Attachment 4

EGG-EA-6051

September 1982

TECHNICAL EVALUATION REPORT

BIG ROCK POINT PLANT

SEISMIC DESIGN

V. B. Call T. R. Thompson

Prepared for the
U.S. NUCLEAR REGULATORY COMMISSION
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Prepared for the
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Washington, D.C.
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INTERIM REPORT

TECHNICAL EVALUATION REPORT
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ABSTRACT

A Systematic Evaluation Program (SEP) was initiated by the Nuclear Regulatory Commission (NRC) to bring eleven older operating nuclear power plants to a level of safety consistent with current standards of acceptability. Consultants to the Consumers Power Company presented two documents concerning the Big Rock Point Plant's safety related piping, mechanical and electrical equipment, and component supports. NRC personnel and their consultants from EG&G Idaho, Inc. formed a review team that performed a preliminary review of these documents. The documents presented to the review team by the licensee's consultants were generally acceptable for the areas of SEP which they addressed, although several suggestions, comments, and questions must be resolved. The major deficiency with the material submitted by the licensee is that it does not address all the areas of concern for the SEP program.

SUMMARY

A Systematic Evaluation Program (SEP) was initiated by the Nuclear Regulatory Commission (NRC) with the goal of bringing eleven older nuclear power plants to a level of safety consistent with current standards of acceptability. The Big Rock Point Nuclear Generating Station is one of these plants. The NRC and their consultants from EG&G Idaho, Inc. formed a review team and made a preliminary review of two documents submitted by the Consumers Power Company and their consultants. These documents are concerned with analyses performed or to be performed on the safety related equipment required to function during a Safe Shutdown Earthquake (SSE).

This report is divided into individual sections covering the balance-of-plant piping, the primary coolant loop piping, electrical equipment, the balance-of-plant mechanical equipment, the primary coolant loop mechanical equipment, and component supports. These sections contain procedures utilized by the Consumer Power Company's consultants for the analyses performed, and proposed criteria and methods to be utilized in further analyses. Each section also contains the review team's evaluation of the information presented.

The analyses and procedures contained in the two documents presented by the Consumer Power Company's consultants to the review team were generally acceptable. However, several open items still remain and must be addressed for the review of these two documents to be complete.

The total acceptability of the licensee's SEP plan cannot be adequately assessed at this time because the documents submitted to date do not address all the required areas of concern necessary for the SEP program.

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TECHNICAL EVALUATION REPORT
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INTRODUCTION

In October of 1977, the Office of the Nuclear Reactor Regulation (NRR), an office of the Nuclear Regulatory Commission (NRC), initiated a Systematic Evaluation Program (SEP) by selecting eleven older operating nuclear power plants with the goal of bringing these plants to a level of safety consistent with current standards of acceptability. These plants were divided into two groups based on their original seismic design. The Big Rock Point Plant, operated by Consumers Power Company of Michigan, is included with the Group II plants. A reanalysis was performed to demonstrate that the structural integrity of the safety related piping systems and their supports, mechanical equipment, and electrical equipment would not be impaired when subjected to a Safe Shutdown Earthquake (SSE) combined with other normal design loadings.

The Big Rock Point Nuclear Generating Station is a boiling water reactor of 70 MWe capacity. The plant went into commercial power production in December 1962. The containment structure was designed to the Uniform Building Code and the ASME Boiler and Pressure Vessel Code. The reactor vessel was analyzed to the ASME Code. Both the piping and piping supports were designed to the ASA B31.1 code for pressure piping.

A decision was made by the NRC to review the reevaluation analyses performed by the licensee and their consultants rather than performing their own analyses on the plant. A review team consisting of NRC staff personnel and NRC consultants from EG&G Idaho, Inc. was formed to evaluate the piping, mechanical, and electrical equipment analyses. The licensee and their consultants were required to present their seismic reevaluation criteria, typical analyses, and results to the review team.

The review team developed an acceptance criteria for guidance in evaluating the analyses. The licensee is required to justify major deviations which appear less conservative than those in the review team acceptance criteria.

The scope of review for the seismic reevaluation program included the systems, structures, and components (including emergency power supply and distribution, instrumentation, and actuation systems) with the following functions:

1. The reactor coolant pressure boundary as well as the core and vessel internals. This also includes those portions of the main steam system up to but not including the turbine stop valve and connected piping of 2-1/2 inch or larger nominal pipe size, up to and including the first valve that is either normally closed or is capable of automatic closure during all modes of normal reactor operation.

2. Systems or portions of systems that are required for safe shutdown as identified in the SEP safe shutdown review (SEP Topic VII-3). The system boundary includes those portions of the system required to perform the safety function and connected piping up to and including the first valve that is either normally closed or capable of automatic closure when the safety function is required.

3. Systems or portions of systems that are required to mitigate design basis events, i.e., accidents and transients (SEP Topics XV-1 to XV-24). The functions to be provided include emergency core cooling, post-accident containment heat removal, post-accident containment atmosphere cleanup, as well as support systems, such as cooling water, needed for proper functioning of these systems.

4. Systems and structures required for fuel storage (SEP Topic IX-1). Integrity of the spent fuel pool structure

including the racks is needed. Failure of the liner plate due to the safe shutdown earthquake must not result in significant radiological releases, or in loss of ability to keep the fuel covered. Failure of cooling water systems or other systems connected to the pool should not permit draining of the fuel pool. Means to supply make-up to the pool as needed must be provided.

5. Structures that house the above equipment.

For the Big Rock Point Plant, the review team required the following systems, and associated structures, and components to be addressed:

(a) Reactor Coolant System (RCS)
(b) Portions of Main Steam System
(c) Portions of Main Feedwater System
(d) Portions of systems directly connected to the RCS up to and including isolation valves
(e) Control Rod Drives
(f) Emergency Condenser
(g) Core Spray System
(h) Backup Core Spray System
(i) Enclosure Spray System
(j) Backup Enclosure Spray System
(k) Reactor Depressurization System
(l) Fire Water System
(m) Post-Incident Cooling System
(n) Spent Fuel Pool and Makeup

As discussed previously, a "system" also includes the power supply, instrumentation and actuation systems.

Only two documents were submitted to the review team by the licensee and their consultants. One consisted of the reevaluation of the primary coolant loop. The other document was a preliminary copy of the seismic reevaluation criteria for the balance-of-plant piping, equipment, and component supports. A preliminary evaluation of these two documents was performed by the review team.

This report is divided into individual sections covering balance-of-plant and primary coolant piping, electrical equipment, balance-of-plant and primary coolant mechanical equipment, and component supports. Each section explains in detail the analysis procedures and criteria presented in the documents submitted by the licensee's consultants. Each section also contains the review team's preliminary evaluation of these procedures and criteria. The review team's conclusions were based solely upon the two documents submitted by the licensee's consultants.

NSSS PIPING SYSTEM

Licensee Evaluations

The seismic reevaluation analysis of the primary coolant loop (PCL) was performed by the licensee's NSSS consultant. The results of the analysis are presented in Reference 1. The results of the analysis indicated that allowable stresses are exceeded in the area of the four-inch crossties, and large displacements are also present in this area. The scope of the analysis did not include piping support modification recommendations.

This analysis was performed using three-dimensional static and dynamic models, depending on the loading under consideration. These models included both the PCL system and the reactor building. The computer code ANSYS and several in-house codes were used to perform these static and dynamic analyses. The dynamic seismic analysis was performed using a reduced time-history method. Three statistically independent artificial time-histories were applied at the base of the model in the two horizontal directions and the vertical direction, respectively. Rayleigh damping coefficients were used to generate the damping matrix for the piping system. The constants α and β were evaluated for a frequency range of 0.78 to 18.9 HZ, and a damping value of 3% was utilized in the computation of these constants. The time-history responses were determined at 0.02 second intervals in a time period between five and ten seconds, and were combined according to the SRSS method.

The three-dimensional model of the PCL system was based upon original drawings of the system that had been periodically updated by the licensee to reflect modifications since plant start-up. The piping was modeled as pipe elements with nodes at all support locations and at the ends of each elbow. Other nodes were introduced in long, unsupported lengths of pipe. Pipe sizes ranged from 4 to 17-inch nominal outside diameter. The weight of the piping system utilized in the analysis included the weight of insulation, steel, steam, and water.

In addition to the PCL piping, the following equipment was included in the PCL system model: PCL valves, recirculating pumps, steam drum, and the reactor vessel. Larger valves were represented by rigid links with one-half of the mass lumped at each end of the link. Small valves were represented by a lumped mass at specific valve locations. The pumps were represented by a pair of rigid links with the mass lumped at the center node. Nonlinear support conditions occurred at the steam drum and reactor vessel. A discussion of these support systems is contained in the Component Supports section of this report.

A third nonlinear support condition occurred at the location of the downcomers in the PCL. This condition was treated by combining the PCL model with a substructure model representing only the upper frame of the two downcomer support frames. The substructure was connected to the PCL model using spring elements to represent the four downcomer support rods. These spring elements were considered active during static and seismic analyses.

For the dynamic analysis of the PCL, constant support hangers (CSH) were modeled as directional point forces of prescribed values (hot loads) at the CSH attachment points. They were also represented as forces equal to their hot loads for the combined static and thermal analyses. Any displacement limitations of the hangers were not considered in the analysis.

Variable support hangers (VSH) were considered as springs acting during both static and dynamic events. Two VSH were neglected in the analytical model of the PCL. The largest displacement for any VSH was sited as 0.40 inches.

Sway braces were modeled as spring elements. Although the line of action of the sway brace is not concentric with the piping centerline, the eccentric effects were considered negligible. For the static and thermal analyses the sway brace stiffnesses were equal to zero, and for the seismic analysis they represented 1000 lbs/in. The largest displacement experienced by any sway brace was 3.4 in.

A stress analysis was performed for the piping system under static, seismic, and internal pressure conditions. The criteria used to evaluate the Class 1 PCL piping was based on the rules of the ASME Code, Section III, Subsection NC, 1977 Edition. The allowable stress utilized for the combination of internal pressure, dead load, and seismic loading was 2.4 S_h.

Stress intensification factors for nonstandard fittings were calculated using the recommendations of the ASME Code. The section modulus of each pipe segment and branch connection was also calculated in accordance with the ASME Code.

Review Team Evaluations

In general, the methods applied by the NSSS consultant in their piping reanalysis are acceptable. The development of the analytical model provided an appropriate representation of the PCL and reactor building. Per licensee conversations with the NRC staff, it is understood that the masses representing the recirculation pumps were omitted from this analysis and the steam drum supports were incorrectly oriented. This will be corrected in later analyses. The stress analysis techniques used were basically appropriate. However, there are several areas of concern which should be examined.

The acceptance criteria for piping provided by the NRC review team is contained in Appendix A. If Class 2 analytical procedures are used, stresses in piping considered as Class 1 should not exceed 1.8 S_h. Other stipulations are also stated in the NRC's Acceptance Criteria for Piping. For the PCL analysis, the NSSS consultant utilized 2.4 S_h for the faulted condition stress allowable. As stated above, the allowable stated in the Acceptance Criteria for Piping is 1.8 S_h. Examination of the stress results, based upon this criteria, may yield further areas of stress problems.

Several computer codes were utilized for the piping stress analysis. Some of these included NSSS consultant in-house programs. Verification of the analytical techniques contained in these codes should be provided to the review team.

Although the piping model was basically acceptable, there are several modeling techniques that should be examined: 1) nodal spacing criteria should be defined in order to assure the review team of proper element length ratios and system response. 2) The centers of gravity (C.G.) should be accounted for on valves and pumps. The masses of these components should be lumped at the appropriate locations. 3) Verification of standard type components should be provided. If nonstandard type components were present, an explanation of the modeling techniques utilized should be provided. 4) Further explanation and justification is needed for modeling only the upper frame of the downcomer support system. There is concern that the upper frame was chosen only on the basis of modal frequency. 5) Information showing rod and variable support hanger (VSH) stiffnesses should be provided. Also, justification for modeling each constant support hanger (CSH) as a directional point force during a dynamic event should be provided to the review team.

The NSSS consultant should also verify whether or not their analysis was based upon current as-built drawings.

The requirements of Regulatory Guide 1.61 require that a damping value of 2% be used for small piping. Justification for use of the higher damping value of 3% of critical damping is required based on overall consideration of stress level as discussed in R.G. 1.61 and NUREG/CR-0098. The frequency range of 0.78 to 18.9 Hz for the evaluation of α and β also requires justification. Explanation should be provided for determining the time-history responses in a time period between five and ten seconds.

Finally, the NSSS consultant should verify that the displacements imposed upon the CSH, VSH, and sway braces are not causing these supports to top or bottom out.

BALANCE-OF-PLANT PIPING SYSTEMS

Licensee Evaluations

The licensee's consultant for the balance-of-plant (BOP) piping system reevaluation submitted their criteria for seismic analyses to the review team. This criteria document is contained in Appendix B. No piping system analyses have been submitted for review.

Review Team Evaluations

A review has been performed on the submitted criteria for the BOP piping reevaluations. The consultant's criteria was compared to the Acceptance Criteria for Piping provided by the NRC review team. The criteria and methods of proposed analysis generally appear acceptable. However, there are several points of concern that need clarification and/or modification.

The BOP consultant's criteria specifies several loading conditions to which the piping will be evaluated. It has been assumed that the phrase "loading due to restraint of design temperature free end displacements" includes both thermal expansion and thermal anchor movements. In Section 3.0 and Table 1, seismic anchor movements have not been taken into consideration as specified in the NRC criteria. These seismic anchor movements should be addressed by the licensee's consultant. Also, clarification and/or definition of the term "deadweight" should be provided to the review team.

As stated under Section 4.0, "Stress Evaluation Criteria," the BOP consultant intends to utilize the rules of the ASME Code for their piping analyses. It should be recognized that the ASME Code does not match the current NRC Acceptance Criteria for Piping. When using the ASME Code, the Code does not refer to OBE and SSE. The general philosophy behind the development of the ASME Service Levels is contained in Code Section NCA. Considering this philosophy and the fact that only an SSE evaluation is being performed (different from normal practice of designing for OBE and

SSE), modifications must be made to meet acceptable criteria. Level D service Limits alone in an SSE only evaluation are not in themselves appropriate. Otherwise, justification for any deviation from the acceptance criteria should be presented to the review team.

For small bore piping, the BOP consultant intends to utilize chart methods of analysis. These chart methods should be defined, with a discussion of their assumptions and limitations, and presented to the review team for evaluation.

The BOP consultant's criteria states that piping supports will not be analyzed if the original design load is not exceeded by more than 10%. Concern exists as to how the original criteria compares to the NRC current criteria. Clarification of the original criteria and justification of its use for current analyses should be presented for review.

In their acceptance criteria, the licensee distinguishes between "design mechanical loads" and "operating mechanical loads." Explain the difference and justify why the distinction is considered acceptable.

In Table 1 of the BOP consultant's criteria, the allowable stress range, S_a, is defined as $f(1.25\ S_c + 0.25\ S_h)$ where $f = 1.0$. Clarification should be made as to whether or not "f" will be adjusted according to the number of thermal cycles the system under investigation may experience.

Appendix A of the BOP consultant's criteria provides their analysis guidelines. Several points of concern are discussed below and are designated in the same manner as the BOP consultant's criteria:

A-1. Further information should be provided concerning the versions and verification of the computer codes utilized.

A-2-b. Regulatory Guide 1.61 states that 2% damping must be utilized for small pipe. Justification for using 3% damping for all pipe sizes should be provided based on overall consideration of stress level as discussed in R.G. 1.61 and NUREG/CR-0098.

A-2-e. Explanation as to whether or not closely spaced modes have been taken into consideration should be provided.

A-3-a. Further detail should be provided with regard to analyses models and the information from which they are generated. Definition should be provided for "analysis models . . . will be conventional in nature." Detailed information concerning modeling techniques should also be provided for masspoint spacing, valves and other equipment, and linear and non-linear piping supports.

A-3-b. Detail should be given concerning the clearances and grouting of wall and floor penetrations utilized as six-way restraints.

A-3-c. Further explanation of the philosophy of model overlapping should be provided. Justification should be given for where models are terminated.

A-3-e. Justification should be provided for considering variable support hangers as double acting and including them as dynamic supports. Also, explanation should be given as to whether or not the displacement limitations of variable support hangers will be taken into consideration.

A-3-g. Further explanation should be given for the modeling techniques utilized for rod hangers.

A-3-i. Further explanation should also be provided for sliding supports. The term "sliding support" needs definition, and justification for utilizing a friction factor of 0.3 should be provided.

ELECTRICAL EQUIPMENT

The BOP consultant's acceptance criteria for SEP (Appendix B) has not addressed the area of electrical equipment. Nothing has been submitted to address the licensee's plan for analysis, load combinations to be used, or acceptance criteria for electrical equipment so this is a major open item for the Big Rock Point Nuclear Power Plant.

MECHANICAL EQUIPMENT

The BOP consultant's acceptance criteria for SEP (Appendix B) addresses load combinations and allowable stress limits to be used for vessels, pumps, and valves. Several items do need clarifying:

(1) Anchor movement effects must be included. How does the licensee plan to address this consideration to agree with the NRC acceptance criteria?

(2) Although some normal operating conditions may be considered to have been satisfied by the original designer of the component, design allowables must be reconsidered if faulted conditions require modifications to the original design.

(3) Specify the bolting criteria to be used including allowance for tension/shear interaction.

(4) Provide the basis for the 3 g horizontal and 2 g vertical acceleration limits for value operations.

(5) Footnotes (c) and (d) of the tables in Revision 1 of the NRC mechanical equipment guidelines stating criteria for pumps and valves are not addressed

COMPONENT SUPPORTS

The BOP consultant's acceptance criteria for SEP (Appendix B) addresses load combinations and allowable stress limits to be used for piping and mechanical supports. In general, good agreement exists between their acceptance criteria and the NRC criteria. However, the following items need clarifying:

(1) Seismic anchor movements must be included for faulted conditions. How does the licensee plan to address this consideration to agree with the NRC criteria?

(2) Explain and justify the limit to be used for linear type supports for faulted conditions.

(3) Specify the bolting criteria to be used. Using footnote (9), how are possible shear and axial interaction effects to be included? Will an interaction formula be used? If so, explain and justify how it will be done.

(4) If reanalysis does not change the original design loads for component supports by more than 10%, using the original design criteria as discussed in Section 4.4 of Appendix B must be shown to be more conservative than the current NRC acceptance criteria.

(5) Verify that the application of footnote (8) includes an evaluation of the embedment into the concrete to develop the full ultimate strength of the embedded steel. State and justify the criteria to be used.

A brief discussion of modeling techniques used to represent supports for the reactor pressure vessel and steam drum are presented in Reference 1. Calculations are not presented which would allow for actual audit type review but the methods seem in general to be based on reasonable judgment.

CONCLUSIONS

BOP Piping System Analyses

The BOP consultant submitted a copy of their analysis criteria to the NRC review team for evaluation. The review team evaluated this information and concluded that several open items must be addressed and clarified or modified as detailed within the Review Team Evaluations section for BOP piping of this report. These open items deal with the following subjects:

1. Loading conditions
2. Seismic and thermal anchor movements
3. Chart methods for small bore piping
4. Original piping support design criteria
5. High thermal cycle systems
6. Computer code verification
7. Damping values
8. Closely spaced modes
9. Model generation
10. Wall and floor penetrations
11. Model overlapping
12. Variable support hangers
13. Rod hangers
14. Sliding supports
15. ASME Code utilization

BOP Electrical and Mechanical Equipment Analyses

Since nothing has been submitted by the licensee to address their plan for analysis, load combinations to be used, or acceptance criteria for electrical equipment this is a major open item for the Big Rock Point Nuclear Power Plant.

No analyses were presented by the licensee for mechanical equipment. The items which need clarification are detailed in the Mechanical Equipment section of this report.

NSSS Piping and Mechanical Equipment Analyses

Seismic reevaluation analyses were performed for the Big Rock Point Plant PCL. Results of the analyses demonstrated that allowable stresses are exceeded, and large displacements occur in the area of the four-inch crossties. Support modification was not included in the scope of the analyses.

After reviewing these analyses, it is concluded that the NSSS piping analyses were generally performed in an acceptable manner. However, there are several areas of concern which must be clarified or modified as detailed within the Review Team Evaluations section for NSSS piping of this report. These areas of concern deal with the following subjects:

1. Faulted condition stress allowables
2. Computer codes utilized
3. Node spacing
4. C.G.'s of valves and pumps
5. Standard and nonstandard type components
6. Downcomer support system
7. Support stiffnesses
8. As-built drawings
9. Damping values
10. Support displacements

Component Support Analyses

Detailed analyses for component supports were not submitted by the licensee. The general analysis procedures seem to be based on reasonable judgment; however, no analyses were available for an audit type review. Items which need clarifying are detailed in the Component Supports section of this report.

REFERENCES

1. D'Appolonia, Seismic Safety Margin Evaluation Big Rock Point Nuclear Power Plant Facilities, Vol. I and IIA, August 1981; Rev. 1.

APPENDIX A

REEVALUATION GUIDELINE FOR SEP GROUP II PLANTS
(EXCLUDING STRUCTURES)

REEVALUATION GUIDELINE
FOR
SEP GROUP II PLANTS
(EXCLUDING STRUCTURES)

INTRODUCTION

In support of NRC's Systematic Evaluation Program (SEP) for Group II Plants, the following Reevaluation Criteria have been established. These criteria include recommended load combinations with allowable stresses and/or loads for piping systems, component supports, concrete attachments, and equipment. These criteria are based on linear elastic analyses having been performed. The acceptance criteria are generally based on the ASME Code. For situations not covered by these criteria, (i.e. items 1
constructed of cast iron) compatible criteria shall be developed by the licensee and will be reviewed on a case-by-case basis. The licensee is requested to justify major deviations in criteria which appear less conservative than those specified herein.

DEFINITIONS

Code = ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," 1980 Edition, Winter 1980 Addenda.

σ_m = General membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

σ_b = Bending stress. This stress is equal to the linear varying 1
portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

P_D = Design or maximum operating pressure loads and design mechanical loads.

SSE = Inertial loads due to Safe Shutdown Earthquake (SSE) and design mechanical loads where applicable.

T = Loads due to thermal expansion of attached pipe (constraint of free end displacement).

W = Loads due to weight effects.

AM = Loads due to SSE anchor movement effects.

S_{bk} = Critical buckling stress.

S_m = Allowable stress intensity at temperature listed in ASME Code.

S_y = Yield strength at temperature listed in ASME Code.

S_u = Ultimate tensile strength at temperature listed in ASME Code.

σ_ℓ = Local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities. 1

S = ASME Code Class 2 allowable stress value. The allowable stress shall correspond to the metal temperature at the section under consideration.

P_m = General Primary Membrane Stress Intensity. This stress intensity is derived from the average value across the thickness of a section of the general primary stresses produced by design internal pressure and other specified Design Mechanical Loads, but excluding all secondary and peak stresses. Averaging is to be applied to the stress components prior to determination of the stress intensity values. 1

P_ℓ = Local Membrane Stress Intensity. This stress intensity is the same as P_m except that it includes the effects of discontinuities.

P_b = Primary Bending Stress Intensity. This stress intensity is derived from the linear varying portion of stresses across the solid section under consideration produced design pressure and other specified design mechanical loads. Secondary and peak stresses are not included. 1

SPECIAL LIMITATIONS

1. Critical buckling loads (stresses) must be determined taking into account combined loading (i.e., axial, bending, and shear), initial imperfections, residual stresses, inelastic deformation, and boundary conditions. Both gross and local buckling must be evaluated. Critical buckling loads (stresses) shall be determined using accepted methods such as those contained in NASA Plates and Shells Manual or ASME Code Case N-284. 1

2. Where stresses exceed material yield strength, it shall be demonstrated that brittle failures and detrimental cyclic effects are precluded, and that dynamic analysis assumptions are not nonconservatively affected. Where significant cyclic effects are identified, it shall be demonstrated that the structure or component is capable of withstanding ten full peak deformation cycles.

3. Where results of analysis indicate that the allowable stresses of the original construction code are exceeded in any of the load combinations specified herein, it shall be demonstrated that the in-situ item was designed and fabricated using rules compatible with those required for the appropriate ASME Code Class (Subsection NX2000,

4000, 5000, and 6000). In cases where compatibility with the appropriate ASME Code Subsections was not substantially achieved, appropriate reductions in these limits shall be established, justified, and applied.

ACCEPTANCE CRITERIA FOR PIPING

Using Code[a] Class 2 analytical procedures [Equation (9), NC-3653.1], the following stresses are not to be exceeded for the specified piping: 1

Class 1: $P_m + P_b = |W + P_D| + |SSE| \leq 1.8\ S$ 1

Class 2: $P_m + P_b = |W + P_D| + |SSE| \leq 2.4\ S$

The effects of thermal expansion must meet the requirements of Equation (10) or (11) of NC-3653, including moment effects of anchor displacements due to SSE if anchored displacement effects are omitted from Equation (9) of NC-3653. Class 1 analytical procedures (NB-3600) can also be utilized if appropriate allowable stresses specified in NB-3650 are used. 1

Branch lines shall be analyzed including the inertial and displacement input due to the response of the piping to which it is attached at the attachment point.

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a. The references to ASME Code equation and paragraph numbers on this page correspond to the 1980 edition of the code, 1981 winter addenda. This was done in order to avoid confusion introduced by the initial 1980 edition of the code which renumbered the equations differently from past and present editions of the code. Equation numbers presented on this page reflect common nomenclature utilized in the nuclear industry. 1

ACCEPTANCE CRITERIA FOR CLASS 1 COMPONENT SUPPORTS 1

	Acceptance Criteria[a]	
Imposed Load Combinations	Linear	Plate and Shell[b]
The higher of: $\lvert W + P_D \rvert$ or $\lvert W + P_D + T \rvert$	Code Subsection NF Design, Level A, and Level B Limits	$P_m \leq 1.0\ S_m$ $P_\ell + P_b \leq 1.5\ S_m$ 1
The higher of: $\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert AM \rvert$ or $\lvert W + P_D + T \rvert + \lvert SSE \rvert + \lvert AM \rvert$	---------- Code Subsection NF Level D Limits	$P_m \leq 1.5$ Sm or 1.2 Sy[c] not to exceed 0.7 Su $P_\ell + P_b$ 2.25 Sm or 1.85 Sy [c] not to exceed 1.05 Su 1

In addition to the above criteria, the allowable buckling stress shall be limited to 2/3 S_{bk}, where S_{bk} is determined in accordance with Special Limitation 1.

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a. These load combinations shall be used in lieu of those specified in ASME Code Subsection NF. In addition, for brittle types of material not specified in the Code, appropriate stress intensification factors for notches and stress discontinuities shall be applied in the analysis.

b. The 1.5 Sm value from NB 3221 on which these are based (Code Appendix F 1323.1) shall be limited by Code Section NB 3221.3. 1

c. Use larger of.

ACCEPTANCE CRITERIA FOR CLASS 2 COMPONENT SUPPORTS

Imposed Load Combinations	Acceptance Criteria[a] Linear	Acceptance Criteria[a] Plate and Shell
The higher of: $\lvert W + P_D \rvert$ or $\lvert W + P_D + T \rvert$	Code Subsection NF Design, Level A, and Level B Limits	$\sigma_\ell \leq 1.0\ S$ $\sigma_\ell + \sigma_b \leq 1.5\ S$
The higher of: $\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert AM \rvert$ or $\lvert W + P_D + T \rvert + \lvert SSE \rvert + \lvert AM \rvert$	Code Subsection NF Level D Limits	$\sigma_\ell \leq 1.5\ S$ or $0.4\ S_u$ [b] $\sigma_\ell + \sigma_b \leq 2.25\ S$ or $0.6\ S_u$ [b]

In addition to the above criteria, the allowable buckling stress shall be limited to 2/3 S_{bk}, where S_{bk} is determined in accordance with Special Limitation 1. 1

a. These load combinations shall be used in lieu of those specified in ASME Code Subsection NF. In addition, for brittle types of material not specified in the Code, appropriate stress intensification factors for notches and stress discontinuities shall be applied in the analysis.

b. Use lesser of.

ACCEPTANCE CRITERIA FOR CONCRETE ATTACHMENTS

I. Concrete Expansion Anchor Bolts[a]

Load Combinations: Same as for component supports.

Acceptance Criteria:[b]

Wedge type: 1/4 ultimate as specified by manufacturer.

Shell type: 1/5 ultimate as specified by manufacturer.

II. Grouted Bolts: Replace[a],[b],[c]

III. Concrete Embedded Anchors[a]

Load Combinations: Same as for component supports.

Acceptance Criteria[b]: 0.7 S_u

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a. Base plate flexibility effects must be considered.

b. Both pullout and shear loads must be considered in combined loading situations.

c. Unless stresses in the bolts and structure to which they are attached are shown to be sufficiently low to preclude concrete/grout/steel interface bond failures. Load combinations are the same as those for component supports.

ACCEPTANCE CRITERIA FOR CLASS 1 MECHANICAL EQUIPMENT

Component	Loading Combination[b]	Criteria[d] [g]
Pressure vessels and heat-exchangers	$\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert$ Nozzle Loads $\rvert$	$P_m \leq 2.4\ S_m$ or $0.7\ S_u$ (e) $(P_m$ or $P_\ell) + P_b \leq 3.6\ S_m$ or $1.05\ S_u$ (e)
Active pumps and other mechanical components[a],[c],[d]	$\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert$ Nozzle Loads $\rvert$	$P_m \leq 1.2\ S_m$ or S_y (f) $(P_m$ or $P_\ell) + P_b \leq 1.8\ S_m$ or $1.5\ S_y$ (f)
Inactive pumps and other mechanical components[c]	$\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert$ Nozzle Loads $\rvert$	$P_m \leq 2.4\ S_m$ or $0.7\ S_u$ (e) $(P_m$ or $P_\ell) + P_b \leq 3.6\ S_m$ or $1.05\ S_u$ (e)
Active valves[a],[c],[d]	$\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert$ Nozzle Loads $\rvert$	$P_m \leq 1.2\ S_m$ or S_y (f) $(P_m$ or $P_\ell) + P_b \leq 1.8\ S_m$ or $1.5\ S_y$ (f)
Inactive valves[c]	$\lvert W + P_D \rvert + \lvert SSE \rvert + \lvert$ Nozzle Loads $\rvert$	$P_m \leq 2.4\ S_m$ or $0.7\ S_u$ (e) $(P_m$ or $P_\ell) + P_b \leq 3.6\ S_m$ or $1.05\ S_u$ (e)
Bolt stress shall be limited to:		Tension = Sy or $0.7\ S_u$ (e) Shear = 0.6 Sy or $0.42\ S_u$ (e)

1

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a. Active pumps, valves, and other mechanical components (e.g., CRDs) are defined as those that must perform a mechanical motion to accomplish a system safety function.

b. Nozzle loads shall include all piping loads (including seismic and thermal anchor movement effects) transmitted to the component during the SSE.

c. Scope and evaluation of pumps and valves are to be in accordance with NB 3411, NB 3412, and NB 3546 of the Code, including seismic and thermal anchor movement effects.

d. For active mechanical equipment contained in safe shut down systems, it shall be demonstrated that deformation induced by the loading on these pumps, valves and other mechanical components (e.g., CRDs) do not introduce detrimental effects which would preclude function of this equipment following a postulated SSE event. For valve operators integrally attached to valve bodies, binding can be considered precluded if stresses in the valve body and operator housing and supports are shown to be less than yield. In these evaluations, all loads (including seismic and thermal anchor movement effects) shall be included. 1

e. Use lesser of two values.

f. Use greater of two values.

g. The 1.5 Sm value from NB 3221 on which these are based (Code Appendix F 1323.1) shall be limited by Code Section NB 3221.3.

ACCEPTANCE CRITERIA FOR CLASS 2 MECHANICAL EQUIPMENT

Component	Loading Combination[b]	Criteria[d]
Pressure vessels and heat-exchangers	$\lvert W + P_D\rvert + \lvert SSE\rvert + \lvert \text{Nozzle Loads}\rvert$	$\sigma_m \leq 2.0\ S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 2.4\ S$
Active pumps and other mechanical components[a],[c],[d]	$\lvert W + P_D\rvert + \lvert SSE\rvert + \lvert \text{Nozzle Loads}\rvert$	$\sigma_m \leq 1.5\ S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 1.8\ S$
Inactive pumps and other mechanical components[c]	$\lvert W + P_D\rvert + \lvert SSE\rvert + \lvert \text{Nozzle Loads}\rvert$	$\sigma_m \leq 2.0\ S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 2.4\ S$
Active valves[a],[c],[d]	$\lvert W + P_D\rvert + \lvert SSE\rvert + \lvert \text{Nozzle Loads}\rvert$	$\sigma_m \leq 1.5\ S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 1.8\ S$
Inactive valves[c]	$\lvert W + P_D\rvert + \lvert SSE\rvert + \lvert \text{Nozzle Loads}\rvert$	$\sigma_m \leq 2.0\ S$ $(\sigma_m \text{ or } \sigma_\ell) + P_b \leq 2.4\ S$
Bolt stresses shall be limited to:		Tension = Sy or 0.7 $S_u^{(e)}$ Shear = 0.5 Sy or 0.42 $S_u^{(e)}$

---

a. Active pumps, valves, and other mechanical components (e.g., CRDs) are defined as those that must perform a mechanical motion to accomplish a system safety function.

b. Nozzle loads shall include all piping loads (including seismic and thermal anchor movement effects) transmitted to the component during the SSE.

c. Scope and evaluation of pumps and valves are to be in accordance with NC 3411, NC 3412, and NC 3521 of the Code, including seismic and thermal anchor movement effects.

d. For active mechanical equipment contained in safe shut down systems, it shall be demonstrated that deformation induced by the loading on these pumps, valves and other mechanical components (e.g., CRDs) do not introduce detrimental effects which would preclude function of this equipment following a postulated SSE event. For valve operators integrally attached to valve bodies, binding can be considered precluded if stresses in the valve body and operator housing and supports are shown to be less than yield. In these evaluations, all loads (including seismic and thermal anchor movement effects) shall be included. 1

e. Use lesser of two values.

ACCEPTANCE CRITERIA FOR TANKS

Load Combinations: $|W + P_D| + |SSE|$ + |Dynamic Fluid Pressure Loads|[a]

Acceptance Criteria: Smaller of S_y or 0.7 S_u. In addition, the allowable buckling stress shall be limited to 2/3 S_{bk}, where S_{bk} is determined in accordance with Special Limitation 1.

a. Dynamic fluid pressure shall be considered in accordance with accepted and appropriate procedures; e.g., USAEC TID-7024. Horizontal and vertical loads shall be determined by appropriately combining the loads due to vertical and horizontal earthquake excitation considering that the loads are due to pressure pulses within the fluid. These loads shall also be applied, in combination with other loads, in tank support evaluations.

APPENDIX B

BALANCE-OF-PLANT CRITERIA FOR SEISMIC ANALYSIS

Controlled
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PRELIMINARY

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August 1982
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CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

SEISMIC REQUALIFICATION OF ESSENTIAL PIPING SYSTEMS

CONSUMERS POWER COMPANY
BIG ROCK POINT

APPLIED ENGINEERING ASSOCIATES, INC.
15425 Los Gatos Blvd.
Los Gatos, CA 95030

CPC02-82-002
REVISION A

CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

SEISMIC REQUALIFICATION OF ESSENTIAL PIPING SYSTEMS

CONSUMERS POWER COMPANY BIG ROCK POINT

SPECIFICATION RELEASE RECORD

Rev. No. / Date	Prepared	Checked	Approved & Released	Pages Revised
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CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

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CRITERIA FOR SEISMIC ANALYSIS OF SAFETY-RELATED MECHANICAL EQUIPMENT (SEP TOPIC III-6)

1.0 PURPOSE

The purpose of this document is to provide acceptance criteria to be employed for the Big Rock Point seismic requalification program (SEP Topic III-6). The criteria posed herein will be applied to safety-related piping and supports and the supports and pressure boundaries associated with specific mechanical equipment. Appendix A presents supplemental information concerning analysis and modeling techniques and standard procedures.

2.0 SCOPE

The scope of the equipment to which the proposed criteria apply includes safety-related piping (except primary coolant loop), pipe supports, selective tanks, heat exchangers, pumps and valves. The primary coolant loop is being evaluated as part of the building structural analysis. The tanks, heat exchangers, pumps and valves will be evaluated for pressure boundary and support integrity where appropriate. A list of systems to be evaluated is included in Reference (1). Certain items listed in Reference (1) will not be subject to the criteria proposed herein. These items are: Mechanical and electrical equipment supports considered under the scope of IE Information Notice 80-21 which will be addressed when the results of that work are reported; the fuel pool structure and spent fuel racks which will be evaluated separately under an ongoing program; the masonry walls which will be evaluated by an inelastic analysis associated with the reserve energy method, the results of which will be reported when complete; non ductile materials (e.g. cast iron) which will be handled on a case by case basis.

3.0 LOADING CONDITIONS

3.1 Piping and Equipment

All safety-related piping and pressure retaining mechanical equipment will be evaluated for the following loading conditions:

1. Deadweight combined with design pressure and other design mechanical loads.
2. Design temperature thermal expansion (piping systems) with thermal anchor movements due to design temperature.

3. Deadweight combined with operating pressure, operating mechanical loads, if any, and safe shutdown earthquake intertia (SSE) loads.

3.2 Piping and Component Supports

All safety-related piping and mechanical equipment supports will be evaluated for the following loading conditions:

1. Deadweight combined with loading due to restraint of design temperature free end displacements and design mechanical loads.

2. Deadweight combined with loading due to restraint of operating temperature free end displacement, operating mechanical loads and safe shut-down earthquake inertia (SSE) loads.

4.0 STRESS EVALUATION CRITERIA

4.1 Piping

Piping analysis that will be conducted for the Big Rock Point Plant Seismic Requalification will be based on the rules of the ASME Boiler and Pressure Vessel Code (ASME), Section III, Subsection NC, 1980 Edition, including Winter 1980 Addenda. Load combinations and the stress limits associated with piping are shown in Table 1. All safety related high temperature and some low temperature systems will be evaluated using the analysis guidelines in Appendix A. Design pressures and temperatures for piping will be taken from the Big Rock Point Plant Piping Materials Specification.

4.2 Small Bore Piping

Small bore piping is that piping which has a 2-1/2" nominal pipe size (NPS) or smaller. Chart methods will be prepared and are expected to be used for most small bore piping. Small bore piping will be dynamically analyzed if chart methods are impractical or if it is included as part of a large bore pipe model. Any chart methods to be used will ensure that the piping criteria of Table 1 are met. Charts may be employed for large bore, low temperature piping where applicable.

4.3 Equipment

Vessels, pumps and valves will be evaluated for pressure boundary integrity using stress acceptance criteria consistent with original design criteria, supplemented with criteria for faulted condition load combinations. Pressure boundaries of vessels and extended operator structures of active valves will be evaluated in accordance with the criteria of the 1980 Code, Section III, for Class 2 Components. No special consideration will be given to valve and pump bodies as the connecting pipe moment will be limited in accordance with standard valve and pump design practice. Table 2 summarizes loading combinations and stress limits for equipment.

Special consideration will be given to extended structures of active valves. The stress in active valve operator supports will be limited to the yield strength of the material.

In addition, the acceleration of active valve operators will be limited to 3 g's horizontal and 2 g's vertical.

The additional piping reaction loads on vessels due to SSE will be assumed to be acceptable if they are limited to 0.8 Sh (Normal loads + SSE $\leq$ 1.8 Sh).

4.4 Piping and Component Supports

Existing piping and component supports will be evaluated for loads produced by piping and equipment response to static and dynamic loadings specified in Paragraph 3.2 above.

Piping and component supports will not be analyzed if the original design load for the support is not exceeded by more than 10% for the load combinations described in Section 3.2.

Existing linear piping and component supports will be analyzed in accordance with the stress criteria from ASME, Section III, Subsection NF and Appendix XVII, 1980 Edition, Winter 1980 Addenda.

Plate and shell piping and component supports will be evaluated to the criteria of the ASME Code, Section III, Subsection NF, 1980 Edition, Winter 1980 Addenda.

Most piping and component supports at Big Rock Point are attached to building steel. The attachment to this steel will be evaluated in accordance with the requirements of the ASME Code, 1980 Edition, Winter 1980 Addenda. Concrete embedments and anchor bolts will be evaluated in accordance with the criteria given in Table 3.

Loading combinations and stress limits for piping and component supports are summarized in Table 3.

TABLE 1

LOADING COMBINATIONS AND STRESS LIMITS FOR PIPING

Loading Combinations	Stress Limits
1. Normal	
(a) PD + D (1)	≤ Sh
(b) TD + TAM	≤ Sa
2. Faulted	
P + D + SSE	≤ 2.4 Sh

Where:

PD	=	Design Pressure Stress
D	=	Deadweight Stress
TD	=	Thermal Expansion Stress due to Design Temperature
TAM	=	Stress due to Design Temperature Thermal Anchor Displacements
SSE	=	Stress due to Safe Shutdown Earthquake Inertia Loads
Sa	=	Allowable Stress Range, f(1.25 Sc + 0.25 Sh), where f = 1.0
Sc	=	Cold Material Allowable Stress from ASME, Section III, 1980 Edition, Winter 1980 Addenda or ANSI B31.1, 1980 Edition (2)
Sh	=	Material Allowable Stress at Maximum Operating Temperature from ASME, Section III, 1980 Edition, Winter 1980 Addenda or ANSI B31.1, 1980 Edition (2)

NOTES: (1) If required, any design mechanical loads will be included in this combination.

(2) Material allowables will be taken from B31.1 if they are not available in Section III.

TABLE 2

LOADING COMBINATIONS AND STRESS LIMITS FOR VESSELS, PUMPS AND VALVES

Loading Combination	Stress Limit (1)
PD + D + FD	S1 ≤ 1.0 S (3)
	S1 + S2 ≤ 1.5 S (3)
PN + D + FN + SSE	S1 ≤ 2.0 S (4)
	S1 + S2 ≤ 2.4 S (5)

Where:

PD	=	Design pressure
PN	=	Normal operating pressure
D	=	Deadweight
FD	=	Design mechanical loads from connecting piping excluding earthquake
FN	=	Operating mechanical loads from connecting piping including earthquake inertia loads
SSE	=	Safe Shutdown Earthquake Inertial Loading
S1, S2	=	Membrane stress and bending stress as defined in the ASME Code, Section III, NF-3522
S	=	Allowable stress intensity from ASME Code, 1980 Edition with Addenda through Winter 1980, Table 1-7 or 1-8

NOTES:

(1) Valve and pump bodies are considered stronger than connecting pipe and therefore analyses of valve and pump bodies will not be performed.

(2) For active valves, the extended operator support structure stress will be limited to Sy and the valve operator acceleration will be limited to 3 g's horizontal plus 2 g's vertical.

(3) This limit may be considered to have been satisfied by the original designer of the component.

(4) For active valves and pumps, this limit shall be 1.5 S.

(5) For active valves and pumps, this limit shall be 1.8 S. This limit may be satisfied by limiting the pipe stress at the point of attachment to the component to 1.8 Sh.

CRITERIA FOR SEISMIC ANALYSIS, Continued

TABLE 3

LOADING COMBINATIONS AND STRESS LIMITS FOR SUPPORTS (1, 2, 3, 6)

Loading Combination	Linear Type Support Limits	Plate and Shell Support Limit
D + TD	F all	S1 ≤ 1.0 S
		S1 + S2 ≤ 1.5 S
D + TO + SSE	1.2 Sy but not	S1 ≤ 1.3 S (4)
	> 0.7 Su (7, 8, 9)	S1 + S2 ≤ 2.25 S (5)

Where:

D	=	Deadweight Stress
TD	=	Stress induced by restraint of free end thermal displacement due to design temperature
TO	=	Stress induced by restraint of free end thermal displacement due to operating temperature
SSE	=	SSE inertia loads
Sy	=	Material yield strength at temperature
F all	=	Allowable stress value from ASME Code, Section III, XVII-2000.
S1, S2	=	Membrane stress and bending stress as defined in the ASME Code, Section III, NF-3321.
S	=	Allowable stress from the ASME Code, Appendix I

NOTES: (1) Compressive axial member loads shall be kept to less than 0.67 times the critical buckling load.

(2) Includes Component Standard Supports designed by analysis.

(3) For linear as well as plate and shell support analyses, use ASME Code, 1980 Edition with Winter 1980 Addenda.

(4) Not to exceed 0.4 Su.

(5) Not to exceed 0.6 Su.

(6) Supports may also be designed by load rating per Section III, NF-3360.

(7) As an alternative, the criteria of F-1370 may be used.

(8) Concrete embedded anchors will be evaluated for the same loading combinations using a limit of 0.7 Su.

(9) Anchor bolts will be evaluated for the same loading combinations using a limit of 0.25 Su for wedge type and 0.20 Su for shell type (as specified by manufacturer).

APPENDIX A

ANALYSIS GUIDELINES

A-1. Computer Codes

Where either static or dynamic computer analysis is required, QA qualified computer codes will be employed. Typical programs that may be employed are:

PIPE STRESS:	NUPIPE
COMPONENTS AND SUPPORTS:	ANSYS SAP (SAP 80) STRUDL

Other qualified programs will be employed where required.

A-2. Dynamic Analysis Guidelines

a. With the exception of the main reactor coolant and small bore piping, analysis of components and piping for a seismic event will be done by the response spectrum method. The seismic event will be expected to occur with the plant at normal operation. The response spectra to be employed are generally expected to be those resulting from the present analysis of the plant structures, Reference (2). However, revised amplified floor spectra resulting from an analysis using the site specific spectra of Reference (3) may be employed.

b. Damping values will be as recommended in NUREG/CR-0098, Reference (4). Damping for all sizes of piping will be 3 percent. Equipment damping will be 7 percent.

c. Response spectra associated with different pipe support locations within the structures will be enveloped where a single response spectrum is to be used in an analysis. However, should multiple input spectra be judged necessary, they will be used.

d. Analysis will be performed with a simultaneous input of all response spectra in the global or any convenient local coordinate system.

e. The maximum value of a response component (e.g. x, y, or z) will be determined by taking the SRSS sum of the individual modal responses for each component. The total response will then be taken as the SRSS sum of the individual maximum component responses, in accordance with Regulatory Guide 1.92.

f. The analysis of many mechanical equipment items are expected to be conducted by simplified static coefficient methods. A 1.5 factor for the multi-modal response of flexible equipment systems will be employed where analysis or testing cannot ensure that the equipment can be represented as a single-degree-of-freedom system.

g. Ductility, if used, will be accounted for in accordance with the NRC letter from D. M. Crutchfield to D. J. Van de Walle, dated June 23, 1982.

A-3. General Modeling Guidelines

a. The analysis models to be incorporated in the computer analyses will be conventional in nature. Dimensional isometrics of essentially all safety-related piping exist. These isometrics were generated during the implementation of IE Bulletin 79-14 work and include support locations and support drawings (in most cases).

b. Engineering judgment will be employed to decouple large systems into smaller piping stress problems where possible. Decoupling will be employed at large equipment nozzles, at six-way restraints (wall and floor penetrations) and at pipe interfaces where the moment of inertia ratio of run to connecting pipe is ten or greater.

c. Extremely large systems may be analyzed by overlapping models, e.g., a large portion of the piping may appear on both models.

d. Floor-mounted pumps will be modeled as anchors. Valves will be modeled as pipes with three times the torsional and flexual section moduli of the connecting pipe. Valve operators and other eccentric masses will be modeled as beams, with the properties of the connecting pipe, attached to the valve or in-line component with the eccentric mass at the estimated center of gravity location.

e. Variable support hangers will be input as spring constants for all static and dynamic analysis.

f. Constant support hangers will be modeled as forces for static deadweight analysis.

g. Rod type hangers will be modeled based upon anticipated response.

h. Stiffness for structural piping supports (stanchions, U-bolts, etc.) will be included in the structural models as appropriate.

i. A friction factor of .3 for pipes moving relative to a sliding support will be considered in support loadings when the relative movement exceeds 1/8 inch for piping systems which are dynamically analyzed.

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REFERENCES

1. Letter from R. A. Vincent to D. M. Crutchfield, SEISMIC DESIGN CONSIDERATIONS, DATED 27 JULY 1981.

2. Letter from R. A. Vincent to D. M. Crutchfield, SEISMIC DESIGN CONSIDERATIONS, (transmittal of D'Appolonia Report), dated 26 August 1981.

3. Letter from d. M. Crutchfield to all SEP Owners, SITE SPECIFIC GROUND RESPONSE SPECTRA FOR SEP PLANTS LOCATED IN EASTERN UNITED STATES, 17 JUNE 1981.

4. Newmark, N. M., and W. J. Hall, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR-0098, May 1978.

5. Ridall, R., and N. M. Newmark, "Statistical Analysis of Response of Nonlinear Systems Subjected to Earthquakes," Department of Civil Engineering Report UILU 79-2016, University of Illinois, August 1979.