representative test specimens are selected which envelope the entire family of motor operators. A resonance search test is performed from 1 to 33 Hz in each of the three orthogonal axes. The specimens are then subjected to a series of single axis, sine dwell tests. Since no resonant frequencies are identified below 33 Hz, dwell tests are performed at a frequency of 33 Hz. These tests consist of 150-sec duration sine dwell at 3 g, and a 30-sec dwell test at 6 g. For selected operators, biaxial, random multifrequency tests are also performed. The operators performed their safety functions, i.e., stroked within the required durations and torqued out at the preset load with no indication of malfunction, and are considered qualified to a seismic level of 6 g. The generic test program for motor operators affected by the combined seismic and hydrodynamic loads is as follows: The actuators are tested on shake tables capable of providing acceleration levels which encompass the requirements of the dynamic events. The tests consist of a resonance search up to 100 Hz in each of the three orthogonal axes, followed by vibration aging using swept sine motion in the 5-200 Hz frequency range to a 0.75 g level. The actuators then are subjected to a series of sine beat tests in each axis. These sine beat tests are performed at a minimum of one-third octave intervals in the frequency range of 5 to 100 Hz and account for the forcing function frequencies. A large number of beats is used at each test frequency to simulate the fatigue effects of the hydrodynamic loading. The beat tests are performed at various magnitudes which correspond to the individual seismic and hydrodynamic loading events and loading combinations. In addition, random, multifrequency, multiaxis tests are performed, when necessary, to address the rigidly mounted valves. The operators performed their safety function, i.e., stroked within the required durations and torqued out at the preset loads. The operators are qualified for up to 14 g loadings. Piping design acceptance criteria ensure that as-built loadings are within qualified levels for each motor operator.

TABLE 3.10A-1
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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS (PRIVATE)

Equipment	Methods	Results
HVAC Instruments •Temperature-indicating controllers •Resistance temperature detectors	The temperature-indicating controller which consists of a temperature sensing element, controller mechanism and snap switches is qualified by dynamic testing. The RTDs which contain platinum resistance elements are also dynamically tested. The applicable guidelines and standards are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The equipment is affected by seismic loads only. The equipment was mounted during the test to simulate the plant installation, and instrumented to record accelerations and to monitor operability. The test consisted of a resonance search in three axes, followed by a biaxial, random multifrequency series of five OBE and one SSE tests. The biaxial tests were repeated in a second orientation to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with at least a 10 percent margin. The resistance temperature detectors and the temperature-indicating controllers successfully completed these tests and performed their intended functions.
HVAC Instruments •Flow Switches	The flow switches were qualified by dynamic testing. The applicable guidelines and standards are IEEE-344-1975, IEEE-323-1974, and RG 1.89 and 1.100.	The switches are affected by seismic loads only. Two different types of tests were used to qualify the switches: A sinusoidal dwell test and a biaxial, random multifrequency test. For both tests the switches were mounted to simulate the plant installation and instrumented to record accelerations and to monitor operability. One test consisted of a biaxial, random multifrequency series of five OBE and one SSE tests which was repeated in two orientations to consider all three axes of loading. A sinusoidal dwell test was performed over the range of 1 to 40 Hz, reaching peaks of 4.5 g in the vertical and horizontal directions. After a 90-deg rotation, the dwell test was repeated. The flow switches successfully performed their intended functions during the complete test program.
600-V Load Centers 125-V dc Switchgear 13.8-kV Switchgear	The equipment was qualified by dynamic testing. The applicable guidelines and standards are IEEE-344-1975, IEEE-323-1974, IEEE-308-1971, and RG 1.89 and 1.100.	The equipment is affected by seismic loads only. The equipment was mounted for the testing in a manner that would simulate the plant installation and was instrumented to record accelerations. The equipment was operated during the biaxial, random multifrequency tests which consisted of a series of five OBE level tests followed by one SSE level test. The biaxial test series was repeated in two orientations to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The test specimen did not exhibit any malfunction as a result of the seismic simulation tests.
Electric Bar Rack Heating Elements	The equipment was qualified by static and dynamic analyses. The applicable guidelines and standards are RG 1.61, 1.89, 1.92, and 1.100, and IEEE-344-1975, IEEE-323-1974, and AISC.	The equipment is affected by seismic loads only. The analyses demonstrated that the bar rack heater would remain operational during a seismic event. The maximum deflections were calculated to verify that the heating element would not contact the structural tubing. The stresses in the heating element have been found to be within the allowable stress limits. The lowest margin of safety for the stresses is approximately 25 percent.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Level Switches	Level switches are qualified by dynamic testing. The applicable standards and guidelines are IEEE-344-1975, IEEE-323-1974, and RG 1.89 and 1.100.	The equipment is affected by seismic loads only. There are four models of level switches: FLS, A103F, 291, and A153. For these models, the switches were mounted to simulate the plant installation and instrumented to record accelerations. Models FLS, 291, and A153 were subjected to a biaxial, random multifrequency test series of five OBEs and one SSE while pressurized. The biaxial test series was repeated in two orientations to consider all three axes of loading. These three switch models were also subjected to a resonance search in the three axes. Model A103F was subjected to a biaxial, random multifrequency test equivalent to one SSE in two orientations while pressurized. It was also subjected to two sine sweeps in each orthogonal axis, equivalent to five OBEs. In all of the random multifrequency tests, the TRS enveloped the RRS within the applicable frequency range by a margin of at least 10 percent. The test specimens functioned satisfactorily before, during, and after the tests, and no anomalies occurred.
Hydrogen Recombiner	The hydrogen recombiner is qualified by a combination of analysis and tests. The applicable codes, standards, and guidelines are ASME Code Section III-1974, AISC Code - 1971, IEEE-323-1974, IEEE-344-1975, and RG 1.61, 1.89, 1.92, and 1.100.	The hydrogen recombiner is affected by seismic loads only. The skid base and heater compartment, heating coil and reaction chamber, inlet and outlet piping system, and pipe supports are qualified by dynamic analyses. Stresses in these components are within the allowable limits of Section 3.9A.2.2.2.
		The motor/blower assembly is qualified by a combination of tests and analysis. A generic motor/blower was seismically tested. The test includes a resonance search in three axes, followed by five OBE and one SSE phase incoherent, random, multifrequency biaxial excitations. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The motor/blower also performed its intended function. Similarity of the generic motor/blower and Unit 2 motor/blower was developed by finite element analysis. Components of the recombiner skid such as the valve actuator, heater assembly, thermocouple and pressure transmitter are qualified by seismic testing. The valve actuator, Limitorque Model SMB-000, is qualified as stated on page 1. For the rest of the components, the testing includes the application of random multifrequency input motion and/or sine beat input motions. The test levels exceed the Unit 2 seismic levels, in the applicable frequency range, by a margin of at least 10 percent. The test results indicate that each component successfully performed its function during and after the tests.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
		The power cabinet was qualified by similarity to a unit that was seismically tested. The power cabinet was mounted on the test table to simulate the plant installation and instrumented to record accelerations and monitor operability. The test consisted of a resonance search from 1 to 100 Hz in three axes, followed by a biaxial, random multifrequency testing of five OBE and one SSE tests. The amplitude was controlled in one-sixth octave bandwidths over a frequency range of 1 to 40 Hz. These tests were repeated in the second orientation to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range by a minimum margin of 10 percent. The cabinet successfully completed the test and performed its intended function.
General Purpose Dry-Type Transformers	The transformers are qualified by dynamic testing. The applicable guidelines and standards are IEEE-323-1974, IEEE-344-1975, and RG 1.61, 1.89, and 1.100.	The transformers are affected by seismic loads only. The dynamic testing was performed as follows: The transformers were mounted to simulate the plant installation and instrumented to record accelerations and to monitor operability. A resonance search was performed from 1 to 33 Hz, with fundamental frequencies of 7.0 Hz and 6.5 Hz for the base- and floor-mounted units, respectively, being observed. The transformers were subjected to biaxial, random multifrequency test series of five OBEs and one SSE while energized. The biaxial test series was repeated in two orientations to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The transformers successfully completed the test, and units performed their intended function.
Relief Valve Position Monitoring System	The equipment, which includes a preamplifier, sensor, monitor, and panel, were qualified by dynamic testing. The applicable standards and guidelines are IEEE-381-1977, IEEE-344-1975, IEEE-323-1974, and RG 1.89 and 1.100.	The position sensors are affected by seismic and hydrodynamic loads; the preamplifiers and indicating instruments are subject to seismic loads only. The dynamic test program for the preamplifier and monitor was performed as follows: The equipment was mounted to simulate plant installations and instrumented to record accelerations and monitor operability. The test consists of a resonance search in three axes with 0.2-g amplitude sine sweeps followed by a biaxial, random multifrequency series of five OBE and one SSE tests. The TRS enveloped the RRS in the applicable frequency range with a margin of at least 10 percent. The equipment did not exhibit any malfunction as a result of the seismic simulation tests. The position sensors are precision accelerometers with acceleration limits of 1,000 g in any direction.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Limit Switches (NAMCO)	The limit switches are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, IEEE-382-1972, and RG 1.89 and 1.100.	The limit switches are affected by both seismic and hydrodynamic loads. Dynamic testing is performed as follows: Representative limit switches are mounted on a rigid test fixture attached to the vibration test table with instrumentation provided to record accelerations and monitor operability. A resonance search is performed from 1 to 35 Hz in each of the three orthogonal axes. Sine dwell fragility tests are performed at one-third octave intervals between 1 and 35 Hz in each of the three orthogonal axes. A 9.5 g qualification level at all test frequencies is established as a result of these tests. These qualification levels exceed the required levels from all of the dynamic loads. For the limit switches affected by hydrodynamic loads, results of the above testing and additional single frequency dwell testing in the frequency range of 4-100 Hz are utilized. The combined test data show adequacy with respect to the frequency content of the dynamic load and indicate that the switches remain operable to a level of 7.2 g. In addition, the test motions contain equivalent stress cycles greater than those imposed by the postulated dynamic loads.
Thermowells and RTDs	Thermowells and RTDs are qualified by dynamic testing or by combination of test and analysis. Applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, RG 1.89 and 1.100, and the AISC Code.	Some of these items of equipment are affected by seismic loads only. Others are affected by both seismic and hydrodynamic loads. The dynamic testing for equipment affected by seismic load is as follows: The equipment is mounted on the test table in a manner that simulates the intended service mounting. The tests consist of a resonance frequency search from 1 to 175 Hz, followed by biaxial, random multifrequency testing for five OBEs followed by one SSE. Each of these tests consists of phase coherent input motions in four orientations. The TRS envelops the RRS in the applicable frequency range by a margin of at least 10 percent. The equipment does not exhibit any malfunction as a result of the multifrequency tests. For equipment affected by both seismic and hydrodynamic loads, additional dynamic testing is performed on the same units which were previously tested with multifrequency test motions. The additional tests utilize sine beat test input motions up to a frequency of 100 Hz. Equipment remains functional during and after the tests. Supplemental analyses are performed on some RTDs located inside the drywell and suppression chamber air and suppression pool. All stresses are within Code allowable limits. In addition, the calculated allowable stress cycles of the equipment are greater than those imposed by the postulated dynamic loads.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Electronic Transmitter	Electronic transmitters are qualified by dynamic test. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The electronic transmitters are affected by seismic loads only. The generic test program was performed as follows: The transmitters were mounted during the test to simulate the plant installations and instrumented to record accelerations and to monitor operability. The test consists of a resonance search in three axes, followed by a biaxial, random multifrequency series of five OBE and one SSE tests repeated in the second orientation to consider all three axes of loading. The TRS enveloped the RRS in the applicable frequency range by a margin of at least 10 percent. The electronic transmitter successfully completed these tests and performed its intended function.
Electrical Penetrations	The electrical penetration assemblies are qualified by a combination of dynamic testing and static analyses. The applicable standards, codes, and guidelines are IEEE-317-1976, IEEE-344-1975, ASME Boiler and Pressure Vessel Code Section III, 1977 Edition, and RG 1.89, 1.92, and 1.100.	The electrical penetrations are affected by both seismic and hydrodynamic loads. Dynamic testing is performed on prototype units in accordance with IEEE-317-1976 for each of the following assemblies: medium voltage, low voltage power, control and instrumentation penetration assemblies. Six random multifrequency tests of 30-sec durations each are performed using independent biaxial motions. The six tests are repeated in the other horizontal orientation to consider all three axes of loading. The natural frequency results indicate that the penetration assemblies are rigid, i.e., natural frequency is greater than 100 Hz. The TRS envelops the RRS in the rigid range with more than 250 percent margin. The complete system is energized, and no electrical discontinuities occur during the test. The assemblies remain functional before, during, and after the test. To address the hydrodynamic loading durations and the associated stress cycles, which are considerably higher than those of the seismic loads, an analysis of the test input motions was performed. It was demonstrated that the test motions contained many more stress cycles than those postulated for the combined seismic and hydrodynamic loads. Thus, no further testing was necessary. Design adequacy is also demonstrated through a design stress report in accordance with ASME III, paragraph NCA-3550.
Storage Batteries and Rack	Batteries and racks are qualified by a combination of analysis and tests. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.61, 1.89, 1.92, and 1.100.	The storage batteries and racks are affected by seismic loads only. The rack was qualified by static analysis. The calculated natural frequency indicates that the rack is rigid and that the floor motion is not amplified at the battery locations. Stresses in the rack are well within the allowable limits of paragraph 3.9A.2.2.2. The batteries are qualified by dynamic testing, performed as follows: The batteries were mounted on rigid racks, simulating the plant installation. They were instrumented to record accelerations and to monitor operability. The test consisted of a resonance search from 0.5 to 35 Hz in three axes, followed by a biaxial, random multifrequency excitation for five OBE and one SSE tests. The amplitude was controlled in one-third octave over a frequency range

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
		of 0.5 to 40 Hz. These biaxial tests were repeated in the alternate horizontal orientation to include all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. All the batteries successfully completed these tests and performed their intended functions.
Battery Chargers	The battery chargers are qualified by dynamic test. The applicable standards and guidelines are IEEE-323-1974, IEEE-334-1975, and RG 1.89 and 1.100.	The battery chargers are affected by seismic loads only. They were qualified by similarity to a unit which was dynamically tested. The chargers were mounted during the test to simulate the plant installation, and instrumented to record accelerations and to monitor operability. The test consisted of a resonance search from 1 to 50 Hz in three axes, followed by a biaxial, random multifrequency series of five OBE and one SSE tests. The amplitude was controlled in one-third octave bandwidths over a frequency range of 1 to 40 Hz. These tests were repeated in the second orientation to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The test specimen did not exhibit any malfunction as a result of the seismic simulation tests.
Uninterruptible Power Supplies (UPS)	The UPS systems were qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, IEEE-650-1979, and RG 1.61, 1.89, and 1.100.	The UPS systems are affected by seismic loads only. The dynamic testing for qualification of UPS 2VBA*UPS2A and 2B was performed as follows: A representative test specimen was mounted on the vibration test table such that the in-service condition is simulated. The specimen was instrumented to record accelerations and monitor operability. A resonance search was performed from 1 to 35 Hz in each of the three orthogonal axes. Biaxial, random multifrequency tests of five OBEs and one SSE in each of two test orientations were performed. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The specimen did not exhibit any malfunction as a result of the seismic simulation tests. Redundant UPS units 2VBA*UPS2C and 2D were qualified by similarity to a previously tested assembly. The test specimen was mounted on a vibration test table using a bolted connection. The difference between the bolted connection applied in the test and the welded installation used in the plant was reconciled by analysis. The test methods and test monitoring applied in the qualification of this equipment were similar to that described for 2VBA*UPS2A and 2B above. The test specimen was qualified for use in seismic environments that exceed that associated with the installed location.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Miscellaneous Electrical Motors: Application: Fans Pumps Strainers Unit Coolers Air Conditioners	Qualification of electrical motors is by a combination of tests and analyses. The applicable standards and guidelines are IEEE-323-1974, IEEE-334-1974, IEEE-344-1975, RG 1.61, 1.92, and 1.100, and the AISC Code.	The motors are affected by seismic loads only. The Reliance motors are qualified by analysis and/or testing. Some motors were dynamically tested as follows: The motor was installed in the unit cooler, which was mounted on the vibration test table such that the service condition was simulated. A resonance search was performed from 1 to 35 Hz, followed by biaxial, random multifrequency tests of five OBEs and one SSE.
Manufacturers: Westinghouse Reliance		The motor remained operational during the tests, and the TRS enveloped the RRS by a margin of at least 10 percent in the applicable frequency range. The natural frequency of the other Reliance motors was determined by analysis. Since it was determined that these motors were rigid, static analysis was used to demonstrate the structural and functional qualification of the individual motors. Stresses in all critical components were within the allowable limits of paragraph 3.9A.2.2. Deflection of the rotor was within the allowable clearance, and bearing life corresponding to the loads was in excess of the qualified life of the motors. The natural frequency of the Westinghouse motors was determined either by analysis or shaker tests. Since it was determined that all of the motors were rigid, static analysis was used to demonstrate the structural and functional qualification of the individual motors. Stresses in all critical components were within the allowable limit of paragraph 3.9A.2.2. Deflection of the rotor was within the allowable clearance, and bearing lives corresponding to the loads were in excess of the qualified life of the motors.
Motor Control Center 600-V ac 125-V dc	MCCs are qualified by dynamic testing. The applicable standards and guidelines are IEEE-344-1975, IEEE-323-1974, and RG 1.89 and 1.100.	The MCCs are affected by seismic loads only. The dynamic testing was performed as follows: Representative test specimens were mounted on the vibration test table such that in-service conditions were simulated. The specimens were instrumented to record accelerations and monitor operability. A resonance search was performed from 1 to 35 Hz for each of the three orthogonal axes. The seismic simulation vibration tests consisted of triaxial, random multifrequency tests for five OBEs and one SSE. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The test specimens did not exhibit any malfunction as a result of the seismic simulation tests.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Solenoid Valves Target Rock	Solenoid valves are qualified by a combination of tests and analysis. The applicable standards and guidelines are ASME Section III-1974, IEEE-323-1974, IEEE-344-1975, IEEE-382-1980, and RG 1.61, 1.89, 1.92, and 1.100.	Some of the solenoid valves are affected by seismic loads only; others are affected by both seismic and hydrodynamic loads. An analysis of the valves was performed, which meets the ASME Section III requirements. For valves affected by seismic loads only, the dynamic testing was performed as follows: A resonance search was conducted in the range of 1 to 35 Hz. No structural resonances were found. This was followed by biaxial sinusoidal dwell tests at a 4.5-g input level to account for the OBE and SSE loadings. Twelve tests of 30-sec duration each were performed in the frequency range of 1 to 35 Hz. The tests were repeated with the input between horizontal and vertical axes 180 deg out of phase. At the completion of dwell testing in the first biaxial pair of axes, the above tests were repeated for the remaining horizontal and vertical axis combinations. The test valve was pressurized to 2,485 psig with water at the inlet and was cycled during the testing. Piping end loads of 285 ft-lb were applied. The valve functioned satisfactorily during and after the test. Valves affected by the combined seismic and hydrodynamic loads are qualified by a combination of random multifrequency and single frequency sine sweep and sine beat test motions. The sine beat tests were performed at test frequencies in the range of 1 to 100 Hz at one-third octave intervals at an input level of 6.0 g, except in low frequencies where the input levels were limited by 5.0-in double displacement. The test valve was pressurized at 1,250 psig. The valve functioned satisfactorily during and after the test. Piping design acceptance criteria ensure that actual dynamic loadings are within the qualified levels for each valve.
Solenoid Valves Valcor Engineering	Solenoid valves are qualified by a combination of tests and analysis. The applicable standards and guidelines are ASME Section III-1977, IEEE-323-1974, IEEE-344-1975, IEEE-382-1985, and RG 1.61, 1.89, 1.92, and 1.100.	These valves are affected by both seismic and hydrodynamic loads. An analysis of the valves was performed, which meets the ASME Section III requirements. Two test valves were subjected to a resonance search in the range of 1 to 100 Hz. No structural resonances were found. The valves were then qualified by a combination of single frequency sine sweep and sine beat test motions. The sine beat tests were performed at test frequencies in the range of 1 to 100 Hz at one-third octave intervals at an input level of 5.0 g, except in low frequencies where the input level was limited by the test equipment. The test valves were pressurized with water at 1,250 psig. The valves functioned satisfactorily during and after the test. Piping design acceptance criteria ensure that actual dynamic loadings are within the qualified levels for each valve.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Solenoid Valves - AVCO	Solenoid valves are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, IEEE-382-1980, IEEE-382-1985, and RG 1.89 and 1.100.	The valves are affected by seismic loads only. The testing consists of two single-axis sine sweep tests, from 2 Hz to 35 Hz to 2 Hz, followed by single-axis sine beat tests at each one-third octave frequency from 2 Hz to 32 Hz. The required safety function of the valves to shift position is demonstrated during and after the testing. Piping design acceptance criteria ensure that actual dynamic loading is within the qualified levels for each valve.
Pressure Switches - Static O-Ring Switches	Pressure switches are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The pressure switches are affected by seismic loads only. The pressure switches are qualified by biaxial, random multifrequency tests of 30-sec duration each for each of the five OBE and one SSE conditions. The tests were repeated in the second horizontal and vertical orientation. The pressure switches successfully completed the seismic testing by performing their intended safety functions during and after all tests. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent.
Positioner - Wyle/Virginia Valve	Pressure switches are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The positioner is affected by seismic loads only. The positioner is qualified by triaxial, random multifrequency tests of 30-sec duration each for each of the five OBE and one SSE conditions. The positioner successfully completed the seismic testing by performing its intended safety functions after all tests. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent.
Control Panels and Instrument Racks	Control panels, instrument racks, and mounted devices are qualified by a combination of dynamic testing and analysis. Applicable code, standards, and guidelines are the AISC Code, IEEE-323-1974, IEEE-344-1975, and NRC RG 1.61, 1.89, 1.92, and 1.100.	Control panels and racks are affected by seismic loads only. The panels and racks are qualified by a finite element analysis. The natural frequency results indicate that the panel and racks are rigid and that the floor motion was not amplified at the various component mounting locations. Results of the static analysis indicate that the stresses are well within the allowable limits of paragraph 3.9A.2.2.2, and the margin of safety is over 15 percent. All of the active components, including Foxboro racks, are qualified by dynamic testing. The dynamic test is performed as follows: The test items are mounted during the test to simulate plant installation and are instrumented to record accelerations and monitor operability. The test consists of a resonance search from 1 to 35 Hz in three axes, followed by a biaxial, random multifrequency series of five OBE and one SSE tests with amplitude controlled in one-third octave bandwidths over a frequency range of 1 to 40 Hz. These tests are repeated in the second horizontal orientation to consider all three axes of loading. The TRS envelops the RRS within the applicable frequency range with at least a 10 percent margin. All of the tested items successfully completed these tests and performed their intended functions.

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(Sheet 12 of 19)

CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results

Radiation Monitoring System
 	
<u>Component</u>
• Liquid monitor assembly
• Gas monitor assembly with process monitor microcomputer
• Gas monitor assembly without microcomputer
• Particulate and gas monitor assembly
• Remotely mounted microcomputer
• Control room cabinet, including:
  • Interface modules
  • Safety isolation modules
  • Remote indication and control units
  • Analog and digital isolation modules
  • Strip chart recorders
• Ion chamber detector
• Remote indicator and alarm module
• Electric motor for gas monitor sample pumps
• Isokinetic probes
• Pump/motor for liquid monitor sample pumps
	The radiation monitoring system is qualified by a combination of analysis and dynamic testing. The following is a list of essential components and the corresponding methods of qualifications:
	
	<u>Method</u>
	Static analysis, dynamic test
	Static analysis, dynamic test
	Static analysis, dynamic test
	Static analysis, dynamic test
	Dynamic test
	Dynamic analysis
	Dynamic test
	Dynamic test
	Dynamic test
	Dynamic test
	Dynamic test
	Dynamic test
	Dynamic test
	Static analysis
	Static analysis
	Static analysis (with exception of 2SWP*CAB23A and 2SWP*CAB23B, and 2SWP*CAB146A and 2SWP*CAB146B, pumps originally qualified by static analysis; later replaced and qualified by dynamic testing).
	
	Non-Class 1E components are qualified through their similarity to the Class 1E components or by static analysis. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and NRC RG 1.89, 1.92, 1.97, and 1.100.
		All components are affected by seismic loads, with the ion chamber detectors additionally subjected to hydrodynamic loads. All devices are identical or similar to parent items, which are qualified by dynamic testing, with the exception of the isokinetic nozzles and the control room cabinets. In addition, all radiation monitor skids are analyzed for structural integrity using ANSYS modal finite elementand static analysis options to determine frequencies, stresses, and deflections. The control room cabinets are qualified by use of the dynamic finite element analysis option of the same program. The isokinetic probes, being simple collector tubes, are analyzed by conventional manual methods, as are the pump/motor assemblies (with the exception of the liquid monitor sample pumps in 2SWP*CAB23A and 2SWP*CAB23B, and 2SWP*CAB146A and 2SWP*CAB146B), since these items have natural frequencies higher than 33 Hz.
		
		The dynamic testing is performed as follows: A resonance search in three axes is performed from 1 to at least 33 Hz. Five OBE and one SSE random multifrequency tests of 30-sec duration each, using biaxial/triaxial motions, with amplitude controlled in one-third octave bandwidths over a frequency range of 1 to at least 33 Hz, are performed and, in the case of biaxial motions, repeated in the alternate horizontal orientation to consider all three axes of loading. The TRS envelopes the RRS by at least a 10 percent margin in the frequency range of interest. The components are instrumented to record accelerations and monitor operability before, during, and after the vibration tests. Equipment remained functional, and no structural damage was noted.
		
		For ion chamber detectors affected by hydrodynamic loads, testing includes high frequency and long duration characteristics of the loading as follows: The resonance search is extended to a frequency of 200 Hz. The input motions for the random testing contain frequencies between 1 and 100 Hz. The TRS envelopes the RRS by at least a 10 percent margin in the applicable frequency range. The random testing consists of several additional tests with a frequency range to 200 Hz, at various amplitudes, in addition to the six tests of 30-sec duration and for 30-min duration in each axis. An analysis to compare the test equivalent stress cycles with those from the postulated dynamic loads is also performed. This analysis shows that the test motions contain equivalent stress cycles greater than those from the postulated dynamic loads.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Loose Parts Monitoring System (Category II)	The equipment was qualified by a combination of test and dynamic analysis, utilizing the response spectrum modal analysis technique. Applicable code, guidelines, and standards are the AISC Code, NRC RG 1.100, 1.133 and IEEE-344-1975.	The loose parts monitoring system equipment is affected by seismic loads and is qualified to withstand five OBE events only. A dynamic response spectrum modal analysis was performed on a model simulating the cabinet and masses of the large instruments. The lowest natural frequency of the cabinet was 24 Hz. The maximum stress margin of safety is greater than 75 percent. The devices in the cabinet were qualified by testing a generic unit. The test consisted of a resonance search followed by a biaxial, random multifrequency series of five OBE tests. The biaxial tests were repeated in a second orientation to consider all three axes of loading. The TRS enveloped the RRS within the applicable frequency range with at least a 10 percent margin.
Centrifugal Liquid Chillers	Centrifugal liquid chillers are qualified by a combination of analysis and tests. The control panel and Class 1E electrical components of the centrifugal liquid chillers are qualified by dynamic testing. The skid, main shell, and pipes are qualified by finite element analysis. The applicable standards, guidelines, and codes are IEEE-323-1974, IEEE-334-1974, IEEE-344-1975, RG 1.89 and 1.100, and ASME Section III, Subsections ND and NF, including Addenda, 1974 Edition.	Centrifugal liquid chillers are affected by seismic loads only. The control panel and Class 1E electrical components of the chillers are qualified by dynamic testing. Representative test specimens were mounted on the vibration test table such that in-service conditions were simulated. The specimens were instrumented to record accelerations and monitor operability. A resonance search from 1 to 35 Hz was performed in each of three orthogonal axes. The seismic simulation vibration tests consisted of biaxial, random multifrequency tests of five OBEs and one SSE in each of two test orientations 90 deg apart. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The test specimens did not exhibit any malfunctions as a result of the seismic simulation tests. The skid, main shell, and pipes are qualified by finite element analysis. A local shell analysis of all major pipe-to-shell attachments was also performed. The stresses and deflections were found to be within the acceptable limits of Table 3.9A-8.
Electric Heat Tracing Control Panels	Electric heat tracing control panels are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and RG 1.89 and 1.100.	The heat tracing control panels are affected by seismic loads only. A test specimen of identical construction was mounted on the vibration test table such that in-service conditions were simulated. The specimen was instrumented to record accelerations and monitor operability. A resonance search from 1 to 35 Hz was performed in each of three orthogonal axes. The seismic simulation tests consisted of biaxial, random multifrequency tests, five OBEs and one SSE in each of two test orientations 90 deg apart. The TRS enveloped the RRS within the applicable frequency range with a margin of at least 10 percent. The test specimen did not exhibit any malfunction as a result of the seismic simulation tests.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Electrical Air Duct Heaters	Qualification of air duct heaters is by analysis and test. Applicable guidelines, codes, and standards are NRC RG 1.61, 1.89, 1.92, 1.100, the AISC Code, and IEEE-323-1974 and IEEE-344-1975.	The air duct heaters are affected by seismic loads only. Analysis of the enclosures for the heater and remote control panel is performed using a finite element model. The natural frequencies are determined. Static and dynamic analysis is performed to calculate stresses and deflections. The results show that stresses are within the allowables of paragraph 3.9A.2.2.2 and that deflections are negligible. For qualification of devices, a test program consisting of resonance search and random multiaxial and multifrequency tests shows that the TRS envelopes the RRS in the applicable frequency range by a margin of at least 10 percent.
Diesel Generator System <u>Component/System</u> • Engine mounted systems (including combustion air manifold, exhaust manifold, shutdown butterfly valve, jacket water headers, governor linkages, fuel oil and lube oil systems, and starting air system • Air intake filter • Air intake silencer • Exhaust silencer • Engine-driven lube oil pump • Jacket water standpipe • Jacket water circulating pump • Fuel oil filter and strainer • Turbocharger lube oil filter	This system is qualified by a combination of analysis and dynamic testing programs. The following is a list of essential components and systems and the corresponding methods of qualification. <u>Method</u> Static analysis Static analysis Static analysis Static analysis Static analysis Dynamic analysis Static analysis Dynamic analysis Dynamic analysis	The diesel generator system is affected by seismic loads only. The main unit is qualified seismically by response spectrum finite element modal analysis. The model consists of major mass and structural items, including the engine itself, the flywheel, generator rotor, outboard bearing, pedestal, and base. Items too small to affect the dynamic characteristics of the system are excluded. Results of the dynamic analysis indicate that the stresses in the analyzed components are well within the allowable limits of paragraph 3.9A.2.2.2 with substantial margin. Amplified response spectra are also generated (by analysis) at different points of the diesel generator where various equipment is mounted. The tested components are subjected to sine sweeps from 1 to 40 Hz in three axes, followed by a biaxial, random multifrequency series of at least five OBE and one SSE tests. The TRS envelopes the RRS within the frequency range of interest with at least a 10 percent margin. Each component is mounted during the test to simulate the plant installation and instrumented to record acceleration and monitor operability. The lube oil thermostatic valve is qualified through analysis and single frequency testing. It is subjected to a series of increasingly severe sine sweeps at the rate of two octaves/min from 1 to 50 Hz at a level of 2.0 g, increased to 16.0 g. Auxiliary skid piping, jacket water standpipe, fuel oil filter and strainer, turbocharger lube oil filter, jacket water cooler, lube oil heat exchanger, and generator stator and brush mounting structures are all analyzed by the modal response spectrum analysis method using floor response spectrum.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Component/System	Method	Torsional frequencies of the crankshaft system are determined by analysis. Torsional stresses are also determined at several locations of the crankshaft due to the stimulation torques at the potentially significant critical speeds. There is no conceivable operating condition in which the system torsional vibration can damage or adversely affect operation of the unit. The remaining components are qualified through static analysis. The results of all analyses and tests show substantial margins compared to the maximum required acceleration level, ensuring the ability of the diesel generator to function under all operating and postulated loadings.
• 3-in check valve	Static analysis	
• 6-in check valve	Static analysis	
• Lube oil and jacket water heater	Static analysis	
• Auxiliary skid piping	Static & dynamic analysis	
• Exhaust expansion joint	Static analysis	
• Intake expansion joint	Static analysis	
• Governor actuator and overspeed governor	Dynamic analysis	
• Intercooler water piping	Static analysis	
• Starting air tank	Static analysis	
• Lube oil filter	Static analysis	
• Outboard bearing	Static analysis	
• Jacket water cooler	Dynamic analysis	
• Lube oil heat exchanger	Dynamic analysis	
• Generator stator and brush mounting structure	Dynamic analysis	
• Ac outlet box	Dynamic test	
• Starting air separator	Static analysis	
• Lube oil strainer	Static analysis	
• Jacket water thermostatic valve	Static analysis & dynamic test	
• Lube oil thermostatic valve	Static analysis & dynamic test	
• Standby fuel oil booster pump	Static analysis	
• Lube oil circulating pump	Static analysis	
• Starting air relief valve on compressor	Static analysis	
• Air compressor	Static analysis	
• Engine-driven water pump	Static analysis	
• Intercooler	Static analysis	
• Engine-driven fuel oil booster pump	Static analysis	
• Jacket water thermo regulating valve	Static analysis	

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
Component/System • Various control system components: control valves, check valve, pressure switch, relay, temperature switch, solenoid valve, diaphragm valve, shuttle valve, etc. • Jacket water level switches • Lube oil relief valve • Fuel oil relief valve • Starting air relief valve • Fuel oil cooler • Entronic control panel • High-voltage panels	Method Dynamic test Dynamic test Static analysis Static analysis Static analysis Static analysis Dynamic test Dynamic test The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, and NRC RG 1.61, 1.89, 1.92, and 1.100.	
Electrohydraulic Valve Operators - Borg-Warner and Paul Munroe	The Borg-Warner and Paul Munroe electrohydraulic valve operators and electronic controllers are qualified by dynamic testing. The applicable standards and guidelines are IEEE-323-1974, IEEE-344-1975, IEEE-382-1972, and NRC RG 1.89 and 1.100.	The Borg-Warner electrohydraulic operators and remote electronic controllers are affected by seismic loads only. The operators are line (valve) mounted, whereas the electronic controllers are wall mounted. Therefore, the operators and controllers are seismically qualified to different parameters. The Borg-Warner electrohydraulic operator seismic qualifications are based on dynamic testing. A representative test specimen was mounted to the vibration test table using a specially designed test fixture specimen was instrumented to record accelerations and monitor operability. The specimen was then subjected to three orthogonal,single axis, vibration aging tests over the frequency range of 5 to 200 to 5 Hz at the rate of two octaves per minute with an acceleration level of 0.75 g. Each uniaxial test was for a 90-min duration, and the operator assembly was continuously functionally stroked at a rate of approximately five cycles per minute. A resonance search in each orthogonal axis was performed over the frequency range of 1 to 100 Hz using an input acceleration of 0.2 g. The specimen was then subjected to biaxial, random multifrequency vibration tests for five OBEs followed by one SSE in each of two orthogonal axes. The TRS enveloped the generic OBE (2.3 g zpa) and

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
		SSE (4.6 g zpa) spectra. The specimen was then subjected to required input motion (RIM) OBE tests that consisted of two sinusoidal sweeps from 2 to 35 to 2 Hz with an acceleration input of 3.3 g. The testsingle axis, vibration aging tests over the frequency range of 5 to 200 to 5 Hz at the rate of two octaves per minute with an acceleration level of 0.75 g. Each uniaxial test was for a 90-min duration, and the operator assembly was continuously functionally stroked at a rate of approximately five cycles per minute. A resonance search in each orthogonal axis was performed over the frequency range of 1 to 100 Hz using an input acceleration of 0.2 g. The specimen was then subjected to biaxial, random multifrequency vibration tests for five OBEs followed by one SSE in each of two orthogonal axes. The TRS enveloped the generic OBE (2.3 g zpa) and SSE (4.6 g zpa) spectra. The specimen was then subjected to required input motion (RIM) OBE tests that consisted of two sinusoidal sweeps from 2 to 35 to 2 Hz with an acceleration input of 3.3 g. The test was performed in each of three orthogonal axes. The first sweep was performed with the operator assembly in the open position and the second sweep with the operator in the closed position. Each OBE RIM test was followed by a SSE RIM test which consisted of a series of sine beats at each one-third octave frequency from 2 to 32 Hz with an input acceleration of 4.95 g. The input at each frequency was a continuous series of sine beats of 15 oscillations per beat for a duration of 15 sec. The operator assembly was cycled under load during each test. The operator assembly did not exhibit any malfunctions or loss of structural integrity. The remote electronic controller seismic qualifications are also based on dynamic testing. Representative test specimens were attached to the vibration test table such that the in-service mounting conditions were simulated. The specimens were instrumented to record acceleration levels and monitor operability. A resonance search from 1 to 100 Hz was performed in each of three orthogonal axes with an input acceleration of 0.2 g. The specimens were then subjected to biaxial, random multifrequency vibration tests for five OBEs followed by one SSE in each of two orthogonal axes. The TRS enveloped the RRS over the frequency range of interest by a minimum margin of 10 percent. The specimens did not exhibit any malfunction or loss of structural integrity. The Paul Munroe electrohydraulic valve operators are affected by seismic loads only. The operator seismic qualification is based on dynamic testing. The test specimen was mounted to the vibration test

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
		table using a specially designed test fixture such that the in-service mounting conditions were duplicated. The specimen was instrumented to record accelerations and monitor operability. A resonance search in each of the three orthogonal axes was performed over the frequency range of 1 to 40 Hz using an input acceleration of 0.2 g. The results of the resonance search test indicated no frequencies below 35 Hz. The specimen was then subjected to single-axis sine beat tests at 32 Hz in each of its orthogonal specimen axes to satisfy the OBE level requirements. Tests in each axis consisted of a string of beats (35 beats) of 15 oscillations (a sinusoid of the test frequency) per beat, with a 2-sec pause between beats for the total test time duration of 75 sec. The horizontal and vertical input accelerations were 1.6 g. These tests were performed with the valve actuator in the open position. After the OBE RIM test, the specimen was subjected to SSE level single-axis sine beat tests at 32 Hz along each of its orthogonal axes. Tests in each axis consisted of a string of beats (a minimum of five beats) and 15 oscillations (a sinusoid of the test frequency) per beat with a 2-sec pause between beats for a total duration of 15 sec. The horizontal and vertical input accelerations were 2.4 g. The specimen was operated under loaded conditions during each test and did not exhibit any malfunctions or loss of structural integrity. Piping as-built analyses ensure that the OBE and SSE acceleration levels are smaller than the qualified levels for each electrohydraulic valve actuator.
Electrohydraulic Damper Operators - Preferred Metal Technologies, Inc. (PMT)	The PMT electrohydraulic damper actuators are qualified by dynamic testing. The applicable standards and guidelines are IEEE-344-1975, IEEE-323-1974, IEEE-382-1972, and RG 1.61 and RG 1.100.	The PMT electrohydraulic operators are affected by seismic loads only. The operators are equipment (damper) mounted and qualified as follows: A representative specimen was mounted on a vibration test table and subjected to vibration aging tests over the frequency range of 5 to 100 to 5 Hz at a rate of two octaves per minute, with an acceleration level of 0.75 g in each of the orthogonal axis for a duration of 90 min. A resonant search in each of the orthogonal axis was performed with the results indicating no resonant frequencies less than 18 Hz. The specimen was then subjected to triaxial, random multifrequency input motions, with 30-sec duration for five OBEs followed by one SSE. The TRS envelops the applicable portion of the RRS by a minimum of 10 percent. The specimens were monitored and did not exhibit any malfunction or loss of structural integrity during and after dynamic testing.

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CLASS 1E ELECTRICAL EQUIPMENT QUALIFICATION RESULTS

Equipment	Methods	Results
I/P Converters – CONOFLOW	The I/P converters are qualified by dynamic testing. Applicable standards and guidelines are IEEE-323-1974 and IEEE-344-1975.	The I/P converters are affected by seismic loads only. The testing consisted of a resonance search testing and sine beat testing. The resonance search testing consisted of a sinusoidal vibration at an acceleration of 0.5 g from 5 to 50 Hz. No resonant frequencies are identified below 33 Hz.
Pressure (Filter) Regulators - CONOFLOW	The pressure (filter) regulators are qualified by dynamic testing. Applicable standards and guidelines are IEEE-323-1974 and IEEE-344-1975.	The pressure (filter) regulators are affected by seismic loads only. The testing consisted of a resonance search testing and sine beat testing. The resonance search testing consisted of a sinusoidal vibration at an acceleration of 0.5 g from 5 to 50 Hz. No structural resonant frequencies less than 33 Hz are found. The sine beat testing consisted of applying a series of continuous sine beats over a frequency range of 5 to 50 Hz. The accelerations used for excitation were 4.5 g horizontal and 3.0 g vertical. The units operated satisfactorily both during and after the tests.

3.10B SEISMIC AND HYDRODYNAMIC QUALIFICATIONS OF SEISMIC CATEGORY I INSTRUMENTATION AND ELECTRICAL EQUIPMENT (GE SCOPE OF SUPPLY)

3.10B.1 Dynamic Qualification Criteria

3.10B.1.1 Seismic Category I Equipment Identification

Seismic Category I instrumentation and electrical equipment is listed in Table 3.2-1. "Active" NSSS pumps, motors, valves, and valve-mounted equipment are listed in Table 3.9B-4.

Seismic Category I instrumentation and electrical equipment are designed to withstand the faulted event without functional impairment.

The Class 1E instrumentation electrical equipment and support structures supplied by GE requiring seismic qualification are identified in Table 3.10B-1. The seismic qualification of these instrumentation, equipment, and supports is described in the following subsections.

Section 3.9B.2.2 of this FSAR addresses the dynamic qualification testing and analysis of the Category I mechanical components, equipment, and their supports, including the integral or associated electrical components such as valve-mounted components and pump motors.

3.10B.1.2 Dynamic Design Criteria

3.10B.1.2.1 NSSS Equipment

The seismic criterion used in the design and subsequent qualification of all Class 1E instrumentation and electrical equipment supplied by GE is described in the following paragraph.

The Class 1E equipment is capable of performing its safety-related functions during 1) normal plant operation, 2) anticipated transients, 3) design basis accidents, and 4) post-accident operation while being subjected to, and after the cessation of, the accelerations resulting from the seismic and hydrodynamic loads at the point of attachment of the equipment to the building or supporting structure.

The criteria for each of the devices used in the Class 1E systems depend on the use in a given system, e.g., a relay in one system may have as its safety function to de-energize and open its contacts within a certain time, while in another system it must energize and close its contacts. Since GE supplies many devices for many applications, the approach taken was to test the device in the worst-case configuration. In this way, the capability of protective action initiation and the proper operation of fail-safe circuits is ensured.

From the basic input ground motion data, a series of response curves at various building elevations is developed after the building layout is completed. Standard requirement levels that meet or exceed the maximum expected unique plant information are included in the design specifications for seismic Category I equipment. Equipment is qualified dynamically either by GE or by the supplier; in either case, test data, operating experience, and/or calculations substantiate that the components, systems, etc., do not suffer loss of function during or after exposure to seismic and hydrodynamic loads. The magnitude and frequency of the SSE loadings which each component may experience are determined by its specific location within the plant.

3.10B.2 Methods and Procedures for Qualifying Electrical Equipment and Instrumentation

3.10B.2.1 Methods of Showing NSSS Equipment Compliance with IEEE-344-1975 and Regulatory Guide 1.100

RG 1.100 is not the Unit 2 licensing basis for the GE scope of supply. However, GE dynamically reevaluates the equipment to the requirements of IEEE-344-1975. This is accomplished through the GE Seismic Qualification Review Team (SQRT) program.

Under the GE SQRT program, the qualification of recently qualified equipment or equipment yet to be qualified complies with RG 1.100 and IEEE-344-1975. For equipment originally qualified to IEEE-344-1971, the SQRT methodology is applied to the original test data to demonstrate that requirements of IEEE-344-1975 are satisfied also.

If the SQRT requirements are not satisfied for a specific piece of equipment, the equipment is requalified to IEEE-344-1975 or replaced with a component that is qualified to IEEE-344-1975.

Procedures

GE-supplied Class 1E equipment meets the requirement that the dynamic qualification should demonstrate the capability to perform the required safety function during and after the seismic and hydrodynamic loads. Both analysis and testing were used, but most equipment was tested. Analysis was primarily used to determine the adequacy of mechanical strength, such as mounting bolts and pressure boundaries.

Analysis - GE-supplied Class 1E equipment performing primarily a mechanical safety function (pressure boundary devices, etc.) was analyzed since the passive nature of their critical safety role usually made testing unnecessary. Analytical methods outlined in IEEE-344-1975 were utilized in such cases. (See Table 3.10B-1 for indication of which items were qualified by analysis.)

Testing - GE-supplied Class 1E equipment having an active electrical safety function was tested in compliance with IEEE-344-1975.

Documentation

Available documentation verifies the seismic qualification of GE-supplied Class 1E equipment.

3.10B.2.2 Testing Procedures for Qualifying Electrical Equipment and Instrumentation

The test procedure required that the device be mounted on the table of the vibration machine in a manner similar to its normal, installed configuration. The device was tested in the operating states as if it were performing its Class 1E functions; these states were monitored before, during, and after the test to ensure proper function and absence of spurious function. In the case of the relay example, both energized and de-energized states and normally open and normally closed contact configurations were tested if the relay is used in those configurations in its Class 1E functions.

The dynamic excitation was a random multiple frequency test in which the applied vibration was a sinusoidal table motion at a fixed peak acceleration and a discrete frequency at any given time. The vibratory excitation was applied in two orthogonal axes, horizontal and vertical simultaneously, with the axes chosen as those coincident with the most probable mounting configuration. The device was then rotated 90 deg in the horizontal plane, and the test was repeated. Each device, therefore, has been tested in the three major orthogonal axes.

The first step was usually a search for resonances in each axis since resonances cause amplification of the input vibration and are the most likely cause of malfunction. The resonance search was usually run at low acceleration levels to avoid damaging the test sample if a severe resonance was encountered. The resonance search was performed for the applicable frequency range in accordance with IEEE-344; if the device was large enough, the vibrations were monitored by accelerometers placed at critical locations from which resonances were determined by comparing the acceleration level with that at the table of the vibration machine. Sometimes the devices either were too small for an accelerometer, with their critical parts in an inaccessible location, or had critical parts that will be adversely affected by the mounting of an accelerometer. The vibrations were monitored at the closest location.

Following the frequency scan and resonance determination, the devices were tested to determine their dynamic capability limit. For multifrequency testing, five OBE and one SSE tests were run at the appropriate TRS. In some cases, the TRS was increased gradually until device malfunction occurred or the shake table limit was reached. For single frequency testing, a malfunction limit test was run at each resonant frequency as determined by the frequency scan. In this test, the acceleration level was gradually increased until either the device malfunctioned or the limit of the vibration machine was reached. If no resonances were detected (as was usually the case), the device was considered to be rigid (all parts move in unison) and the malfunction limit was therefore independent of frequency. To achieve maximum acceleration from the vibration machine, rigid devices were malfunction tested at the upper test frequency since that allowed the maximum acceleration to be obtained from deflection-limited machines.

The summary of the tests on the devices used in Class 1E applications is given in Table 3.10B-1.

The above procedures were required of purchased devices as well as those made by GE. Vendor test results were reviewed and, if unacceptable, the tests were repeated either by GE or the vendor. If the vendor tests were adequate, the device was considered qualified to the limits of the test.

3.10B.2.3 Qualification of Valve Operators

The qualification of valve operators is discussed in Section 3.9B.2.2.

3.10B.2.4 Qualification of NSSS Motors

Seismic qualification of NSSS motors is discussed in Section 3.9B.2.2 in conjunction with the ECCS pump and motor assembly. Seismic qualification of the standby liquid control (SLC) pump motor is discussed in Section 3.9B.2.2.2 in conjunction with the SLC pump motor assembly.

3.10B.3 Methods and Procedure of Analysis or Testing of Supports of Electrical Equipment and Instrumentation

3.10B.3.1 Dynamic Analysis and Testing Procedures

3.10B.3.1.1 Panel-Mounted Equipment

The Class 1E equipment supplied by GE is used in many systems on many different plants and is subjected to widely varying dynamic loads. The qualification tests were performed to envelop the applicable frequency range. For supports subjected to seismic loads only, the tested frequencies range from 1 to 33 Hz. Where testing below 5 Hz was limited by capability of the test facility, a combination of test and analysis was used to ensure that there were no untested resonances.

For multicabinet assemblies that are too large for the test table, one or two bays of the assembly are tested, giving representative results in the front-to-back and vertical directions. The side-to-side results are evaluated and generally found to be conservative due to the increased flexibility of the narrower section. If conservatism cannot be established, the panel is modeled accurately and a computer analysis of its structural response is performed.

Some GE-supplied Class 1E devices were qualified by analysis only. Analysis was used for passive mechanical devices and was sometimes used in combination with testing for larger assemblies containing Class 1E devices. For example, a test might have been run to determine natural frequencies in the equipment within the critical frequency range. If the equipment was determined to be free of natural frequencies, it was assumed to be rigid. If it had natural frequencies in the critical frequency range, then calculations of transmissibility and responses to varying input accelerations were determined to see if Class 1E devices mounted in the assembly would operate without malfunctioning. Generally, the testing of Class 1E equipment was accomplished using the following procedure.

Assemblies (i.e., control panels and local racks) containing devices with established seismic and hydrodynamic malfunction limits were either analyzed or mounted on the table of a vibration machine in the manner it was to be mounted when in use. All control panel and local rack tests have been performed according to the requirements of IEEE-344. The initial vibration test in each case was a low-level resonance search. As with the devices, the assemblies were tested in the three major orthogonal axes. The resonance search was run in the same manner as described for devices. Alternately, control panel assemblies (such as the nuclear management analysis and control power range neutron monitor [NUMAC PRNM] panel assembly) were modeled accurately and a computer analysis of their structural response was performed. If resonances were present, the transmissibility between the input and the location of Class 1E devices was determined by measuring or computing the accelerations at the device locations and calculating the magnification between them and the input. Once known, the transmissibilities could be used analytically to determine conservatively the input motion at any Class 1E device location for any given input to the base of the assembly.

The described full acceleration level tests or analysis showed that the panel types had more than adequate mechanical strength and that acceptability was just a function of its amplification factor and the malfunction levels of the devices mounted in it. Many devices were mounted in the test panel or rack and qualified as an assembly. Other devices were tested individually as previously described. Sometimes panels were tested at lower acceleration levels and the transmissibilities measured to the various devices. By dividing the device's malfunction levels by the panel transmissibility between the device and the panel input, the panel seismic qualification level could be determined. Several high-level tests have been run on selected generic panel designs to ensure the conservatism in using the transmissibility analysis described.

3.10B.4 Operating License Review

The dynamic test results for safety-related panels and control equipment within the NSSS scope are maintained in a permanent file by GE and can be readily audited in all cases. The equipment used in Class 1E applications at Unit 2 passed the prescribed tests.

A summary of the test results for the devices used in Class 1E applications is given in Table 3.10B-1.

TABLE 3.10B-1
(Sheet 1 of 4)

ESSENTIAL CLASS 1E ELECTRICAL COMPONENTS AND INSTRUMENTS
SEISMIC QUALIFICATION TEST SUMMARY

Equipment	Method	Results
Temperature elements	The temperature elements are qualified by both dynamic testing and analysis. The applicable standard is IEEE-344-1975.	The temperature elements that have been designated as having an active safety function have been dynamically tested demonstrating qualification. Mounted similar to field conditions, they have been subjected to SRV vibration aging, chugging, seismic, and hydrodynamic loads. Biaxial testing, over the frequency range of 1 to 100 Hz, was accomplished in three mutually perpendicular axes with TRS enveloping the RRS. The temperature elements maintained their functional and structural integrity during testing. Those elements having a passive safety function were analyzed to show structural integrity when subjected to process pressures and loads in excess of the requirement for their location.
Temperature switch	The temperature switch is qualified by an analysis of its structural capability.	The safety function of the temperature switch is passive. Analysis shows that it exceeds its structural requirements when subjected to required seismic and hydrodynamic loads. Calculations indicate a high natural frequency making it a rigid body in the range of interest and its capability far exceeds its stress requirements.
Pressure transmitters, differential, absolute, and gauge	The transmitters are qualified by dynamic testing meeting the guidelines of IEEE-344-1975.	The transmitters can be subjected to both seismic and hydrodynamic loads during their installed life. Testing in an as-installed condition included random frequency excitation to meet SRV aging, upset and faulted seismic, and chugging requirements. Tests were performed in three mutually perpendicular axes. During testing, the transmitters maintained structural integrity and met functional requirements.
Pressure transmitters	The transmitters are qualified by dynamic testing meeting the guidelines of IEEE-344-1975.	The transmitters can be subjected to both seismic and hydrodynamic loads during their installed life. Testing in as-installed condition included biaxial random frequency excitation to meet upset and faulted seismic and chugging requirements. During testing, the transmitters maintained structural integrity and met functional requirements.
Level transmitters	Level transmitters are qualified for their application by both analysis and testing. Testing was performed to meet the guidelines of IEEE-344-1975.	The level transmitters have an active or passive safety function depending on their application. Those transmitters with a passive safety function have been shown to meet structural requirement by analysis. They have natural frequencies higher than the range of interest and have been shown to have structural integrity to withstand the required seismic and dynamic conditions. Those transmitted whose safety function is active were tested in their safety-related operating mode and were continuously monitored. They maintained their structural integrity and met accuracy requirements during testing. Five OBE and one SSE tests were performed in three mutually perpendicular axes. Excitation was applied biaxially over a frequency range of 1-100 Hz.

TABLE 3.10B-1
(Sheet 2 of 4)

ESSENTIAL CLASS 1E ELECTRICAL COMPONENTS AND INSTRUMENTS
SEISMIC QUALIFICATION TEST SUMMARY

Equipment	Method	Results
Level switch	The switches are qualified for their application by test performed to meet the guidelines of IEEE-344-1971 for a passive safety function and IEEE-344-1975 for an active safety function.	The level switches have an active or passive safety function depending on their application. Those switches with a passive safety function have been shown to meet structural requirements by test, and have been shown to have structural integrity to withstand the required seismic and dynamic conditions. Those switches with an active safety function can be subjected to seismic and hydrodynamic loads during their plant life. Vibration aging, SRV, OBE, SSE and sine beat testing were performed in three mutually perpendicular axes to levels greater than required for their Unit 2-installed location. During testing, the switches met structural and functional requirements.
Pressure indicators	The pressure indicators have been qualified by dynamic testing, meeting the guidelines of IEEE-344-1975.	Indicators can have an active or passive safety function. The indicators mounted in an as-installed condition were subjected to biaxial random testing over a frequency range of 1-250 Hz. Five OBEs and one SSE were applied in three mutually perpendicular axes. TRS that included both seismic and hydrodynamic loads enveloped the RRS. The indicator maintained structural integrity throughout testing.
Insulated detectors	The detectors have been qualified by dynamic testing to meet the guidelines of IEEE-344-1975.	Detectors have an active safety function and met structural and functional requirements when subjected to seismic testing at amplitudes greater than required. Five OBE and one SSE biaxial random tests were performed in three mutually perpendicular axes over a frequency range of 1-100 Hz. Functional performance was demonstrated before, during, and after seismic excitation.
IRM detector	A combination of test and analysis demonstrates qualification of the detectors for their installed location.	The IRM detector movement during a seismic event is controlled by the fuel bundle and maximum excitation occurs at the natural frequency of the bundle. The detector was tested at discrete frequencies in the horizontal axes and analyzed for vertical loads. Capabilities, both tested and analyzed, exceed the qualification requirements.
Conductivity element	The conductivity cell was analyzed to withstand seismic loads significantly greater than required.	The safety function of the cell is passive; however, it must maintain its structural integrity. Analysis indicates no resonances in any axis below 100 Hz and the ability to withstand loads more than fifteen times greater than required.
Condensing chamber	This equipment is qualified by analysis to meet the Unit 2 seismic requirement applying the ASME Boiler and Pressure Vessel Code Section III.	Stress analysis indicates that the condensing chamber meets the requirements of the ASME Code and that the lowest calculated allowable moment reaction exceeds the maximum moment of any Unit 2 condensing chamber installation.

TABLE 3.10B-1
(Sheet 3 of 4)

ESSENTIAL CLASS 1E ELECTRICAL COMPONENTS AND INSTRUMENTS
SEISMIC QUALIFICATION TEST SUMMARY

Equipment	Method	Results
Local panels	All panel qualification is by test of equivalent panels and devices. The applicable standard is IEEE-344-1975.	All panels were installed in an equivalent manner to those tested. Multifrequency, biaxial testing was performed by applying five OBE and two SSE level tests in each of three mutually perpendicular axes. Functional performance and structural integrity were monitored throughout the test series. In instances where instruments were not tested on the panel, the response at the device location was determined by multiplying the RRS and ZPA by the amplification factor for that device location on the panel and comparing the result with individual instrument test data. Qualification of panels is assured since the TRS enveloped the TRS, and functional and structural requirements were met.
Control room panels	The control room panels were qualified by test to the specified requirements IEEE-344-1975, except for the NUMAC PRNM system equipment control panel (PNL608) which was qualified by a combination of analysis and testing.	Control room panels and essential devices are seismically qualified to the IEEE-344-1975 criteria by comparing these panels to similar panels that have been qualified by test. The control room panels are steel structures that can be compared to other seismically similar structures, and the instruments can be considered separately. After the comparison panel is selected, the panel "g" fields are obtained by multiplying transmissibilities at each location by the ZPA in the respective axis. If the tested panel is identical to the Unit 2 panel, then the panel is qualified using the panel test data rather than the "ZPA times transmissibility" method. In these cases, the TRS must envelope the RRS and electrical operability of devices must be verified. Qualification by similarity of Class 1E mounted equipment when the tested panel is not identical to the Unit 2 panel is based on the current seismic capability of the device with the peak acceleration predicted at or near with the device's mounting location on a control room panel. The expected peak acceleration for the control room panel is obtained using the comparison panel transmissibility field. In the case of the NUMAC PRNM panel assembly, its structure is qualified by finite element analysis that demonstrates that all member stresses are below material allowables. The bounding in-panel RRS are then generated using multisupport input motion and the applicable floor response spectra (FRS) input at the base of the panel. Its Class 1E mounted equipment are generically qualified by testing to the requirements of IEEE-344-1975. The tested equipment is either identical or similar to the equipment installed at Unit 2. The TRS used in the generic tests envelope the bounding in-panel RRS.

TABLE 3.10B-1
(Sheet 4 of 4)

ESSENTIAL CLASS 1E ELECTRICAL COMPONENTS AND INSTRUMENTS
SEISMIC QUALIFICATION TEST SUMMARY

Unit 2 Ship Loose			
Temperature element	145C3224	A	Pyco
Temperature element	159C4520	P	Rosemount
Temperature element	133D9679	P	Pyco
Temperature element	117C3485	P	California alloy
Temperature switch	157C4629	P	Weed
Temperature indicator	169C8974	P	Weed
Differential pressure transmitter	163C1560	P	Rosemount
Pressure transmitter	188C7360	A	Rosemount
Level transmitter	188C4775	A	Gould
Level transmitter	145C3156	P	Barton
Level switch	184C4776	A	Magnetrol
Level switch	159C4361	P	Magnetrol
Pressure indicator	163C1184 DD188C8915	P	Robertshaw/Sycon
Insulated detectors	237X731	A	GE
IRM detector	112C3144	A	GE
Conductivity element	163C1544	P	Balsbaugh
Condensing chamber	204B7269	P	GE

TABLE 3.10B-2
(Sheet 1 of 1)

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3.11 ENVIRONMENTAL QUALIFICATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

Safety-related equipment and components are qualified to meet performance requirements under normal, abnormal, accident, and post-accident environmental conditions for the length of time they are required to function and to remain in a safe mode after their safety function is performed. The environmental conditions for those portions of the plant containing safety-related equipment have been established and are contained in the Environmental Qualification Program.

Environmental qualification for equipment located in harsh environments is addressed in the Environmental Qualification Program. The Maintenance Program addresses equipment located in mild environments.

Equipment qualification documentation described herein, including the Environmental Qualification Program configuration bases documents, and including the Unit 2 Environmental Qualification Master List (EQML), is maintained as part of the Unit 2 Environmental Qualification Program. These documents are maintained separately from the FSAR and are not considered part of the FSAR.

3.11.1 Equipment Identification and Environmental Conditions

Environmentally qualified electrical equipment includes all three categories of 10CFR50.49(b)[1]. Safety-related mechanical equipment includes pumps, MOVs, SRVs, and check valves.

A list of all environmentally qualified electrical and mechanical equipment that is located in a harsh environment area is provided in the Unit 2 MEL.

Environmental conditions for the zones where the equipment is located have been established for normal, abnormal, and accident conditions. Environmental conditions are listed by zones, each zone defining a specific area in the plant. Environmental parameters include temperature, pressure, relative humidity, beta and gamma radiation dose, dose rate and neutron dose. Where applicable, these parameters are given in terms of a time-based profile. A summary presentation of environmental conditions and qualified conditions for the environmentally qualified equipment located in a harsh environment zone is contained in the configuration bases documents.

3.11.2 Qualification Tests and Analyses

3.11.2.1 Qualification

Original environmentally qualified electrical equipment located in a harsh environment was qualified by test or other methods as described in IEEE-323 and permitted by 10CFR50.49(f)[1]. Equipment type test was the preferred method of qualification.

Environmentally qualified mechanical equipment that is located in a harsh environment has been qualified by analysis of materials data which are generally based on tests and operating experience.

The qualification methodology is contained in the Environmental Qualification Program.

The requirements of GDC 1, 4, 23, and 50 of Appendix A to 10CFR50 and Criterion III of Appendix B to 10CFR50 are met as outlined below:

> GDC 1 of 10CFR50, Appendix A, requirements are achieved by incorporating performance, design, construction, and testing requirements into equipment specifications and by the establishment of a system of reviews to ensure conformance with these specified requirements. Appropriate auditable records are maintained in a permanent file. Refer to Chapter 17 for a further definition of how Criterion III of Appendix B to 10CFR50 is met.
>
> GDC 4 requirements are met for harsh environment equipment by designing and qualifying the equipment for satisfactory operation and proper safety function performance during normal, abnormal, test, and DBA environments.
>
> The protection system meets GDC 23. FMEAs have been performed to prove that no single failure results in a loss of the capability of a system to perform its safety function. Both electrical and mechanical failures have been considered from causes such as loss of power supply, loss of control signal, and failures induced by normal, abnormal, accident, and seismic events. Harsh environment equipment has been environmentally qualified to preclude common mode failures.
>
> GDC 50 requirements are achieved by analysis and testing of pressure boundary components to ensure containment integrity.

The recommendations provided in RGs 1.9, 1.30, 1.40, 1.63, 1.73, 1.89, and 1.131 have been utilized by including these recommendations in appropriate equipment specifications. A discussion of compliance with these regulatory guides is provided in Section 1.8.

3.11.2.2 Method of Qualification of Class 1E Equipment and Components

The date of the construction permit Safety Evaluation Report for Unit 2 is prior to July 1, 1974; therefore, Unit 2, classified as a Category II plant under the guidance of NUREG-0588, July 1981, Interim Staff Position on Environmental Qualification of

Safety-Related Electrical Equipment; and the environmental qualification of Class 1E equipment located in harsh environments, met or exceeded the requirements for Category II qualification in accordance with NUREG-0588, including the guidance provided for incorporation of IEEE-323. The environments for which Class 1E equipment must perform its safety function have been specified and used as the basis for environmental qualification.

The methodology and acceptance criteria are addressed in the Environmental Qualification Program.

3.11.3 Qualification Test Results

The results of qualification tests for environmentally qualified equipment are maintained in an auditable file. A summary presentation of qualification test results for environmentally qualified electric equipment that is located in a harsh environment is contained in the configuration bases documents.

3.11.4 Loss of Heating, Ventilating, and Air Conditioning

To ensure that loss of HVAC systems does not adversely affect the operability of safety-related controls and electrical equipment in buildings and areas served by safety-related HVAC systems, the HVAC systems serving these areas meet the single-failure criterion.

The HVAC systems and the respective sections where specific safety evaluation details may be found are as follows:

1. Main control room, relay room, standby switchgear rooms, and electrical tunnels (Section 9.4.1.3).

2. Reactor building and standby gas treatment filter rooms (Section 9.4.2).

3. Diesel generator building (Section 9.4.6.3).

4. Service water pump bays (Section 9.4.7.3).

3.11.5 Estimated Chemical and Radiation Environment

3.11.5.1 Chemical Environment

The environmental parameters, including chemical environments, are included in the Environmental Qualification Program documents.

Sampling stations are provided for periodic analysis of reactor water, refueling and fuel storage pool water, and suppression pool water to assure compliance with operation limits of the plant Technical Specifications.

3.11.5.2 Radiation Environment

Safety-related systems and components are designed to perform their safety-related function when exposed to normal operational radiation levels and accident radiation levels. The normal operational exposure is based on the radiation sources provided in Chapters 11 and 12.

Radiation sources associated with the DBA and developed in accordance with NUREG-0588 Revision 1 are provided in Chapter 15.

Integrated doses associated with normal plant operation and the DBA condition for various plant compartments have been established and included in the Environmental Qualification Program documents.

The qualification methodology for safety-related equipment is described in the Environmental Qualification Program.

3.11.6 Submergence

The Environmental Qualification Program includes any safety-related equipment which may be submerged due to a LOCA.

3.11.7 References

1. Title 10, Code of Federal Regulations, Paragraph 50.49, Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants. Federal Register Vol. 48, No. 15, January 21, 1983.

2. A. J. Szukiewicz, et al. Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment, NUREG-0588, Revision 1, July 1981.

3. NRC Regulatory Guide 1.89, Environmental Qualification of Electrical Equipment Information to Safety for Nuclear Power Plants. Proposed Revision 1, November 1983.

4. NRC Regulatory Guide 1.7, Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident, Revision 2, November 1978.

5. NRC Regulatory Guide 1.97, Revision 3, Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident.

6. IEEE-323-74, Qualifying Class I Electric Equipment for Nuclear Power Generating Stations.