San Onofre Nuclear

Generating Station

Unit 1

Balance of Plant

Mechanical Equipment and Piping

Seismic Reevaluation Criteria

14000-165

September 1, 1981

TABLE OF CONTENTS

1.0 INTRODUCTION AND PROGRAM DESCRIPTION

1.1 Introduction

This document describes the Seismic Reevaluation Program for the San Onofre Nuclear Generating Station, Unit 1, Balance of Plant Mechanical Equipment and Piping (BOPMEP) which is being conducted as part of the Systematic Evaluation Program (SEP). This report presents the methodology and acceptance criteria to be employed in the BOPMEP Seismic Reevaluation Program. In addition, this report provides the scope of the program which was previously discussed in Reference 1. It should be noted that accident mitigating systems are not included in the scope of the BOPMEP Seismic Reevaluation Program as indicated in Reference 1, but will be reevaluated as part of a separate program.

1.2 Program Description

1.2.1 Scope

The scope of the BOPMEP Seismic Reevaluation Program will consist of:

A. The remainder of the Reactor Coolant Pressure Boundary (RCPB) not previously reevaluated;

B. The piping, equipment and field erected tanks necessary to bring the plant to a safe cold shutdown condition (less than

200°F). This includes boration of the Reactor Coolant System (RCS), heat removal, depressurization of the RCS and miscellaneous supporting functions;

1.2.2 Systems

The plant systems to be reevaluated in the BOPMEP Seismic Reevaluation Program are discussed in the following subsections. These subsections include discussions of system boundaries.

1.2.2.1 Reactor Coolant Pressure Boundary

The RCPB includes piping and valves which are connected to the RCS, up to and including the following:

(a) The outermost containment isolation valves in piping which penetrates the containment sphere.

(b) The RCS safety and relief valves.

(c) Piping, fittings and valves leading to connecting systems up to and including the first normally closed valve (from the high pressure side) or the first normally open valve capable of automatic or remote manual closure.

1.2.2.2 Safe Shutdown Systems

Systems listed below which are required to bring the plant to a safe cold shutdown will be reevaluated.

System boundaries will include all connected piping up to and including the first valve that is normally closed or capable of automatic or remote manual closure when the safe shutdown is required.

A. Boration and Depressurization Function

(a) Portions of the Chemical and Volume Control System (CVCS) that supply borated water from the Refueling Water Storage Tank (RWST) to the RCS via the normal charging lines and the auxiliary spray line to the pressurizer.

(b) Portions of the Miscellaneous Water System which ensure pressure boundary integrity of the RWST and piping to the CVCS.

B. Heat Removal Function

(a) Portions of the Main Steam System required to remove decay heat from the RCS by venting steam to the atmospheric steam dump valves in the main steam relief header.

(b) Portions of the Condensate and Feedwater System and Auxiliary Feedwater System required to provide makeup to the steam generators.

(c) Portions of the Auxiliary Coolant System required to remove decay heat in going from hot shutdown to cold shutdown including Residual Heat Removal System piping and equipment.

In addition, all portions of the Auxiliary Coolant System required to support equipment cooling requirements and maintain its pressure boundary will be reevaluated. Piping and equipment connected to the spent fuel pool will be reevaluated to ensure integrity of the fuel pool. Means will be investigated to supply makeup to the pool as needed.

(d) The Salt Water Cooling System from the intake structure to the component cooling water heat exchangers.

C. Miscellaneous Support Systems

To support the primary functions noted above, instrument air and service water will be reevaluated insofar as they support the capability to effect a safe cold shutdown.

2.0 BOPMEP APPROACH

The BOPMEP Seismic Reevaluation Program will utilize the Design Basis Earthquake (DBE) described in subsection 3.7.1 and Figure 3.7-1 of the document entitled "Balance of Plant Structures (BOPS) Seismic Reevaluation Criteria" which was transmitted to the NRC by Reference 2. The design response spectra for horizontal ground motion correspond to the Housner spectra, as described in Section 9.2 of the San Onofre Unit 1 FSA, normalized to 0.67g. The design response spectra for vertical ground motion are normalized to 2/3 of the horizontal spectra.

Floor response spectra to be employed in this program will be based on the above ground motion and will be developed, where required, in accordance with the provisions of Section 3.7.2.5 of the BOPS Seismic Reevaluation Criteria document.

This reevaluation will consider the occurrence of a DBE in combination with normal plant operating loads. Mechanical equipment, piping and tanks will be reevaluated with respect to their ability to withstand the effects of a DBE without loss of the capability to perform their safety functions.

Compliance with stress criteria based upon current code requirements along with consideration of original design codes and quality requirements (as identified in subsections 3.0 and 4.0) will represent adequate reevaluation without further analysis. If the computed stress results do not comply with the stress criteria, alternate stress criteria based upon further consideration of the original design codes, original quality requirements, and failure probabilities and consequences may be utilized.

3.0 METHODOLOGY

3.1 Piping and Equipment

The seismic reevaluation methodology will reflect current technology to predict plant response. Equipment and piping will be reevaluated for structural integrity using one of the following methods in conjunction with the stress criteria of Section 4.0.

(a) lumped mass dynamic models using the appropiate amplified floor response spectra as input to the dynamic analysis.

(b) a similarity approach where a component or piping system is reevaluated on the basis of its similarity to other qualified or reevaluated piping systems or components. For example for similar pipe runs, one line will be chosen for detailed analysis and other similar lines will be reevaluated by comparison to the line analyzed in detail.

(c) lumped mass models using an equivalent static g loading of 1.5 times the maximum response spectrum value.

(d) reevaluation by inspection.

(e) testing of piping similar to that installed in the plant.

(f) declassification by the addition of isolation valves or safety analysis.

The selection of the appropriate method to be employed in any given instance will depend on a number of factors such as the support configuration, the uniqueness of the line configuration, and the line size. Reevaluation by inspection will only be applied to portions of the small bore piping less than 2½" diameter. Specific inspection criteria will be developed based on the analytical results obtained in reevaluation of comparable small bore piping.

It is anticipated that the majority of the piping systems and mechanical equipment will be reevaluated using dynamic analysis with response spectra input. The following principal computer codes may be used in dynamic and static analyses to determine mechanical loads and stresses and deformations of mechanical systems and components. These programs are described and verified in references (3) through (5).

A. ADLPIPE - static and dynamic pipe design and stress analysis.

B. ME101 - linear elastic analysis of piping systems

C. SAP4 - structural analysis program for static and dynamic response of linear systems.

The percentage of the critical damping value to be used in the analysis of piping and equipment is given in Table 1. These are identical with the damping values recommended in Regulatory Guide 1.61 (Reference 6). Damping values higher than the ones given in Table 1 may be used if sufficient justification is available to support the higher values.

The combination of modal responses will be in accordance with Regulatory Guide 1.92 (Reference 7). The total seismic response for each analysis shall be obtained by combining the individual modal responses utilizing the square-root-of-the-sum-of-the-squares method.

For systems having modes with closely spaced frequencies, the above method will be modified to include the possible effect of these modes. The groups of closely spaced modes will be chosen such that the difference between the frequencies of the first mode and the last mode in the group will be obtained in accordance with Regulatory Guide 1.92.

3.2 Field Erected Tanks

The method of analysis for field erected tanks will be in accordance with the methodology described in chapter 6 of reference 8 and the amended provisions recommended by section III of reference 9. The horizontal response analysis will include at least one impulsive mode and the fundamental convective (sloshing) mode. Damping values to be used in determining spectral acceleration in the impulsive mode will be 4% as specified in Table 1 for welded steel structures. For the horizontal convective mode the spectral acceleration will be determined at a fluid damping ratio of 0.5% of critical damping. If the maximum wave height exceeds the available freeboard, the tank and roof junction will be analyzed for forces resulting from instantaneous fluid distribution in the tanks.

4.0 REEVALUATION ACCEPTANCE CRITERIA

4.1 Piping and Mechanical Equipment

The analysis and reevaluation of piping will consider the faulted condition as defined in the ASME Section III Code. Reference to the ASME Section III Code herein refers to the ASME Boiler and Pressure Vessel Code, Section III, 1974 edition, summer addenda. (Reference 10). The 1974 edition of the code is referenced because the quality assurance review of the ADLPIPE computer code was to that edition. However, the code equations for resultant stresses which are utilized in this computer program have not changed in subsequent editions of the code.

The original design code for most of the piping is Power Piping Code ASA B31.1, 1955. The basic material allowable stresses are comparable between ASA B31.1 and ASME Section III Code. The design fabrication and installation practices employed during the original design and construction of the plant are essentially the same as those used today for safety related systems. These equivalent methods pertain to welding procedures, non-destructive examination, methods of fabrication, material mechanical properties, pipe wall thickness and other basic engineering and construction techniques. For these reasons the rules of ASME Section III Code (Class 2 and 3) have been selected as the guideline acceptance criteria for the RCPB, safe shutdown, and accident mitigation piping systems.

For the BOPMEP program the stress limits presented in Table 2 will be used for piping stress evaluation. Table 2 is a restatement of the stress limits given in the ASME Section III Code.

Similarly, the reevaluation of mechanical equipment (i.e. pressure vessels, heat exchangers, pumps and valves) will be based on the consideration of primary stresses in accordance with the limits for emergency conditions for active components and faulted service for inactive components, as contained in the ASME Section III Code. Table 3 provides the load combinations and stress limits which will be used for mechanical equipment.

The load combination and stress limits which will be used for the reevaluation of supports for piping and mechanical equipment are provided in Table 4. As described in footnote 9 of Table 4, the AISC "Specification for the Design, Fabrication and Erection of Structure Steel For Buildings" (Reference 11) will be used as the basis for allowable stresses for linear supports of mechanical equipment and piping. Otherwise manufacturer's load limit information or ASME Section III code provisions will provide the basis for reevaluation acceptance criteria for piping mechanical component supports and plate and shell type supports.

4.2 Field Erected Tanks

The load combination and stress limits which will be used for the reevaluation of field erected tanks are provided in Table 5. The shell stress limits and anchorage criteria specified are consistent with the ASME Pressure Vessel Code, Section VIII, 1977 Edition and the AISC Manual of Steel Construction, Eighth Edition, respectively, with the exception that the Table 5 values include an increase factor of 1.6 as permitted by the NRC Standard Review Plan Section 3.8.4. The criteria for bearing pressure and safety factors against overturning and sliding are consistent with the BOPS Seismic Reevaluation Criteria Section 3.8.5.5 which was transmitted to the NRC by Reference 2.

TABLE 1

DBE DAMPING VALUES USED FOR BOPMEP SEISMIC REEVALUATION PROGRAM

ITEM	DBE Damping (Percent of Critical)
Mechanical Equipment and Large piping (greater than or equal to 12 inches)	3
Small piping (Less than 12 inches)	2
Welded steel structures	4
Bolted and/or riveted steel structures	7

TABLE 2

LOADING COMBINATIONS AND STRESS CRITERIA FOR

SEISMIC REEVALUATION OF PIPING (a)

CONDITION	LOADING COMBINATIONS	STRESS LIMITS
FAULTED	PO + DW + DBE + DF	$S_{OL} \leq 2.4\ S_h$

LEGEND:

PO - Operating Pressure

DW - Dead Weight

DBE - Design Basis Earthquake (inertia portion)

DF - Dynamic events associated with conduct of safe shutdown during or following which the piping system being evaluated must remain intact, i.e. main steam safety relief valve discharge.

S_{OL} - Defined by EQN. 9 - NC 3652, ASME Section III Code

S_h - Basic material allowable stress at operating temperature, PSI (Refer to Table 1-73 of ASME Section III Code)

(a) Allowable criteria stated herein are guideline criteria. Deviations may be taken when justified.

TABLE 3

LOADING COMBINATIONS AND STRESS CRITERIA FOR MECHANICAL EQUIPMENT[a] (Sheet 1 of 2)

Component	Loading Combination[2]	Criteria [5]
Pressure vessels and heat-exchangers	Deadweight + Pressure + DBE + Nozzle Loads	$\sigma_m \leq 2.0S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 2.4S$
Active pumps[1]	Deadweight + Pressure + DBE + Nozzle Loads	$\sigma_m \leq 1.5S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 1.8S$
Inactive pumps	Deadweight + Pressure + DBE + Nozzle Loads	$\sigma_m \leq 2.0S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 2.4S$
Active valves[1]	Deadweight + Pressure + DBE + Nozzle Loads	Extended Structure: $\sigma_m \leq 1.5S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 1.8S$ Nozzle loads: (3) Pressure Boundary 1.2 P[6]
Inactive valves	Deadweight + Pressure + DBE + Nozzle Loads	$\sigma_m \leq 2.0S$ $(\sigma_m \text{ or } \sigma_\ell) + \sigma_b \leq 2.4S$ Nozzle loads: (4) Pressure Boundary 1.5 P[6]

a. Allowable criteria stated here are guideline criteria. Deviations may be taken when justified.

TABLE 3

LOADING COMBINATIONS AND STRESS CRITERIA FOR MECHANICAL EQUIPMENT[2] (Sheet 2 of 2)

NOTES
1. Active pumps and valves are defined as those that must perform a mechanical motion during the course of accomplishing a system safety function.
2. Nozzle loads shall include piping loads transmitted to the component during the DBE. Operating pressure is the pressure at the normal full power condition.
3. Piping loads at piping/active-valve interfaces shall be limited to below yield stress of the attached piping.
4. Valves, being stronger than the attached piping, and not having a history of gross failures of pressure boundaries, can safely accept piping loads without compromising the valve pressure retaining integrity. Therefore a nozzle loads check is not necessary.
5. 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 = local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.
σ_b = bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.
S = Code allowable stress value. The allowable stress shall correspond to the metal temperature at the section under consideration.
6. P = Pressure rating specified in ASME Section III Code, Table NC-3512(b) at service temp.

a. Allowable criteria stated here are guideline criteria. Deviations may be taken when justified.

TABLE 4

LOADING COMBINATIONS AND STRESS CRITERIA FOR MECHANICAL EQUIPMENT

SUPPORTS AND BOP PIPING SUPPORTS[a] (Sheet 1 of 2)

Support	Loading Combination[3]	Criteria[4]
Linear supports[1] for Mechanical equipment and piping	Deadweight + DBE + Thermal + Nozzle Loads	1.6S $\geq$ Deadweight + DBE + Thermal Loads + Nozzle Loads
Plate and shell[2] supports for Mechanical equipment (Active)	Deadweight + DBE + Nozzle Loads + Thermal	$\sigma_1 \leq 1.2Sa$ $\sigma_1 + \sigma_2 \leq 1.8Sa$ $\sigma_3 \leq 0.5Sa$
Plate and shell supports for Mechanical equipment (Inactive) and piping	Deadweight + DBE + Nozzle Loads + Thermal	$\sigma_1 \leq$ Lesser of 1.5Sa or 0.4 S_u $\sigma_1 + \sigma_2 \leq$ Lesser of 2.25Sa or 0.6 S_u $\sigma_3 \leq 0.5Sa$
Piping Mechanical Component supports	Deadweight + DBE + Nozzle Loads + Thermal	Manufacturer's Load Limit Information

a. Allowable criteria stated here are guideline criteria. Deviations may be taken when justified.

TABLE 4

LOADING COMBINATIONS AND STRESS CRITERIA FOR MECHANICAL EQUIPMENT

SUPPORTS AND BOP PIPING SUPPORTS[(a)] (Sheet 2 of 2)

NOTES

1. Linear type support: A linear type component support is defined as acting under essentially a single component of direct stress. Such elements may also be subjected to shear stresses. Examples of such structural elements are: tension and compression struts, beams and columns subjected to bending, trusses, frames, rings, arches and cables.

2. Plate and shell type supports: Plate and shell type supports are supports such as vessel skirts and saddles that are fabricated from plate and shell elements and are normally subjected to a biaxial stress field.

3. Nozzle loads shall be those nozzle loads acting on the supported equipment during the DBE. Operating pressure is the pressure at the normal full power condition.

4. σ_1 = membrane stress, which is the average stress across the solid section under consideration. It includes the effects of discontinuities but not local stress concentrations.

   σ_2 = bending stress, which is the linear varying portion of the stress across the solid section under consideration. It excludes the effects of discontinuities and concentrations.

   σ_3 = maximum tensile stress at the contact surface of a weld producing tensile load in a direction through the thickness of plate and rolled shape elements.

   Sa = allowable stress value from the applicable Table of Appendix I of ASME Code.

   S_u = ultimate strength of material at a given temperature.

   S = for structural steel, S is the required section strength based on elastic design methods and the allowable stresses defined in Part 1 of the AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" November 1, 1978

a. Allowable criteria stated here are guideline criteria. Deviations may be taken when justified.

TABLE 5

LOADING COMBINATIONS AND ACCEPTANCE

CRITERIA FOR FIELD ERECTED TANKS [a] (Sheet 1 of 2)

ITEM	LOADING COMBINATION [1]	CRITERIA [2]
Shell plate (A283 grade C)	$D + L + F + R_o + E'$	$f_s < 0.6\ F_y$ tensile stress $f_c < F_{cr}$ compressive stress $f_c < 5$ ksi compressive stress
Anchor Bolts (A307-A)	$D + L + F + R_o + E'$	$f_t < 0.9\ F_{yb}$ tensile stress $f_v < 0.4\ F_{yb}$ shear stress
Foundation	$D + L + F + R_o + E'$ $D + F + E$	20 KSF bearing pressure SF = 1.1 overturning, sliding and flotation safety factor

(a) Allowable criteria stated herein are guideline criteria. Deviations may be taken when justified.

TABLE 5

LOADING COMBINATIONS AND ACCEPTANCE

CRITERIA FOR FIELD ERECTED TANKS (Sheet 2 of 2)

NOTES
1. Definitions and Nomenclature for Load Combination D = Dead Loads or their related internal moments and forces. L = Applicable live loads or their related internal moments and forces. F = Lateral and vertical pressure of liquids, or their related internal moments and forces. R_o = Maximum pipe and equipment reactions during normal operating conditions based on the steady-state condition, if not included in the above loads. E' = Loads generated by the Design Basis Earthquake (DBE). 2. Definitions and Nomenclature for Criteria f_s = Maximum calculated tensile stress f_c = Maximum calculated compressive stress f_t = Maximum calculated bolt tensile stress f_v = Maximum calculated bolt shear stress F_y = Specified minimum yield stress per ASME Pressure Vessel Code, Section VIII, 1977 Edition F_{cr} = Critical buckling stress for an unstiffened cylindrical shell F_{yb} = Specified minimum yield strength for bolts per AISC Manual of Steel Construction, Eighth Edition

REFERENCES

1 - Letter K. P. Baskin (SCE) to D. M. Crutchfield (NRC), SEP Topic III-6, Seismic Design Considerations, San Onofre Nuclear Generating Station-Unit 1, dated July 7, 1981.

2 - Letter K. P. Baskin (SCE) to D. M. Crutchfield (NRC), SEP Topic III-6, Seismic Design Considerations, San Onofre Nuclear Generating Station, Unit 1, dated February 23, 1981.

3 - ME101, Linear Elastic Analysis of Piping Systems, Users Manual, Data Processing Division Bechtel International Corporation, April 1977.

4 - Digwell, I. W., ADLPIPE, Static and Dynamic Pipe Design and Stress Analysis, Users Manual, Arthur D. Little, Inc. April 1977.

5 - SAP4, Structural Analysis Program For Static and Dynamic Response of Linear Systems, Users Manual, University of California, Berkeley, April 1974.

6 - Damping Values for Seismic Design of Nuclear Power Plants, U. S. Nuclear Regulatory Guide 1.61, Rev. 0, October 1973.

7 - Combining Modal Response and Spatial Components in Seismic Response Analysis, U. S. Nuclear Regulatory Guide 1.92, Rev. 1, February 1976.

8 - Nuclear Reactors and Earthquakes, TID - 7024, USAEC, Division of Technical Information.

9 - NUREG/CR-1161 RD, Recommended Revision to Nuclear Regulatory Commission Seismic Design Criteria

10 - ASME B & PV Code, Section III, Nuclear Power Plants Components 1974 Edition, plus Summer 1974 Addenda.

11 - AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" November 1, 1978.