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June 25, 1985

Director, Office of Nuclear Reactor Regulation
Attention: Dennis M. Crutchfield, Assistant Director
for Safety Assessment
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
Seismic Analyses
San Onofre Nuclear Generating Station
Unit 1

Your letter of February 15, 1985 requested that we provide original design analyses for San Onofre Unit 1 which pertain to your review of SCE's April 30, 1982 seismic reevaluation report regarding Balance of Plant Mechanical Equipment and Piping (BOPMEP). Available information was provided in response to this request in my letter dated April 1, 1985.

Your February 15 letter also included in Enclosures 1 and 2 a description of scope and general methods and criteria which could be used for possible analyses "consistent with the original licensing basis." We have noted in the past that duplicating original seismic analyses for San Onofre Unit 1 is impossible. This fact was one of the primary considerations that resulted in our decision (in the summer of 1982) to proceed with the 0.67g ungrade rather than address the 0.5g issue. In our judgment, any effort expended on 0.5g analysis (or more specifically, 0.25g analysis) is irrelevant at this time since results produced: 1) will not provide any conclusive information regarding the original design, and 2) will result in another unrelated set of calculations which we believe will serve no purpose.

Notwithstanding this conclusion, we have reviewed your Enclosures 1 and 2. The conclusion of this review is that it would be very difficult to consistently implement analyses based on the information in these Enclosures. Attachment 1 to this letter identifies some of the areas where additional information is required to clarify these criteria and methodology. In

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Attachment 2 we have described criteria and methodology which represent our "best guess" of what the original seismic methods and criteria might have been. Attachment 3 reiterates the list of systems and equipment included in Enclosure 1 to your letter along with additional information specific to these items.

If you have any questions regarding the enclosed information, please call me.

Very truly yours,

Kenneth P Baskin

REVIEW OF NRC PROPOSED ANALYSIS METHODOLOGY AND CRITERIA

The following is a commentary on the "Analysis Methodology and Criteria" proposed by the NRC for performing original plant piping stress analysis and piping and equipment support designs.

NRC ITEM 1

For analysis purposes, the selected components should be reconstructed to the same conditions that existed during the conduct of the BOPMEP effort.

COMMENTS: None

NRC ITEM 2

An equivalent static analysis should be performed using the original damping factors and design ground response spectra scaled to 0.25 g with no factors applied to account for dynamic effects.

COMMENTS:

None

NRC ITEM 3

The ADLPIPE (or an equivalent) computer program with lumped mass finite element models may be used for the stress analysis.

COMMENTS:

This item does not clearly define the adjustments that would have to be made in order to utilize current computer codes to perform original analysis. The current versions of the computer codes have built-in methodologies, modeling techniques and analyses procedures that did not exist at the original plant design time frame. Therefore, use of current codes would entail the adjustment of the computer model and the output to conform to original plant design practices. Two examples of these adjustments follow. Eccentric masses for in-line components, such as valves with extended operators, would be modeled as masses at the pipe centerline.

Current computer codes have built-in stress intensification factors that are used in the computation of primary stresses as required by the current codes and regulations. These intensification factors were not required for calculation of primary (weight and seismic) stresses during original plant design (circa 1964-1968). Therefore, current computer code analysis results would have to be modified to reflect original code requirements.

Also, piping supports other than spring hangers, would be modeled as rigid supports with a stiffness value of 10^{18} lbs./in.

NRC ITEM 4

Different loading cases and stress combinations due to the seismic analysis of the horizontal and vertical directions should be considered according to the original FSAR design criteria.

COMMENTS:

o This criterion does not describe the method for combining loads from vertical and horizontal earthquakes in order to develop piping stresses and support loads. Several methods exist which utilize various combinations of absolute sum and square root of the sum of the squares (SRSS). The load combination which shall be used is the following:

$$F_i = \text{Greater of } \sqrt{F_{i\ n\text{-}s}^{2} + F_{i\ vert}^{2}}$$

Or

$$\sqrt{F_{i\ e\text{-}w}^{2} + F_{i\ vert}^{2}}$$

where i is the global x, y, or z direction

This combination is considered appropriate since vertical loads were combined with loads from only one horizontal direction earthquake during original plant analysis. Also, the probability of simultaneous occurrence of peak loads from horizontal and vertical earthquakes is low.

NRC ITEM 5

Results will be evaluated based on the original design code allowables of the plant, i.e., the 1955 ANSI B31.1 Code.

COMMENTS:

o Design code for piping and equipment supports is not specified.

o Allowable loads for concrete anchors is not specified.

o Allowable loads for nozzles are not specified.

General Note:

In our review of the above criteria and methodology to be used we determined that many areas were not addressed. Examples of these areas are seismic load combinations, use of stress intensification factor for seismic analysis and loads for support evaluation. We have therefore, developed Attachment 2 to clearly and comprehensively define the methods and criteria representative of our interpretation of the original plant design.

ATTACHMENT 2

SAN ONOFRE UNIT 1

PSEUDO ORIGINAL PLANT DESIGN CRITERIA AND METHODOLOGY

(CIRCA 1964-1968)

(3850L)

TABLE OF CONTENTS

I. PURPOSE

The purpose of this document is to present to the NRC a pseudo original design criteria and methodology which could be used for seismic reanalysis of piping systems, piping supports and equipment supports as requested by the NRC and listed in Reference (A). This seismic reanalysis would be performed based on original plant design criteria (Circa 1964-1968). This document provides the present day interpretation of that criteria.

II. SCOPE

The criteria and methodology presented in this document are only for use in the Seismic reanalysis of Category A piping systems and supports, and equipment supports for SONGS 1, as defined in the SONGS 1 FSA Section 9.2, Reference (B).

III. CRITERIA AND METHODOLOGY

III.1 General Design Basis Criteria

The following General Design Basis Criteria for analysis of piping, pipe supports and equipment supports are extracted from Section 9.2 of the SONGS 1 FSA (see Reference B).

- 0.25 g Normalized Seismic Input Earthquake: Primary steady state stresses when combined with seismic stresses shall be maintained within the allowable working stress range based upon the response to a ground motion having a maximum acceleration of 0.25 g.

- Design Spectrum: Figure 1, which is Figure 9.2 of the SONGS 1 FSA, shows a log-log plot of the acceleration response spectra normalized to a maximum ground acceleration of 0.25 g for various percentages of critical damping. The input data for these curves were developed by Dr. G. W. Housner. These curves cover periods from 0.01 to 1.0 second and damping factors of one-half percent to seven percent. The horizontal component of the ground acceleration was taken directly from the curves of Figure 1 and the vertical component was taken as two-thirds of this value.

- Damping Factors: A tabulation of damping factors which were used for various vibratory systems important to the nuclear safety of the plant is presented in Table 1. Conservative values are shown for systems of various materials, methods of construction, and location with respect to the ground. These are typical of the damping factors utilized for the plant design.

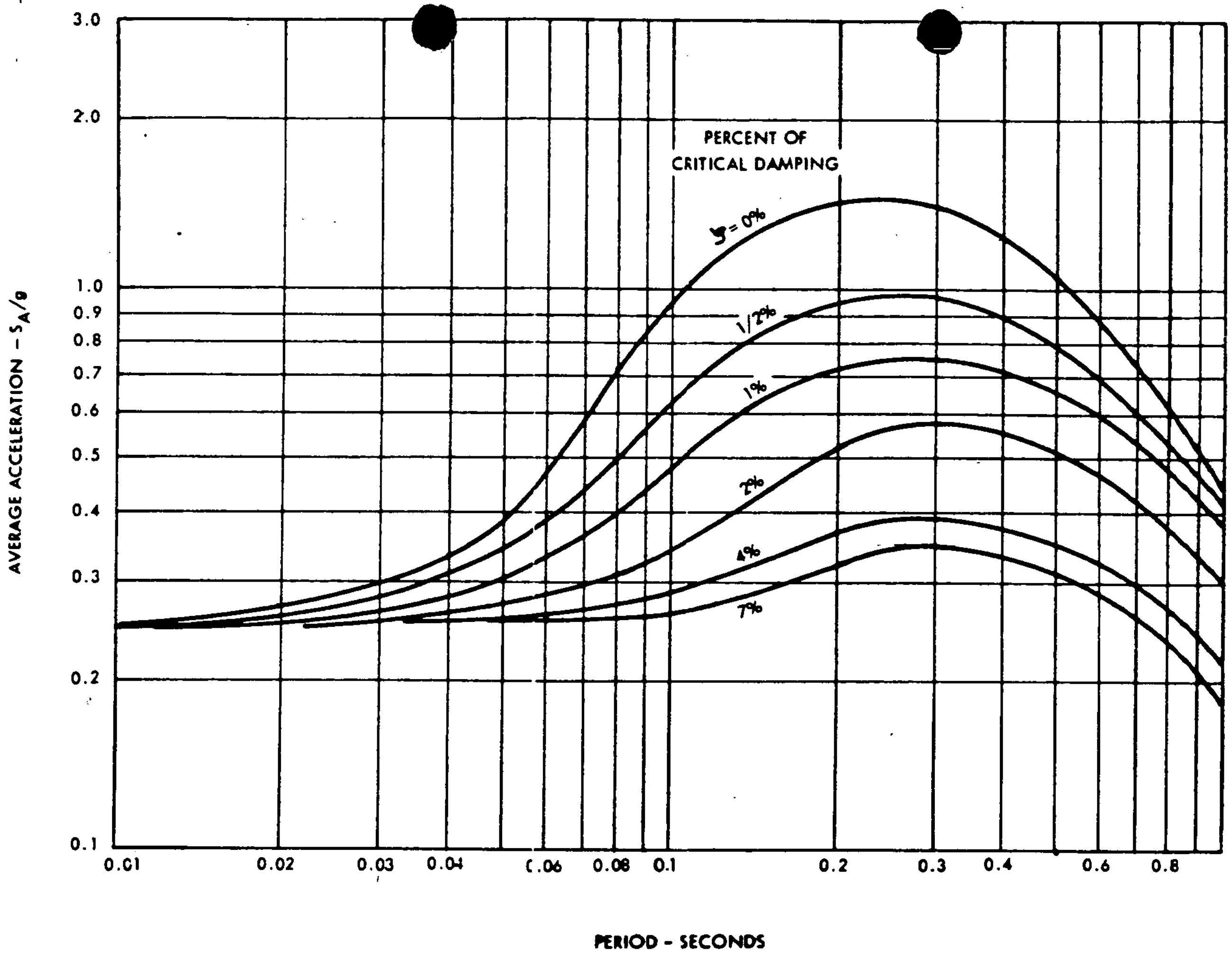


FIGURE 1 (FSA FIGURE 9.2)

Average Acceleration Response Spectra Normalized
for 0.25 g Ground Acceleration

TABLE 1: DAMPING FACTORS (FSA TABLE 9.1)

Component or Structure	Percent of Critical Damping
Reactor Vessel Internals (Stainless Steel Core Support Structure)	
a. Welded Assemblies	4.0
b. Bolted Assemblies	2.0
Reinforced Concrete Reactor Support Structure Including the Reactor Vessel	4.0
Vital Piping Systems	0.5
Steel Containment Vessel and Foundation	4.0
Framed Steel Structures	2.5
Concrete Structures Above Ground	
a. Shear Wall Type	7.0
b. Rigid Frame Type	5.0

III.2 Piping Stress Analysis Criteria and Methodology

A. Criteria

1. Pipe stress allowables and calculations shall be based on the 1955 ANSI B31.1 Code.

2. Seismic analysis shall be performed using static methods. No amplification factors are to be applied to account for dynamic effects.

3. Static seismic loads applied to each pipe segment shall be based on the acceleration corresponding to the natural frequency of that segment as read from the 0.25g normalized response curve for 1/2% of critical damping. The vertical acceleration is 2/3 the horizontal acceleration.

4. Horizontal and vertical earthquake stresses shall be calculated and combined as follows:

$$S_{E_1} = \sqrt{S^2_{N\text{-}S} + S^2_{Vertical}}$$

$$S_{E_2} = \sqrt{S^2_{E\text{-}W} + S^2_{Vertical}}$$

   The greater of S_{E_1} or S_{E_2} shall be combined with the stresses due to weight and internal pressure and be compared to the Code Allowable Stress.

5. Stress intensification factors (SIFs) were developed by Markl for the purpose of considering the effects of fatigue on piping systems. Fatigue was considered to occur only due to thermal cycling. In the 1960's earthquakes were considered to produce sustained loads and fatigue was not a consideration in the evaluation of seismic stresses. Therefore, stresses for external loading such as weight or earthquake conditions shall not consider SIFs.

6. The sum of the longitudinal stresses due to pressure, weight, and other sustained external loading shall not exceed S_h.

$$S_{l_p} + S_w \leq S_h$$

The 1955 ANSI Code Section 6, Chapter 1, Paragraph 607(b) states that "an increase in allowable stress of 20 percent shall be allowed for short time overloading conditions". Based on discussions with individuals working on SONGS 1 in 1965, this section of the Code was interpreted to mean that the allowable stress for pressure, weight, and earthquake conditions could be 1.2 S_h. This was justified by the fact that the earthquake was considered a short time overloading condition. Therefore, the following shall be used to evaluate sustained stresses plus those due to earthquake conditions:

$$S_{EQ} + S_{1_p} + S_w \leq 1.2\, S_h$$

Where

S_{EQ} = Longitudinal Stresses due to the .25g Earthquake

S_{1_p} = Longitudinal Stresses due to Pressure

S_W = Longitudinal Stresses due to the weight of the piping, insulation and fluid

7. Valve Qualification

Since the peak acceleration for 1/2% damping, as shown in Figure 1, is only one g, piping stress allowables shall govern the analysis of piping systems in which valves are included and where no purchase specification or vendor specifications are available that specify lower accelerations.

8. Nozzle Allowables

When available, vendor specified allowable nozzle loads shall be used for evaluating loads on equipment. If allowable nozzle loads are not available, satisfaction of allowable piping stresses shall govern.

9. Small bore piping (piping less than 2-1/2 inches in diameter) was field routed and supported using standard industry practices of that time for power plants. At that time these practices were considered to be sufficient for all loading including seismic.

Testing by ANCO (see Reference D) and an inspection of the El Centro Plant after an earthquake (see Reference E) confirm the ability of small bore piping, supported to standard industry practices, to withstand severe seismic loading without failure. Therefore, analysis of small bore piping is not considered to be required.

B. Methodology

1. Calculation of Longitudinal Pressure Stress

$$S_{lp} = \frac{F}{A} = \frac{pd^2}{D^2 - d^2}, \quad \text{Equation 17}$$

Where

S_{lp} = Longitudinal Pressure stress, psi

P = Internal Pressure, psi

d = Nominal inside diameter of the pipe, in.

D = Nominal outside diameter of pipe, in.

F = Pipe End Force, $F = \frac{p \Pi d^2}{4}$, Equation 15

A = Metal cross-sectional area of the pipe,

$$A = \frac{\Pi}{4} (D^2 - d^2), \quad \text{Equation 16}$$

2. Calculation of Longitudinal Stresses Due to Weight

Section 6, Chapter 3, Paragraph 618 from the 1955 ANSI B31.1 Code states that the weight of pipe, fittings and valves, containing fluid and insulation and other external loading produce sustained stresses which are evaluated by conventional methods. Therefore, the weight stress can be calculated by using classical beam equations. One example of such an equation, for spans which are not adjacent to fixed anchor points, is as follows:

$$s = (\frac{1}{8} wl)^2 (\frac{c}{I})$$

Where:

s	=	stress in the beam (pipe)
l	=	Length of span between vertical supports including spring hangers (in)
w	=	Weight of pipe, insulation, and fluid (lb/in)
c	=	Distance to outer fiber from center line of pipe (in)
I	=	Moment of inertia (in^4)

Where concentrated masses exist, such as valves or flanges, the additional bending moment due to their weight must be considered.

Weight stresses shall be computed by hand calculation or for computational simplicity, by using the bending moments from the ME101 piping analysis. For this evaluation all eccentric concentrated masses shall be modeled along the center line of the pipe. This is consistent with modeling techniques used in the early 1960s.

The stresses shall be calculated using the following formula:

$$S_w = \sqrt{S_b^2 + 4\, S_t^2}$$

Where:

$S_b = M_b/Z$

$S_t = M_t/2Z$

M_b = resultant bending moment, (in-lbs)

M_t = torsional moment, (in-lbs)

Z = section modulus of the pipe (in^3)

3. Calculation of Longitudinal Stresses Due to an Earthquake

Section 6, Chapter 3, Paragraph 618 from the 1955 ANSI B31.1 Code states that external loading such as wind produces stresses that are to be evaluated by conventional methods. Based on the techniques used in the early 1960s, and the fact that seismic conditions are an external loading to the piping, the following equations shall be used to calculate the seismic loads and stresses:

$$S_{EQ} = \text{The Greater of } \sqrt{S_{b_1}^2 + S_{t_1}^2} \text{ or } \sqrt{S_{b_2}^2 + S_{t_2}^2}$$

$$S_{b_1} = M_{b_1}/Z \ , \ S_{b_2} = M_{b_2}/Z$$

$$S_{t_1} = M_{t_1}/2Z \ , \ S_{t_2} = M_{t_2}/2Z$$

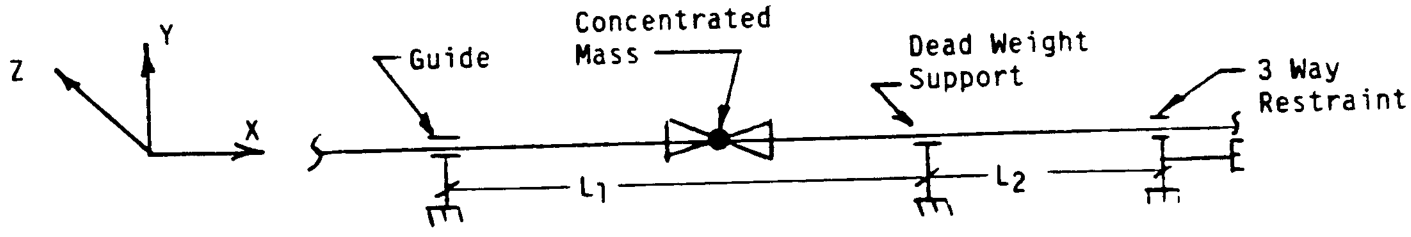
$$M_{b_1} = \sqrt{M_{b_{N-S}}^2 + M_{b_{Vert}}^2}$$

$$M_{b_2} = \sqrt{M_{b_{E-W}}^2 + M_{b_{Vert}}^2}$$

$$M_{t_1} = \sqrt{M_{t_{N-S}}^2 + M_{t_{Vert}}^2}$$

$$M_{t_2} = \sqrt{M_{t_{E-W}}^2 + M_{t_{Vert}}^2}$$

The moments in each direction shall be individually calculated using ME101 or by hand calculation. The piping model used to calculate the weight bending moments shall be used in the seismic analysis. Any snubbers on the piping shall be modeled as rigid restraints in the seismic analysis. The seismic analysis shall be a static run for each earthquake direction. Each piping span natural frequency shall be calculated using conventional formulas for pin-ended and/or fix-ended beams. The acceleration for each span which corresponds to that span's natural frequency will be used to multiply the mass of that span in the applicable direction (see III.2.A.3). This shall be accomplished by applying a uniform load to each span which is equal to the span acceleration multiplied by the uniform weight of the pipe, insulation, and fluid for that span. Also, any concentrated mass such as flanges or valves shall have their weight multiplied times the span acceleration. The following illustrates the methodology to be used:

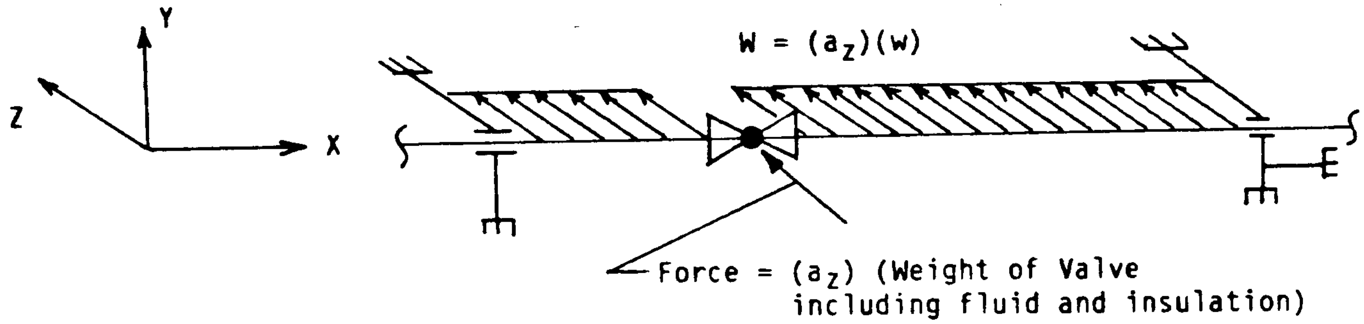


Transverse Earthquake

Step 1 Calculate natural frequency, f_Z, of seismic span, (L_1 + L_2), taking into consideration the concentrated mass (modeled along the center line of the pipe).

Step 2 Read the acceleration corresponding to the natural frequency of that segment in the Z-direction, f_Z, from the 0.25 normalized response curve for 1/2% of critical damping.

Step 3 Multiply the span acceleration by the span uniform load and the concentrated mass.



Axial Direction Earthquake

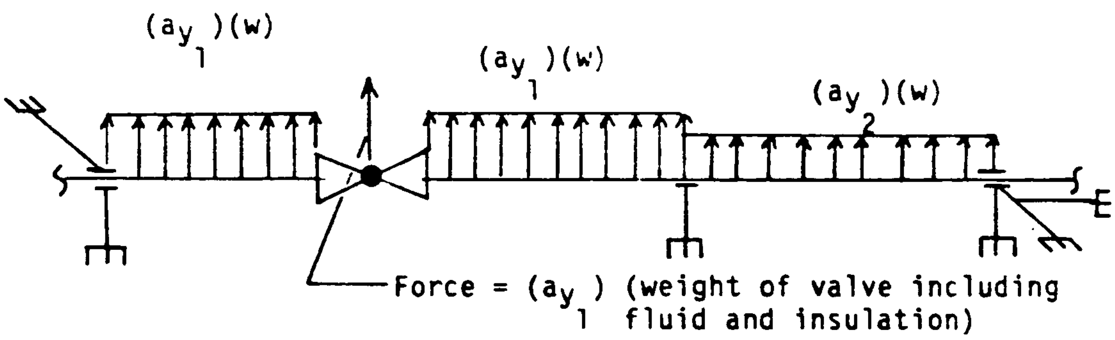
No bending stresses are induced in span L_1 or L_2 by the Axial Direction - Earthquake. All axial load is carried by the 3 way restraint. This load is equal to the mass of the entire span in the X-direction multiplied by the acceleration at 100 cps from the 0.25g normalized response curve for 1/2% of critical damping.

Vertical Direction Earthquake

Step 1 Calculate the natural frequency, f_y, of each seismic span, L_1 and L_2, taking into consideration the concentrated mass (modeled along the center line of the pipe) for span L_1.

Step 2 Read the acceleration corresponding to the natural frequency for each span, L_1 and L_2 in Y-direction from the 0.25 normalized response curve for 1/2% of critical damping. Multiply the accelerations by 2/3 (to obtain vertical component of earthquake).

Step 3 Multiply the span acceleration by the span uniform load and the concentrated mass.



III.3 Piping and Equipment Support Design Criteria and Methodology

A. Criteria

- This criteria addresses the following piping and equipment support structural elements:

  - Integral Attachments
  - Structural Steel
  - Anchorages to Concrete

1. Integral Attachments

- Applicable Code - ANSI B31.1, 1955 ed.

  a. Allowable stress for attachment, Section 6, Paragraph 607

  b. Allowable stress for welds, Section 6, Paragraph 606e

2. Structural Steel

- Applicable Codes - AISC (1963)

  - AWS D1.0 (1963)

- A7 or A36 steel

3. Anchorages to Concrete

  a. Embedded Anchors

  - Applicable Codes - ACI-318 (1963)

    - UBC (1964)

  b. Expansion Anchors

  - Manufacturer's ultimate values of the 1964-1968 time frame if available

  - If not available for this time frame, use earliest catalog data available

B. Methodology

1. Earthquake Loads on Equipment Supports

o The analysis of the dynamic loads imparted by the maximum ground acceleration resulting from an earthquake shall be performed using the response spectrum approach as described below.

o Equipment such as heat exchangers and pumps are considered to be rigid. The natural period of vibration of the rigid equipment and supporting structure will be determined. The damping used for determining the g-loads on the equipment shall be that of the supporting structure. From Table 1, for Framed Steel Structures the percent of critical damping is 2.5. For Concrete Structures above Ground the percent of critical damping is 7.0 for Shear Walls and 5.0 for Rigid Frames.

o Stresses on equipment supports resulting from normal and earthquake loads from the equipment itself and from attached piping shall be compared with the allowables of AISC or ACI as applicable.

2. Loads on Pipe Supports Due to Earthquakes

Forces on pipe supports due to horizontal and vertical earthquakes can be calculated using hand calculations or by equivalent static analysis using ME101. Each piping span natural frequency shall be calculated using conventional formulas for pin-ended and/or fixed-ended beams. The acceleration for each span shall be used to multiply the mass of that span in the applicable direction (see III.2.A.3). This shall be accomplished by applying a uniform load to each span which is equal to the span acceleration multiplied by the weight of the pipe, insulation, and fluid for that span. Also, any concentrated mass such as flanges on valves shall have their weight multiplied by the span acceleration.

Forces on supports due to the different earthquake directions will be calculated as follows:

$$Fi = \text{Greater of } \sqrt{Fi_{e-w}^{\;2} + Fi_{vert}^{\;2}} \text{ or } \sqrt{Fi_{n-s}^{\;2} + Fi_{vert}^{\;2}}$$

where i is the x, y, or z direction, e.g.,

Fx_{e-w} is the force in the x-direction due to the east-west earthquake.

Bending and torsional moments imparted by the piping onto nozzles or anchors are calculated as follows:

$$M_{bi} = \text{Greater of } \sqrt{Mbi_{e-w}^{\;2} + Mbi_{vert}^{\;2}} \text{ or } \sqrt{Mbi_{n-s}^{\;2} + Mbi_{vert}^{\;2}}$$

where i is the x, y, or z direction.

3. Design Load Combinations

Supports shall be evaluated using the combined loads from weight and seismic effects only.

4. Support Deflections

Ensuring that allowable stresses are not exceeded is the criteria for acceptable support design. Limitations on deflection are not a consideration.

5. Design Temperature

Ambient temperature shall be used as the design temperature for support design.

(1) As developed from the .25G Housner curves shown in Figure 1.

IV. REFERENCES

A. Letter, Dennis M. Crutchfield of NRC to Kenneth P. Baskin of SCE, dated February 15, 1985, Subject: San Onofre Nuclear Generating Station, Unit 1, Seismic Analyses - Docket No. SO-206.

B. San Onofre Nuclear Generating Station, Unit 1, Final Safety Analysis, Part II, Volume V.

C. Balance of Plant Mechanical Equipment and Piping Seismic Reevaluation Program (BOPMEP), dated April 1982.

D. Ken Blakely, Paul Ibanez, and Shelley Griffith ANCO Engineers, Inc., "Dynamic Behavior of Piping and Supports at High Load Levels--Experimental Study of a Scaled System", ASME Paper 82-WA/PVP-4.

E. Murry, Nelson, et. al., "Equipment Response at the El Centro Steam Plant during the October 15, 1979 Imperial Valley Earthquake," NUREG CR-1665.

REVIEW OF PIPING SYSTEMS, PIPE SUPPORTS, AND EQUIPMENT PROPOSED BY THE NRC FOR ANALYSIS TO ORIGINAL PLANT SEISMIC CRITERIA

Attached is a listing of piping, supports, and equipment for which original analysis was requested by the NRC in Reference (B). In all cases it is not clear that the items would originally have been classified as Seismic Category A. For example, Items 1 and 3 on the attached list are considered to be non-seismic for the original plant.

Also, since it was the practice at the time to field route small bore piping (piping less than 2 1/2 inches in diameter) it would not be considered consistent with "original plant" design philosophy to analyze the piping listed in Items 2 and 4.

NOTE: Original calculations for certain pipe supports have been located. They are identified as follows:

- * Original Structural calculation exists.
- ** This is a small hanger attached to major structural steel. Original analysis exists for the major steel.

Item	Line Number/ Pipe Support/ Component	System	From/To	Original Plant P&ID
1	811-8"-KN	Circulating Water	From service water Reservoir to Service Water Pump (G17A)	568776
2	2071-2"-601	Chemical and Volume Control	From Regenerative HX to Residual Heat Removal Heat Exchanger	568767 & 568768
3	721-14"-HP	Feedwater and Condensate	From Condensate Storage Tank to Condenser E-2A & E-2B	568776 & 568779
4	342-2"-EG	Feedwater and Condensate	From Steam Generator E-1C to Blowdown Tank	568779
5	3048-8"-152N 8-PS-19	Auxiliary Coolant	Component Cooling Pump to Component Cooling HX	568768
6	3086-6"-151R 8-PS-10*	Auxiliary Coolant	Spent Fuel Pit HX to CCW Pump	568768
7	454-10"-HP Data Pt. 140	Circulating Water	CCW HX to Turbine Plant Cooler	568775
8	728-8"-HP 14-PS-57**	Miscellaneous Water	From Recirc. HX to Refueling Water Pumps	568776
9	737-8"-HP 1-737-UG-002	Miscellaneous Water	Reactor Refueling Cavity to Recirc. HX	568776
10	6003-16"-151R 14-PS-4*	Safety Injection	Safety Injection Pump to Feedwater Pump	568769
11	E-20A/B	Auxiliary Coolant System	CCW HX	568768 & 568775
12	E-34	Chemical and Volume Control	Seal Water HX	568768