ENCLOSURE 1

INSTRUCTURE RESPONSE SPECTRA
FOR THE
TURBINE BUILDING MEZZANINE

SAN ONOFRE NUCLEAR GENERATING STATION

UNIT 1

JUNE 1986

REVISION 1

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1.0 INTRODUCTION

The mezzanine at El. 30' of the north extension of the Turbine Building was upgraded to respond elastically under design loading conditions. The purpose of this report is to:

a. Describe the development of the instructure response spectra of the mezzanine.

b. Evaluate the effects of the modifications implemented in the mezzanine on the overall Turbine Building response.

c. Describe the reanalyses of piping systems FW-04 and SI-51.

2.0 DESCRIPTION OF THE MODIFICATIONS

The structural modifications made to the mezzanine framing are as follows:

a. Beams which may have responded inelastically under design loads have been strengthened by using cover plates.

b. Two in-plane trusses, one spanning in the east-west direction and the other spanning in the north-south direction have been added.

c. Four columns/kickers have been added. These are founded on the existing combined north extension column footing.

d. A new column was added and is supported by a new foundation.

These modifications are shown in Figure 1.

3.0 DESCRIPTION OF THE DYNAMIC ANALYSIS MODEL

The overall model utilized in the generation of instructure response spectra is derived from the global model of the Turbine Building and the turbine generator pedestal (Reference 1).

The Turbine Building consists of four individual structural steel systems which surround the concrete turbine pedestal. These four structural systems are known as the Turbine Building north and south extensions, and the east and west heater platforms. Since the east and west heater platforms, and the south extension do not have a direct link with the north extension and the turbine pedestal is a massive concrete structure which dominates the response of the Turbine Building, the east and west heater platforms, and the south extension were not included in the dynamic analysis model. The global model consists of the north extension, the turbine generator pedestal and the spent fuel pool as was detailed in Reference 1 and the upgraded mezzanine framing (see Figure 2).

The soil-structure interaction effects were taken into account by lumped parameter representation of the soil medium stiffness and damping. In computing the soil parameters, the in-situ soil conditions were utilized (Reference 2). The composite modal damping was conservatively limited to 20 percent.

The time histories utilized are those described in Reference 3. The time histories are statistically independent. Therefore, they were applied simultaneously and the responses were combined algebraically.

4.0 EVALUATION OF RESULTS

The dynamic response characteristics of the model used herein were compared with the results described in References 1, 2 and 3. This was performed to identify whether the structural modifications implemented in the mezzanine framing affected the overall dynamic response of the Turbine Building significantly.

The frequency characteristics of the first three fundamental modes were compared in Table I. The frequencies of the model described herein (Section 3.0) have decreased by 6, 2 and 11 percent in the North-South (NS), Vertical (V) and East-West directions, respectively.

The zero period accelerations (ZPA) were compared in Table II at the location of the north extension operating deck (El. 42') where the dominant responses were obtained in References 1 and 2. The ZPA's at this point increased by 3 percent in the NS direction and decreased by about 3 and 6 percent in the V and EW directions, respectively.

The changes to the frequency content and magnitude of the responses were considered to be negligible and therefore, the effect of the modifications to the mezzanine framing was insignificant on the overall response of the Turbine Building.

The modifications did change the responses at the mezzanine level significantly such that new instructure response spectra were computed for the mezzanine. The enveloping and broadening of the mezzanine response spectra are described in Section 5.0.

Due to the changes in the design spectra for the mezzanine, the mezzanine framing and systems that are supported on the mezzanine were reevaluated. Structural steel members were qualified for the new loads and their stress levels were less than or equal to 1.6 times the stress allowables of AISC Specification, Part 1. The reanalyses of FW-04 and SI-51 are described in Section 6.0.

5.0 INSTRUCTURE RESPONSE SPECTRA

The results of the analysis consisted of the instructure response spectra at the mezzanine (node number 31) in the NS, EW and V directions for 2, 3, 4, 5, 7 and 15 percent damping. The response spectra were modified with "correction factors" using the methodology described in Reference 3. This methodology is identical to the one used in the development of the LTS design spectra for the entire Turbine Building. The correction factors are defined as the ratio of the spectral acceleration at the mezzanine location obtained from the .67g Modified Housner Spectra to the spectral acceleration value obtained from the spectra corresponding to the free-field time histories. The correction factors are frequency as well as damping dependent, i.e. , a different factor is calculated for each frequency (period) point and for each damping value. These correction factors typically range from .85 to 1.10. More information on the methodology of correction factors can be found in Reference 3.

Consistent with LTS procedure, the "factored" spectra were broadened by ±15 percent and then smoothened. The smooth design spectra are shown in the enclosed figures for the NS (SK-C-125A, Rev. A), EW (SK-C-126A, Rev. A) and V (SK-C-127A, Rev. A) directions. These spectra are to be used in conjunction with Figures SK-C-125, Rev. E, SK-C-126, Rev. D and SK-C-127, Rev. C of Reference 3 for the qualification and design of systems and components located on the north extension mezzanine of the Turbine Building.

6.0 EVALUATION OF PIPING SYSTEMS FW-04 AND SI-51

Piping systems FW-04 and SI-51 were analyzed using the spectra described in Section 5.0 and enveloped with the other appropriate spectra of the Turbine Building. Both FW-04 and SI-51 were analyzed using envelope response spectra with PVRC damping. The envelope response spectra for the FW-04 and the SI-51 analyses are shown in Figures 3 to 8. Also, the PVRC damping spectra curves which were used to develop the enveloped response spectra are listed in Tables III and IV for FW-04 and SI-51, respectively.

All the piping, pipe supports and equipment associated with these piping problems were qualified to the LTS criteria without the use of any case-by-case methodologies. SI-51 required no additional pipe support modifications and the maximum piping stress point in the mezzanine area (including SAM) was 99 percent of the ASME Section III Equation 9 (occasional load) code allowable. For FW-04, four new pipe supports were added and seven pipe supports were modified. The support changes were caused by the modifications of the FW-04 piping due to the water hammer effort in conjunction with the seismic qualification effort. The water hammer effort had resulted in the relocation of the 10 inch check valves. The maximum piping stress point (including SAM) for FW-04 in the mezzanine area was 92 percent of the ASME Section III Equation 9 (occasional load) code allowable.

7.0 CONCLUSION

The modifications to the mezzanine framing do not affect the overall dynamic response of the Turbine Building based on the comparisons of the first fundamental frequencies of the global model and the ZPA's at the north extension operating deck.

Instructure response spectra were developed for the mezzanine and the methodology was consistent with the LTS criteria and the seismic reevaluation program.

Piping systems FW-04 and SI-51 were qualified to the LTS criteria using enveloped response spectra analysis with PVRC damping and no case-by-case methodologies.

REFERENCES

1. Enclosure to letter dated April 30, 1982 from K. P. Baskin (SCE) to D. M. Crutchfield (NRC)

2. Enclosure to letter dated September 31, 1983 from R. W. Krieger (SCE) to D. M. Crutchfield (NRC).

3. Generation of Floor Response Spectra for the Reactor and Turbine Buildings, San Onofre Nuclear Generating Station - Unit 1, Long Term Service Re-evaluation Program, March 1986.

TABLE I. FREQUENCY COMPARISON

Fundamental Frequency (cps)

Direction	Present Analysis	Reference 1, 2	Percent Change
NS	3.10	3.31	-6
V	3.17	3.24	-2
EW	2.6	2.91	-11

TABLE II. ZERO PERIOD ACCELERATION COMPARISON

North Extension Operating Deck (El. 42')

Acceleration in g's

Direction	Present Analysis	Reference 3	Percent Change
NS	1.19	1.15	+3
V	0.86	0.89	-3
EW	1.19	1.26	-6

TABLE III. FW-04 SPECTRA LIST

DESCRIPTION

N-S EL. 30' Turbine Building Mezzanine Area 2 Column
E-W EL. 30' Turbine Building Mezzanine Area 2 Column
V EL. 30' Turbine Building Mezzanine Area 2 Column

N-S EL. 42' Turbine Building Deck Area 2
E-W EL. 42' Turbine Building Deck Area 2
V EL. 42' Turbine Building Deck Area 2

N-S EL. 24' Turbine Building Area 4
E-W EL. 24' Turbine Building Area 4
V EL. 24' Turbine Building Area 4

N-S EL. 42' Turbine Building Deck Area 4
E-W EL. 42' Turbine Building Deck Area 4
V EL. 42' Turbine Building Deck Area 4

N-S EL. 31' Reactor Building Steel Sphere
E-W EL. 31' Reactor Building Steel Sphere
V EL. 31' Reactor Building Steel Sphere

N-S EL. 30' Turbine Building Mezzanine Area 2
E-W EL. 30' Turbine Building Mezzanine Area 2
V EL. 30' Turbine Building Mezzanine Area 2

PVRC damping spectra curves are shown in Reference 3, Appendix C and D.

TABLE IV. SI-51 SPECTRA LIST

DESCRIPTION

N-S	EL. 30'	Turbine Building Mezzanine Area 2 Column
E-W	EL. 30'	Turbine Building Mezzanine Area 2 Column
V	EL. 30'	Turbine Building Mezzanine Area 2 Column
V	EL. 42'	Turbine Building Deck Area 2 *
N-S	EL. 35.5'	Turbine Building Deck Area 5
E-W	EL. 35.5'	Turbine Building Deck Area 5
V	EL. 35.5'	Turbine Building Deck Area 5
N-S	EL. 35.5'	Turbine Building Deck Area 6
E-W	EL. 35.5'	Turbine Building Deck Area 6
V	EL. 35.5'	Turbine Building Deck Area 6
N-S	EL. 31'	Reactor Building Steel Sphere
E-W	EL. 31'	Reactor Building Steel Sphere
V	EL. 31'	Reactor Building Steel Sphere
N-S	EL. 30'	Turbine Building Mezzanine Area 2
E-W	EL. 30'	Turbine Building Mezzanine Area 2
V	EL. 30'	Turbine Building Mezzanine Area 2

* SI-51 only has vertical supports on the Turbine Building Deck at Elevation 42'.

PVRC damping spectra curves are shown in Reference 3, Appendix C and D.

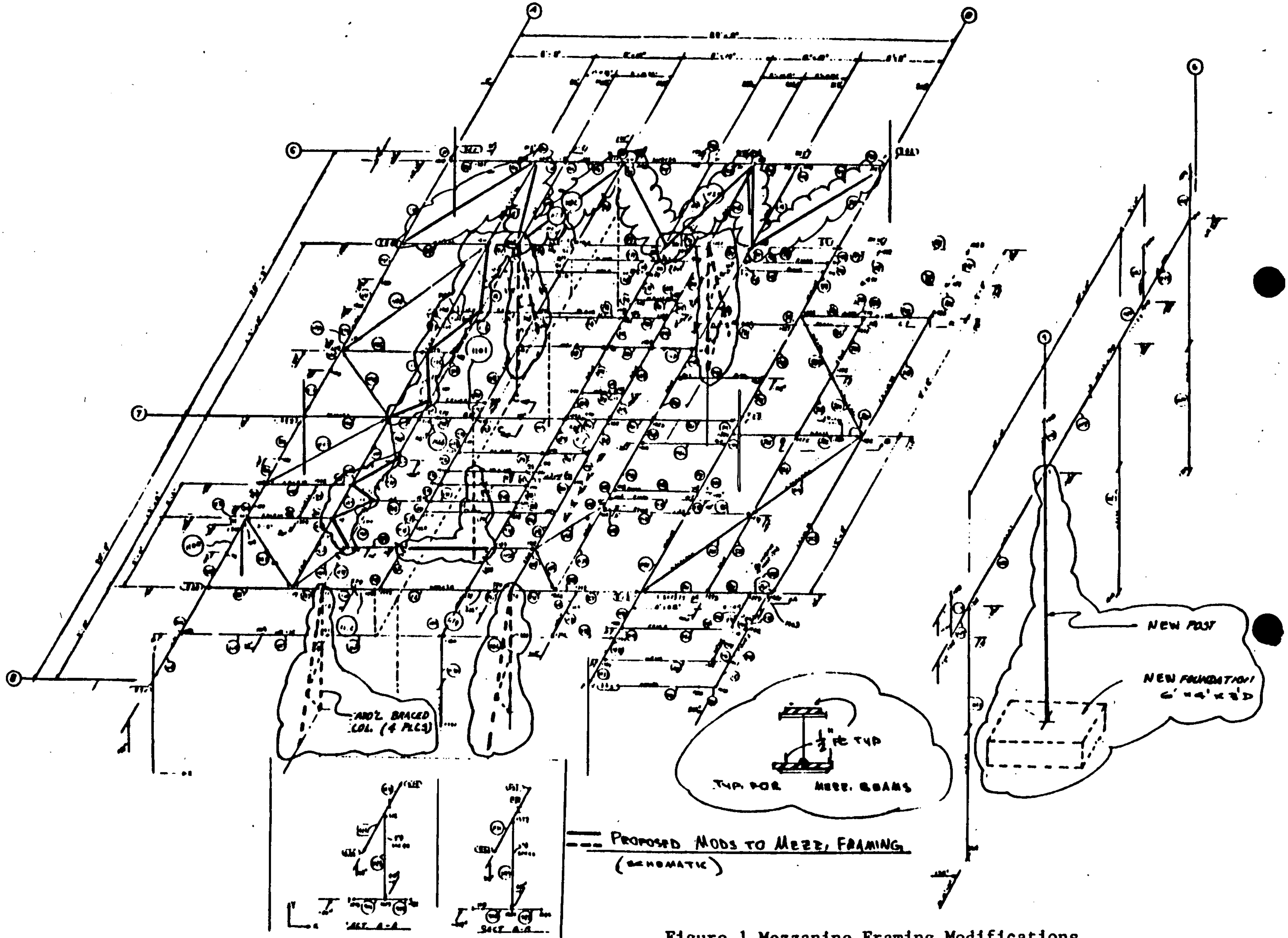


Figure 1 Mezzanine Framing Modifications

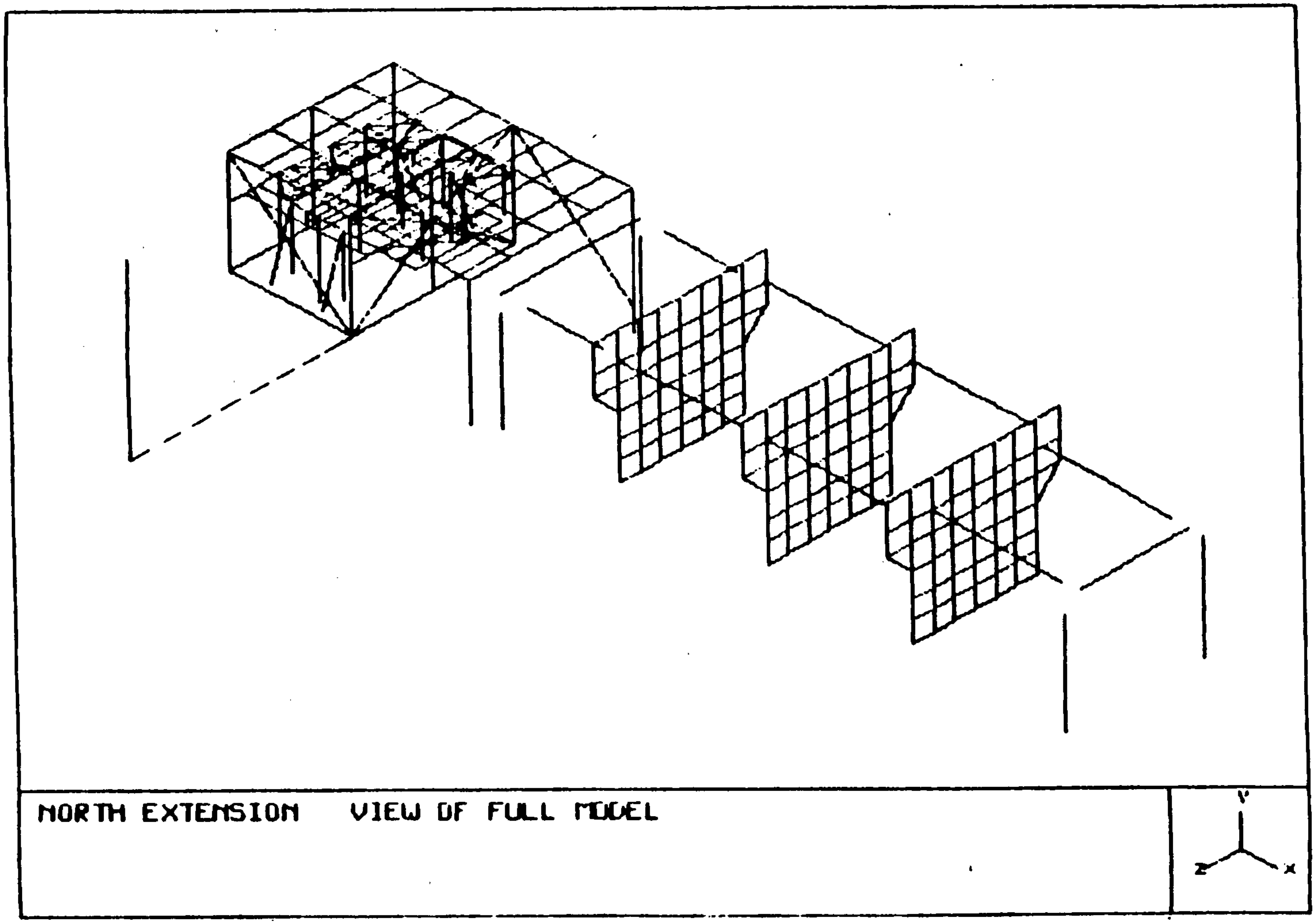
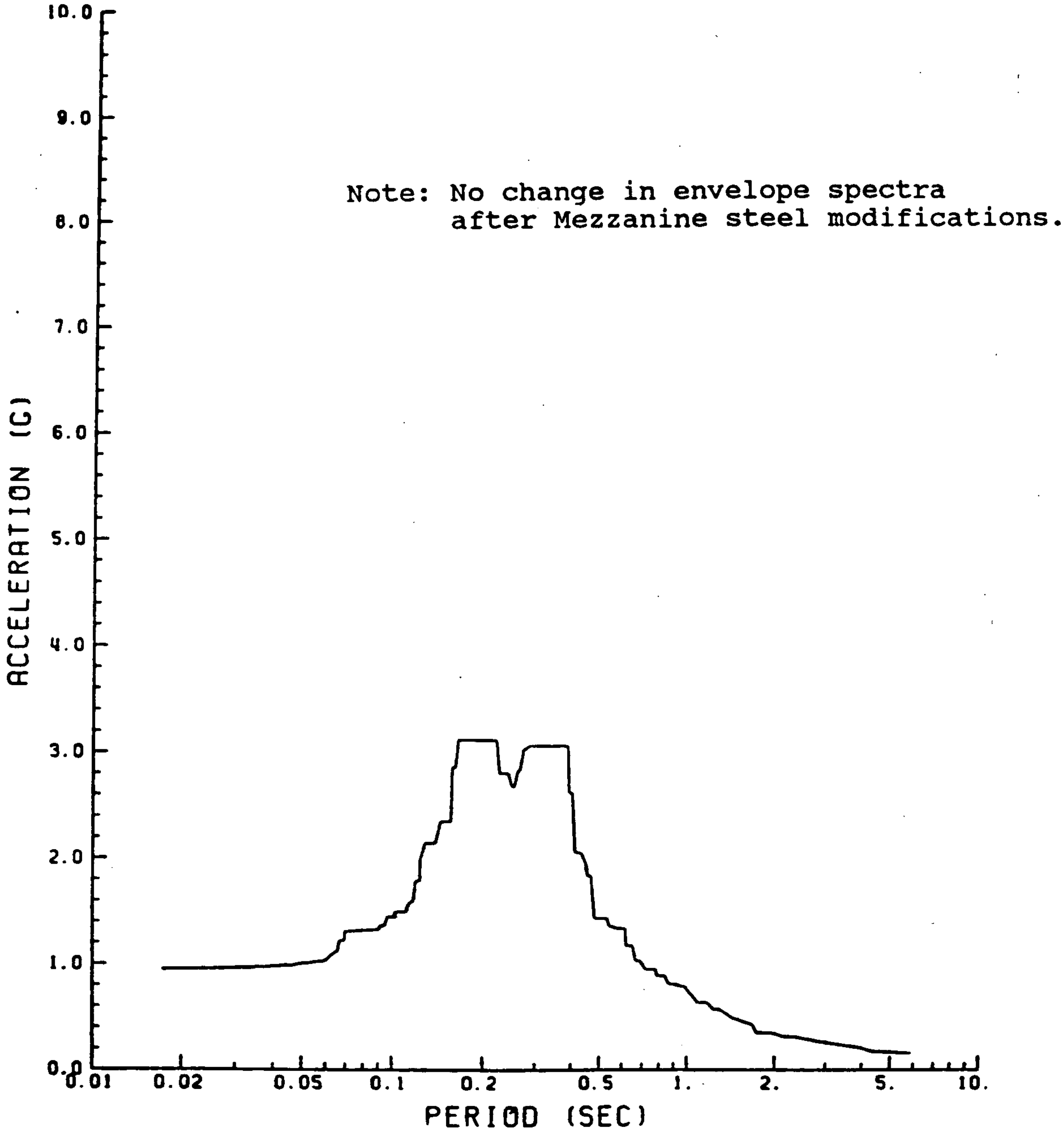
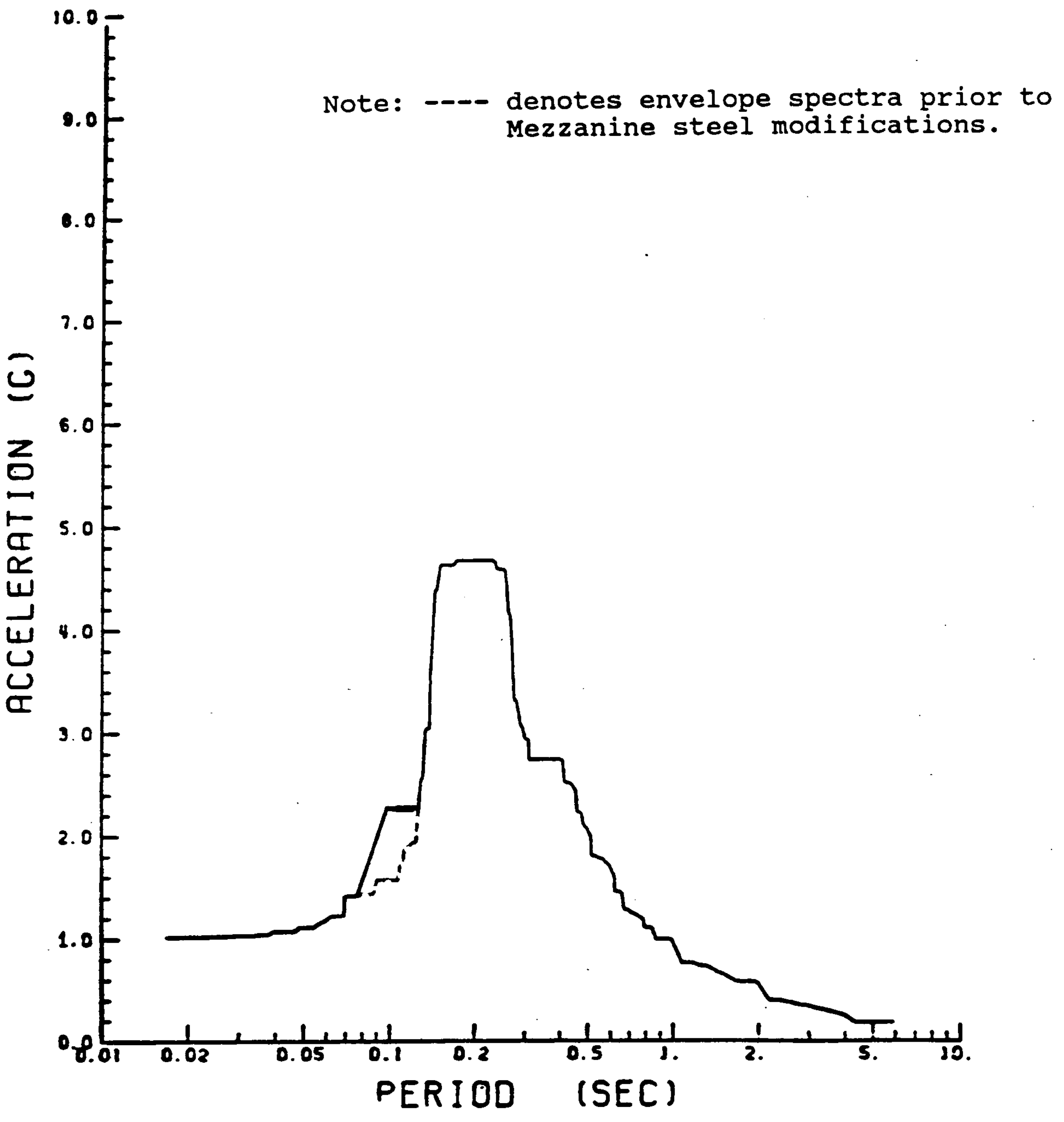


Figure 2 Turbine Building Dynamic Model



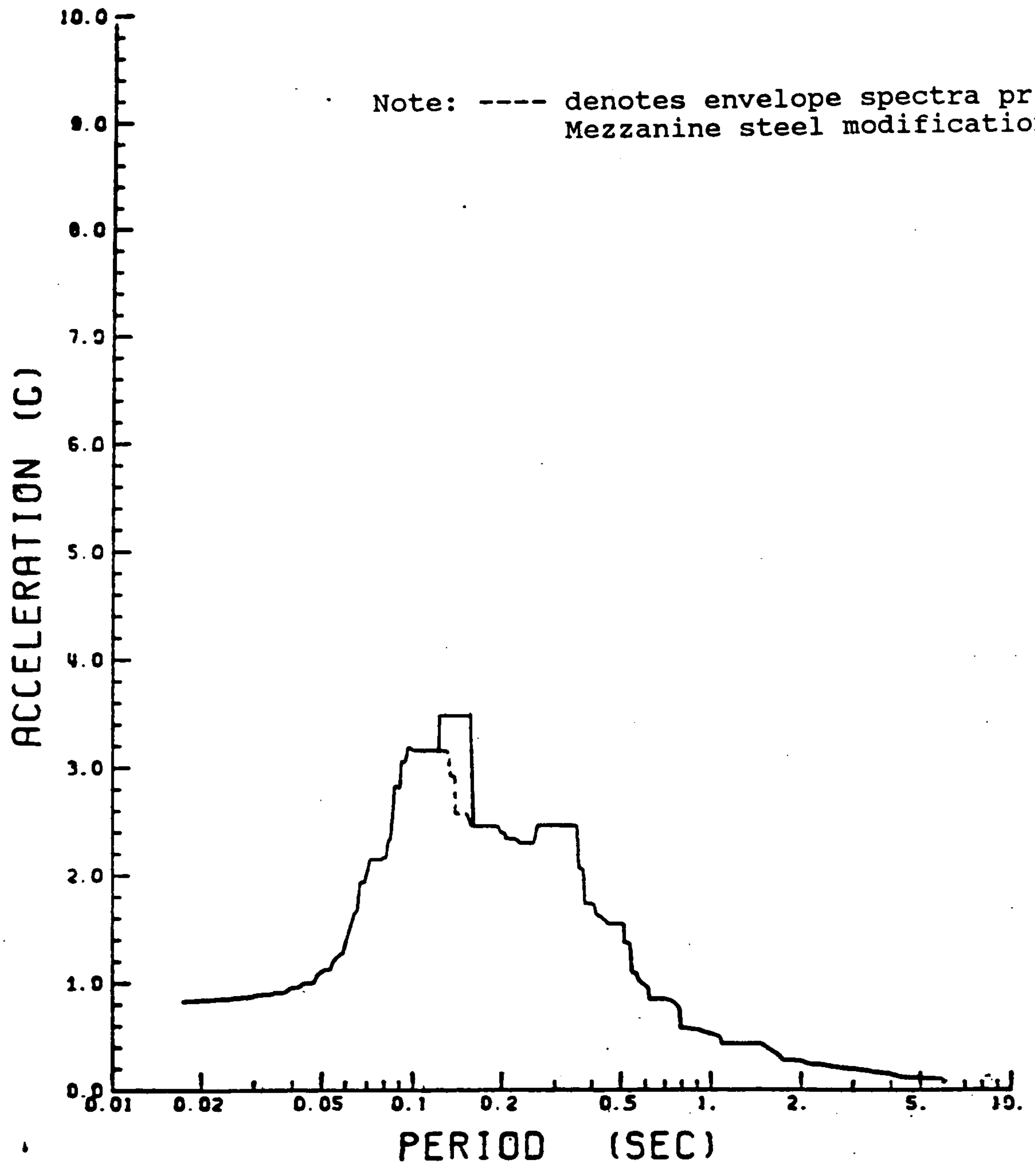
SONGS-1 FW-04 PRODUCTION PVRC SPECTRUM
N--S (X) DIR SPECTRUM

Figure 3



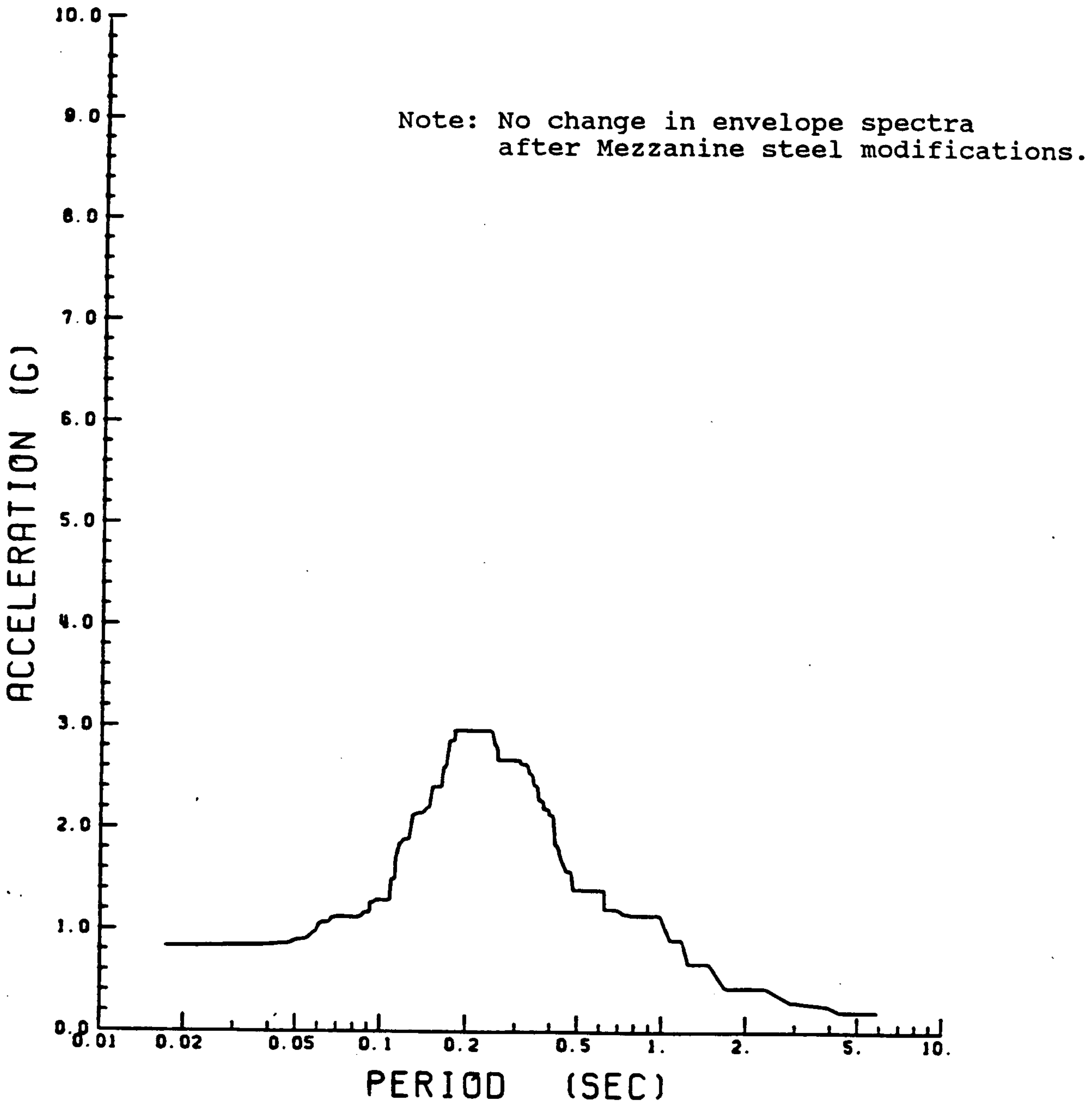
SONGS-1 FW-04 PRODUCTION PVRC SPECTRUM
E--W(Z) DIR SPECTRUM

Figure 4



SONGS-1 FW-04 PRODUCTION PVRC SPECTRUM
VERT(Y) DIR SPECTRUM

Figure 5



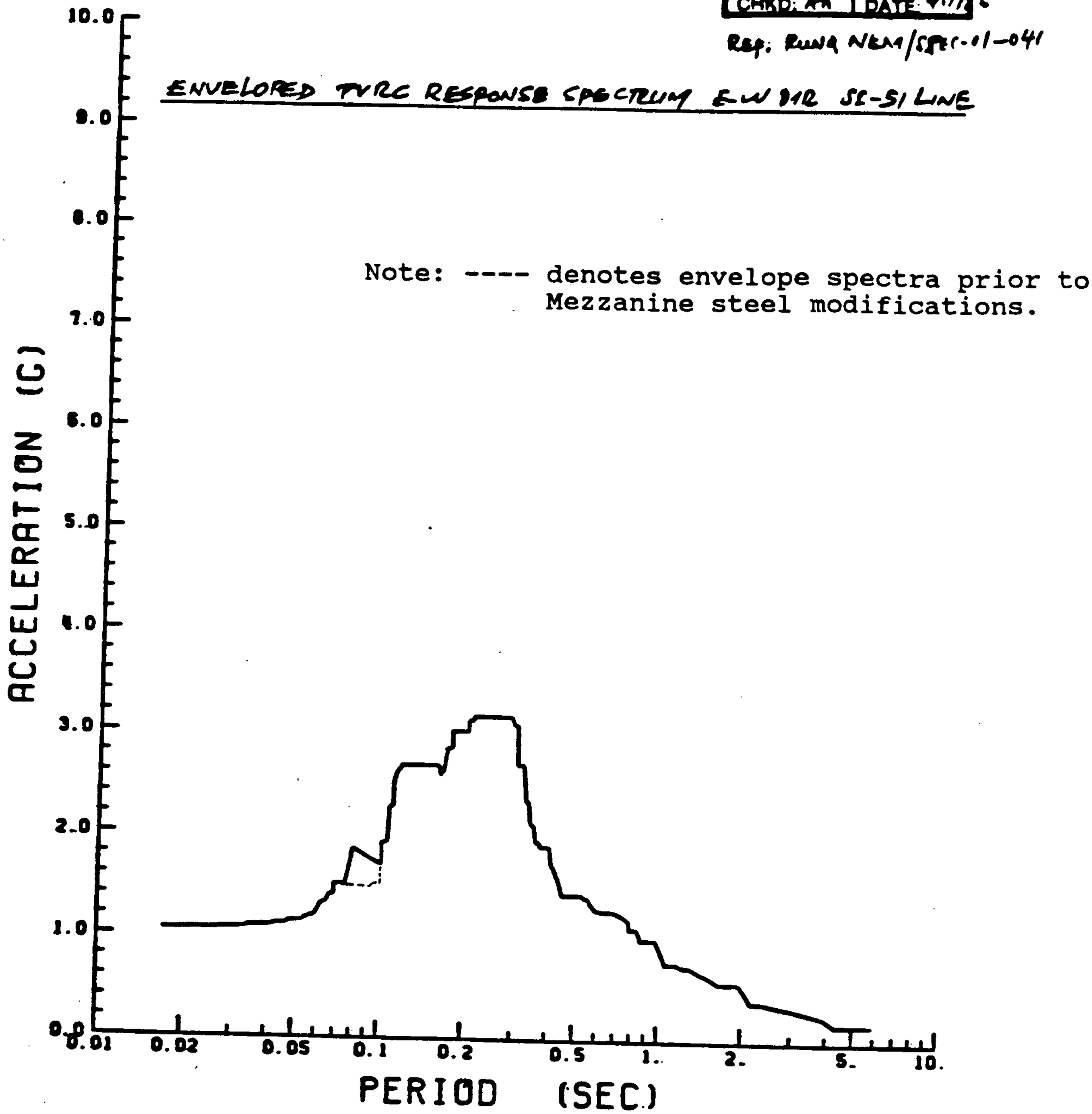
SONGS-1 SI51-ENVELOPED PVRC SPECTRUM
NORTH-SOUTH(X) DIRECTION

Figure 6

DESIGN VERIFICATION

CLIENT SCE
JOB NO. 03/0054 1355
CALC/PROB NO. NEM/SPEC-01
BY: GW DATE: 4-16-86
CHKD: AA DATE: 4/17/86

Ref: Run 4 NEM/SPEC-01-041



MEZZ. NODE 1243 ENVL W/PROD SPECTRUM
E--W (Z) DIR SPECTRUM SI-51

Figure 7

DESIGN VERIFICATION

CLIENT SCE

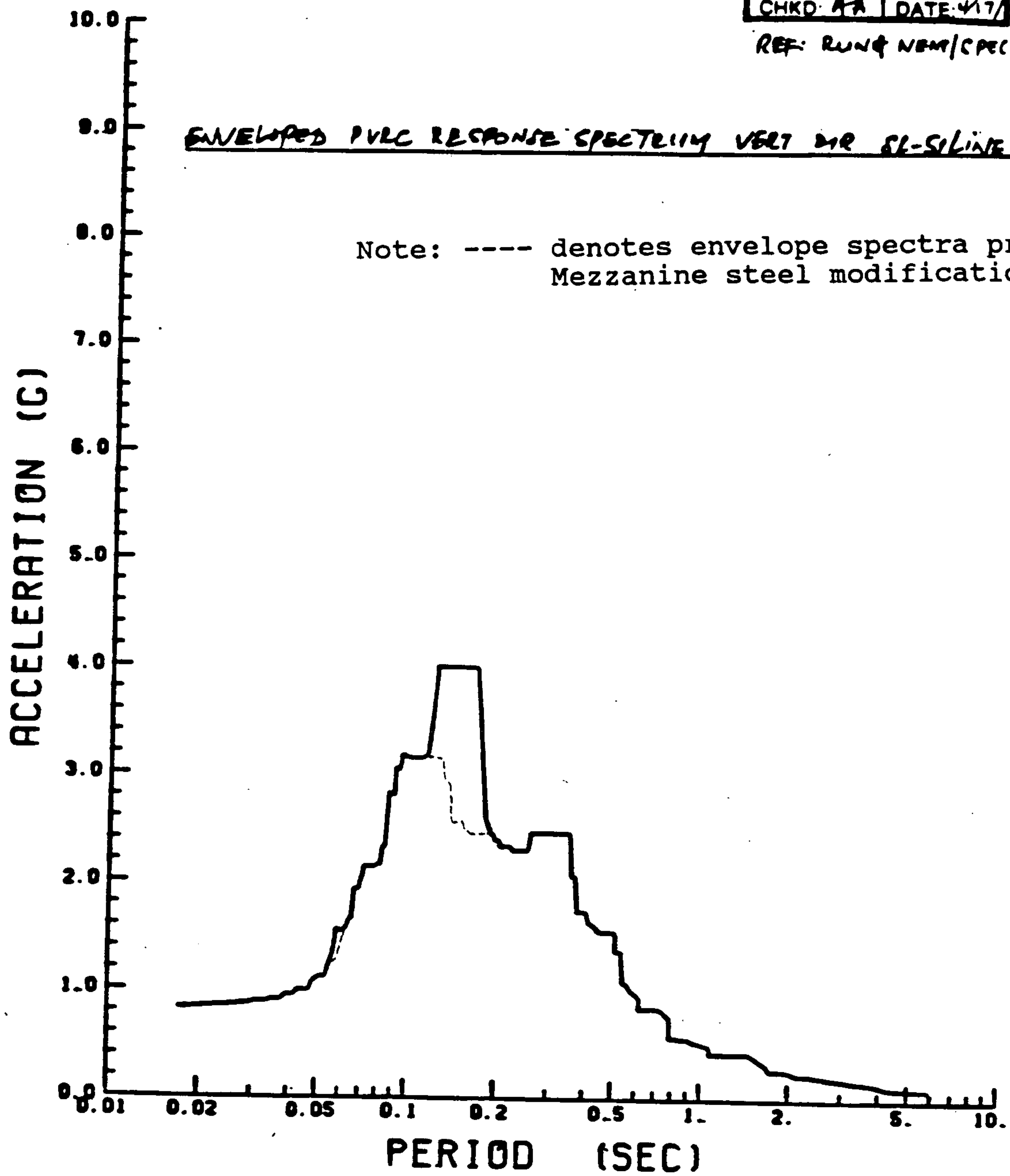
JOB NO. 03'0 054 135

CALC/PROB NO. NEM/SPEC-01

BY: GW DATE: 4-16-86

CHKD: AA DATE: 4/17/86

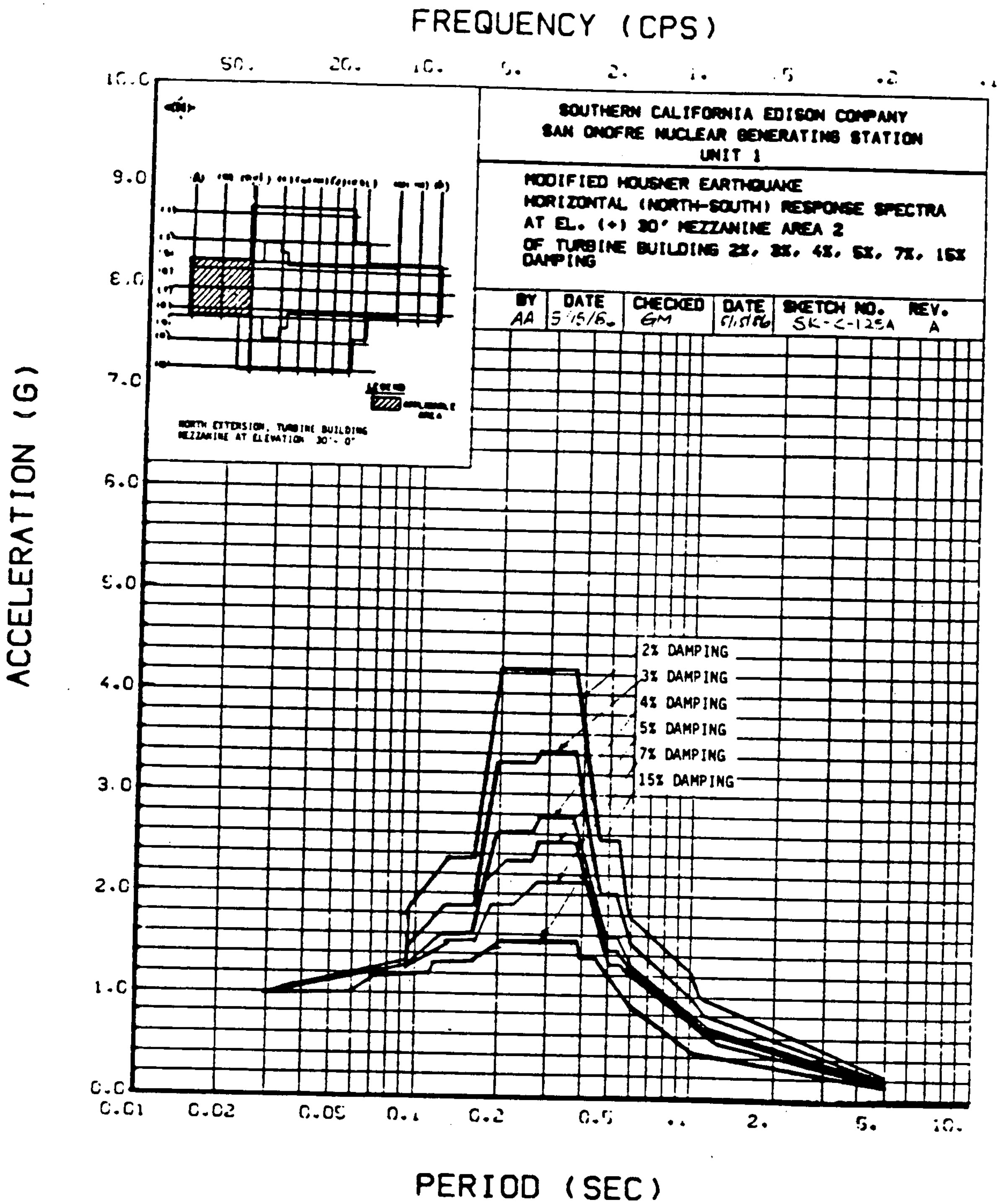
REF: RUN# NEM/SPEC-01-041



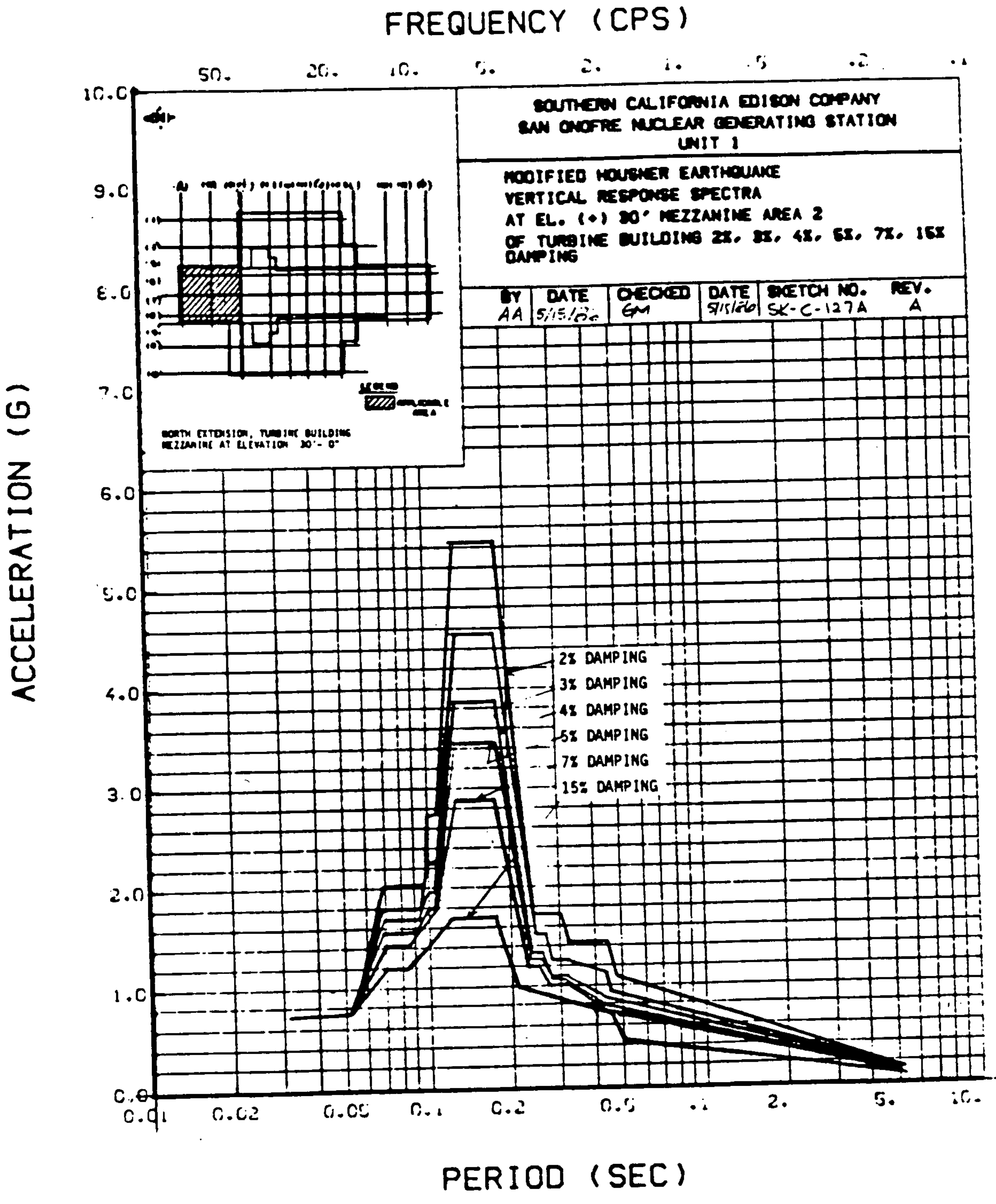
MEZZ. NODE 1243 ENVL W/PROD SPECTRUM

VERT(Y) DIR SPECTRUM SI-51

Figure 8



SONGS-1 MEZZ. BECHTEL NODE 31--X
BROADENED FACTORED SPECTRA



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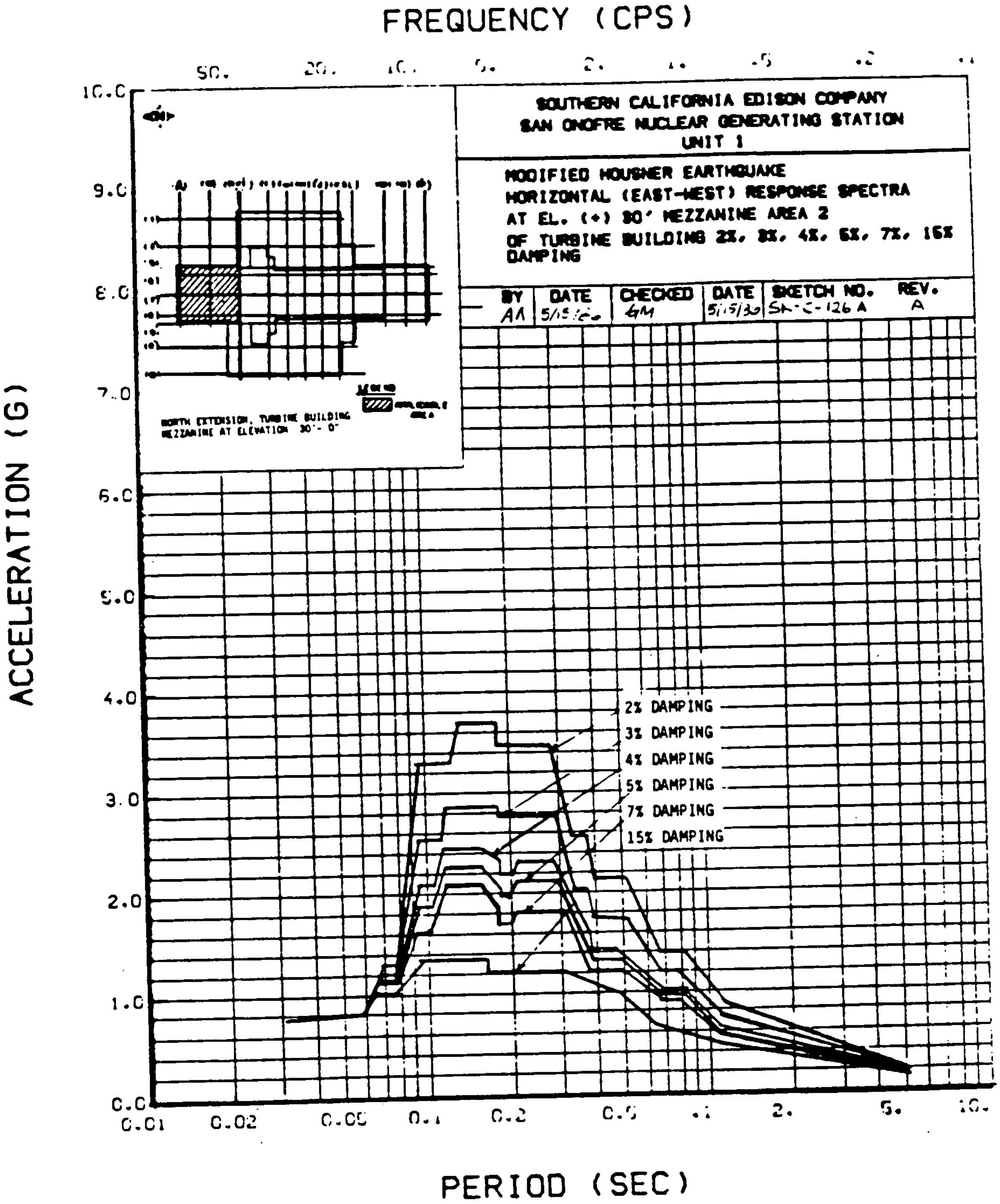

SONGS-1 MEZZ. BECHTEL NODE 31--Z
BROADENED FACTORED SPECTRA

ENCLOSURE 2

SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

SEISMIC PROGRAM FOR
LONG TERM SERVICE

Prepared by:

Impell Corporation

Report No. 01-0310-1368

Revision 1

May 28, 1986

~~8605300502~~ 26pp.

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1.0 INTRODUCTION

This document presents the program for the seismic review of San Onofre Nuclear Generating Station Unit 1 for Long Term Service (LTS), in response to the Nuclear Regulatory Commission's Systematic Evaluation Program.

In November 1984, the San Onofre Nuclear Generating Station Unit 1 (SONGS-1) was returned to service (RTS) after a lengthy outage. During the outage, many new hardware installations were made to upgrade the seismic capability of structures, piping and equipment. The NRC reviewed the seismic capability of SONGS-1 during this outage, and issued a Safety Evaluation Report (SER) documenting their findings [1]. Their findings state that the RTS structures, systems and equipment have adequate assurance of seismic capability to ensure public health and safety, to withstand a 0.67g Modified Housner Design Spectrum event. Other systems are similarly adequate to withstand a 0.50g DBE. The NRC stated that the design criteria and methodologies used for RTS were satisfactory for the continued operation of SONGS-1 for one refueling outage. For LTS, the NRC has required Southern California Edison (SCE) to demonstrate the seismic capability of SONGS-1 to a set of design criteria and methodologies suitable for long term operation of the station.

The design criteria and methodologies that SCE will use to demonstrate the seismic capability of SONGS-1 for LTS follow the philosophy proposed by Drs. Newmark and Hall in NUREG/CR-0098 [20].

> "It is well known that upgrading and retrofitting constitute expensive operations when they can be accomplished at all. In many cases it is economically, if not physically, impossible to carry out significant seismic upgrading improvements. In those cases, where it is possible economically it is desirable to take advantage of the latest concepts pertaining to development of seismic resistance. ...it is possible (and desirable) to take into account the modest amount of nonlinear behavior that can be permitted in many portions of systems without significant decrease in the margin of safety against safe shutdown or containment."
>
> It is observed that "the inherent seismic resistance of well designed and constructed systems is usually much greater than that commonly assumed, largely because nonlinear behavior is mobilized to limit the imposed forces and accompanying deformations. For such systems where the resistance is nondegrading for reasonable deformations, the requirements for retrofitting may be nonexistent or at most minimal."

SCE believes that SONGS-1, in its current configuration, has the seismic withstand capability to meet its original design basis for a 0.50g DBE event. Based on the philosophy described above, SCE will use current methodologies and realistic criteria to demonstrate the seismic withstand capability of SONGS-1 to meet the current 0.67g Modified Housner Design Spectrum and will retrofit where necessary.

Subsequent to the March 12, 1985 submittal of this report, the NRC identified issues requiring resolution in their March 27, 1985 letter to SCE [24]. In September 1985, the NRC issued a Safety Evaluation Report for the SONGS-1 LTS seismic reevaluation criteria and methodology [2]. Revision 1 of this report incorporates the changes resulting from the NRC evaluation as stated in the SER and the March 27, 1985 NRC letter [2,24]; as well as responses and resolutions to the comments raised by the NRC and their consultants during numerous NRC audit meetings since March 1985.

2.0 SCOPE

The Return to Service Program included structures and systems required to attain a hot standby condition. The scope of the Long Term Service Program will include all structures and systems previously evaluated and upgraded, with the addition of the South Extension of the Turbine Building. The previously established hot standby capability will be improved by reevaluating and, if necessary, upgrading the Refueling Water Storage Tank to provide the source of borated water for reactor coolant make-up (the Spent Fuel Pool will not be used). In addition, the hot standby capability will be augmented by upgrading systems and equipment necessary to achieve cold shutdown and to provide accident mitigation. This will include the replacement of the cast iron piping between the Saltwater Cooling pumps and the Component Cooling Water heat exchangers.

2.1 Structures

All major plant structures will be capable of withstanding a 0.67g Modified Housner Design Spectrum event, including:

Reactor Building
Containment Sphere
Sphere Enclosure Building
Reactor Auxiliary Building
Ventilation Equipment Building
Control and Administration Building
Fuel Storage Building
Seawall
Intake Structure
Turbine Pedestal and Turbine Building Extensions
Diesel Generator Building
Masonry Walls

2.2 Systems and Equipment

As a minimum, the following systems will be capable of withstanding a 0.67g Modified Housner Design Spectrum event:

Reactor Coolant Pressure Boundary
Main Steam and Main Feedwater Piping
Atmospheric Steam Dump System
Auxiliary Feedwater System
Chemical and Volume Control System for Reactor Coolant Make-up
Safety Injection System
Containment Spray System
Post-LOCA Recirculation System
Saltwater Cooling System

Detailed system boundaries have been developed in the form of a scope chart and marked-up P&IDs as part of the Long Term Service Program.

3.0 DESIGN CRITERIA

3.1 Large Bore Piping

The general criteria for the piping systems shall be based upon the requirements set forth in Section III, Subsection NC of the 1980 ASME B&PV Code [3]. Stress allowables shall be taken from the Systematic Evaluation Program (SEP) criteria previously applied to SONGS-1 piping. Alternatively, specific strain criteria may be applied to demonstrate piping capability (i.e., the limitation of pipe ovalization to maintain rated flow) to withstand a 0.67g Modified Housner Design Spectrum. In general, large bore piping analysis will be performed via response spectrum computer analysis. However, on a case-by-case basis, conservative hand calculations may be performed. Pipe supports and structural steel members carrying pipe loads shall be individually assessed per criteria in Sections 3.3 and 3.4. Interface boundary loads at equipment nozzles, penetrations, tanks, etc., and valve accelerations shall be assessed per criteria in Sections 3.5 thru 3.8.

3.1.1 Primary Stresses

Primary stresses resulting from internal pressure, gravity, and 0.67g Modified Housner Design Spectrum loads shall be compared to SEP allowables, as defined below:

$$\frac{PD_o}{4t} + 0.75\, i\, \frac{M_a+M_b}{Z} \leq kS_h$$

where

P	=	Maximum internal operating pressure, psig
D_o	=	Outside diameter of pipe, in
t	=	Nominal wall thickness of pipe, in
Z	=	Section modulus, in^3
i	=	Stress intensification factor as listed in Table NC-3673.2(b)-1 of ASME B&PV, Section III, Subsection NC, 1980 Edition, Winter 1980 Addenda [3]. The product of 0.75i is never below 1.0.
M_a	=	Resultant moment due to gravity loads, in-lb
M_b	=	Resultant moment due to Modified Housner Design Spectrum inertia, as calculated by linear elastic methods, in-lb (Resultant moment due to amplitude of Modified Housner Design Spectrum anchor movements may be combined with intertia moments by Square-Root-of-the-Sum-of-Square (SRSS) method, if omitted in the secondary stress check).
S_h	=	Piping material allowable stress at maximum operating temperature, psi (obtain S_h from Appendix I of the ASME Code [3]).
k	=	2.4 for Class 2 and 3 piping
	=	1.8 for Class 1 piping

3.1.2 Stress-Strain Correlation

In cases where the elastically calculated primary stress exceeds the SEP allowables, piping may be alternatively qualified with a stress-strain correlation. This qualification requires that the piping strain associated with an elastically-calculated primary stress be determined and limited, as detailed in [12] and [13].

The stress to strain conversion and strain limits are as follows:

For carbon steel $\quad \epsilon_t = K_S \dfrac{\sigma_e}{E} \leq 1\%$

For stainless steel $\quad \epsilon_t = K_S \dfrac{2.0\sigma_e}{E} \leq 2\%$

where

ϵ_t = pipe membrane plus bending strain
σ_e = elastically-calculated primary stress based on stress intensification factor approach, psi
E = Young's modulus, psi (obtain E from Appendix I of the ASME Code [3])
K_S = Strain correlation factor.

The strain correlation factor K_S is defined as follows:

$K_S = 1.0$ $\quad$ when $3.4 \dfrac{\sigma_e}{S_y} \leq 1.0$

$K_S = 1.0 + \dfrac{1 - n}{n(m-1)} \left(3.4 \dfrac{\sigma_e}{S_y} - 1\right)$ $\quad$ when $1.0 < 3.4 \dfrac{\sigma_e}{S_y} \leq m$

$K_S = 1/n$ $\quad$ when $m < 3.4 \dfrac{\sigma_e}{S_y}$

where

S_y = Piping material yield strength at maximum operating temperature, psi (obtain S_y from Appendix I of the ASME Code [3])
n = Strain hardening exponent
m = Code-defined parameter to produce correction correlation.

The material parameters n and m used on SONGS-1 piping are defined in Table NB-3228.3(b)-1 of the ASME Code [3] and are summarized below:

Material	m	n
Stainless Steel	1.7	0.3
Carbon Steel	3.0	0.2

For stainless steel piping, two additional checks will be performed if the calculated strain is in the range of 1 to 2 percent as follows (both checks 1 and 2 need to be satisfied):

Check 1: $\epsilon_t \leq 0.2 \frac{t}{R}$

where

t = nominal wall thickness of pipe, in
R = mean radius of pipe, in

Check 2: $\frac{n}{N} \leq Ua$

where

n = Number of significant cycles for a Modified Housner Design Spectrum event
N = Number of allowable cycles for a Modified Housner Design Spectrum event
Ua = Allowable usage factor for Modified Housner Design Spectrum event

N will be calculated as follows:

$$N = \left[\frac{91.875}{0.75i \; \frac{M}{Z}} \right]^5$$

where

M = Resultant elastically calculated moment due to a Modified Housner Design Spectrum event (in-kip).
Seismic anchor movement moments may be combined with inertia moments by SRSS methods.

Piping may be qualified by the strain criteria above, provided that the following constraints are observed:

(1) In calculating the intensified primary stress σ_e, at least 50% of σ_e is due to earthquake loading.

(2) In calculating moments due to earthquake loading, a response spectrum method is used, with damping not exceeding that specified in Code Case N-411 [9].

(3) Diameter/wall thickness ratio (D_o/t) does not exceed 50.

(4) Weldments as well as piping base materials are ductile. (No quenched and tempered ferritic steels or cold worked austenitic stainless steels.)

(5) Joints are butt welded or girth fillet welded. (Bolted-flanged joints are qualified per the requirements of NC-3658 of the ASME Code [3].)

(6) The cumulative usage factor due to a Modified Housner Design Spectrum event does not exceed 0.25.

(7) A clearance check for pipe displacement, as detailed in [13], shall be performed for large bore piping qualified by the strain criteria.

(8) A boundary load capacity check (pipe supports, mechanical equipment, penetrations, valves, etc), as detailed in [14], shall be performed for large bore stainless steel piping qualified by the strain criteria and with strain exceeding 1 percent.

3.1.3 Secondary Stresses

Secondary stresses resulting from thermal expansion, thermal anchor movements, and seismic anchor movements shall be compared to ASME Code allowables, as defined below:

$$\frac{iM_c}{Z} \leq S_A$$

where

M_C = range of resultant moments due to thermal expansion and thermal anchor movements, in-lb. Also include moment effects of seismic anchor movements due to a Modified Housner Design Spectrum event if omitted in the primary stress check.

S_A = allowable stress range for expansion stresses, psi $f(1.25\ S_C + 0.25\ S_h)$

S_C = basic material allowable stress at minimum (cold) temperature, psi

S_h = basic material allowable stress at maximum (hot) temperature, psi

f = stress range reduction factor from Table NC-3611.2(c)-1 of the ASME Code [3].

Secondary stresses may alternatively be combined with stresses due to internal pressure, gravity, and other sustained loads and be compared to Code allowables, as defined below:

$$\frac{PD_o}{4t_n} + 0.75i\frac{M_a}{Z} + i\frac{M_c}{Z} \leq (S_h + S_A)$$

3.1.4 Non-Repeated Anchor Movement Stresses

Stresses due to the effects of any single non-repeated anchor movement (e.g., predicted building settlement) shall be compared to ASME Code allowables, as defined below:

$$\frac{iM_D}{Z} \leq 3.0\ S_c$$

where

M_D = resultant moment due to any single non-repeated anchor movement, in-lb

3.1.5 Additional Criteria

Piping analysis shall be performed by methods generally accepted by the nuclear power industry. The following criteria shall be used where applicable:

(1) Branch Line Decoupling: In general, a branch line may be decoupled from any piping provided that: (a) the moment of inertia ratio is greater than or equal to 25 for a pipe diameter ratio greater than or equal to 3; (b) decoupling would not be allowed if there is an anchor or another branch-line in close proximity; and (c) decoupling would not be allowed if the pipe segment includes a termination which defines a reaction load. If this decoupling criteria is satisfied, then the run line may then be evaluated, without considering the branch line. The branch line may be evaluated considering the run line to be an anchor with imposed movements. In other cases, the branch line shall be included with the model of the run line, up to an anchor point or up to and including the second support in each of three orthogonal directions.

As an alternative, a coupled run line and branch line analysis is acceptable.

(2) Seismic to Non-seismic Piping Decoupling Criteria: If a line contains a seismic to non-seismic boundary, the piping analysis will include a portion of non-seismic piping either to the next anchor point, or to the second support in each of three orthogonal directions, whichever is closer.

(3) Support Stiffnesses: Generic stiffness values (see Table 3.1-1) will be used to model pipe supports for computer analysis. These values reflect the lower bound support stiffnesses used for the typical pipe support design. They are compatible with the stiffness values used for other nuclear power plants. For cases where pipes are connected to flexible secondary structures or pipe supports, the influence of this flexibility shall be assessed.

(4) Snubber/Rigid Support Interaction: Wherever a snubber is located in close proximity to a rigid support, the analysis shall assume that the snubber fails to lock. Snubbers are considered inactive if their locations, with respect to a rigid support in the same direction, fall within the following distances:

(a) 3 times the pipe diameter, for pipe sizes equal to or greater than 8" in nominal diameter, and

(b) 5 times the pipe diameter, for pipe sizes less than 8", but greater than 2" in nominal diameter.

If the seismic analysis displacement, in the direction of restraint is greater than 1/16 of an inch at an inactive snubber location, the snubber may be considered to be functional. The line may then be reanalyzed with the snubber activated.

3.2 Small Bore Piping and Tubing

Small bore piping (NPS equal to or less than 2 inches) and tubing shall be qualified by applying simplified procedures as defined in the report entitled "SONGS-1 LTS Program, Review and Development of Small Bore Piping and Tubing Criteria" [15]. Application of these hand calculation criteria ensure that allowable stresses or strains, as defined in Section 3.1 are satisfied.

Alternatively, computerized piping analysis may be performed to qualify small bore piping and tubing.

3.3 Pipe Supports

The pipe support criteria for LTS are developed for the following component types:

- Structural steel
- Concrete expansion anchor bolts
- Catalog items
- Welds

The criteria are presented in Table 3.3-1. The following subsections discuss the criteria in detail.

3.3.1 Structural Steel

The capacity of structural steel components will be obtained by applying the design requirements for structural steel members. These are described in the ASME Boiler & Pressure Vessel Code, Section III, 1983 Edition, and include the Summer 1983 Addenda for Level D loads [4] (Summer 1983 Addenda has revised Level D allowables for structural steel).

In applying the Code rules, a departure from the Code will be taken for the qualification of steel supports. The Code values for material yield stress will be increased by 18 percent to represent the average rather than the lower bound yield stress. This overstrength is based on the yield stress test results reported in Reference [21]. This allowance will be credited for only those materials at SONGS-1 for which these test results are applicable. For steel components loaded at high strain rates, a 10 percent increase in yield stress will be taken. In combination, these two factors result in a 30 percent increase in yield stress. See also [22,23] for further discussion.

3.3.2 Concrete Expansion Anchor Bolts

The allowable loads for concrete expansion anchor bolts will be obtained by using the manufacturer's reported ultimate capacity with a minimum factor of safety of four on wedge type anchor bolts and five on shell type anchor bolts. On a case-by-case basis, a factor of safety less than four will be used to qualify existing supports. A factor of safety less than four (but not less than two) may be used if:

1. The adjacent supports, carrying load in the same direction, are qualified according to this criteria.
2. There are a minimum of four anchor bolts on the baseplate,
3. Not more than half the bolts are subjected simultaneously to tension loads,
4. The anchor bolts are wedge-type,
5. The load differences between the actual loads and the loads corresponding to a factor of safety of four are distributed to adjacent supports, and
6. The anchor bolt as-installed condition is not deficient.

3.3.3 Catalog Items

The manufacturer's load capacity data for Level D service conditions will be used to qualify supports. For existing supports, qualification by engineering analysis or by comparison to test results for these catalog items may also be used. In such cases, a minimum factor of safety of two will be maintained.

3.3.4 Welds

The allowable stresses for welds will be based on the design requirements as specified in the ASME Boiler & Pressure Vessel Code, Section III, 1980 Edition including Winter 1980 Addenda for Level D loads [3]. For full penetration welds, the allowable stresses will be those of the base metal. The allowable stresses used for welds do not include the increases for material overstrength or strain rate effects.

3.4 Structural Steel Members

The criteria for structural steel members is the "Balance of Plant Structures Seismic Reevaluation Criteria" [18,19], which includes the acceptance criteria based upon AISC specification [5], Standard Review Plan and ductility. In all instances, the ductility of all steel members shall be less than or equal to one.

3.5 Mechanical Equipment (Pumps, Heat Exchangers, Filters)

The design criteria for mechanical equipment are developed for both pressure-retaining and non-pressure retaining parts.

3.5.1 Pressure-Retaining Parts

The design criteria for mechanical equipment will be based on the rules and criteria in the ASME, Boiler & Pressure Vessel Code, Section III, Subsection NC, 1983 Edition including Summer 1983 Addenda [4]. The criterion specified for LTS is that components must maintain their structural and pressure integrity during and after a 0.67g Modified Housner Design Spectrum event.

For all components except active pumps, the Level D stress limits are specified for the evaluation of pressure-retaining parts. The criteria are defined in NC-3000 of the Code and are summarized below:

Catagory	Allowables
Primary membrane stress	2.0 S
Primary membrane + bending stress	2.4 S

where S = Component material allowable stress

For active pumps the Level C stress limits are specified for the evaluation of pressure-retaining parts. The criteria are defined in NC-3000 of the Code and are summarized below:

Category	Allowables
Primary membrane stress	1.5 S
Primary membrane + bending stress	1.8 S

where S = Component material allowable stress

These stress allowables are applicable to all pressure-retaining parts including shells and nozzles.

Alternatively, the criteria of NC-3200 and Appendix XIII of the ASME Code [4] may be used.

3.5.2 Non-Pressure Retaining Parts and Equipment Supports

The design criteria for non-pressure retaining parts and equipment supports will be based on the design requirements for structural steel members defined in Subsection NF and Appendix F of the ASME Code, Section III, 1983 Edition, and include the Summer 1983 Addenda for Level D loads [4]. This includes a check of the stresses for bending, axial and shear loads, as well as a check on stability, weld and anchor bolts (See Section 3.3 for detailed discussion). A summary of the support evaluation criteria is contained in Table 3.3-1.

All support loads will be combined as shown below:

Design loads for support = Gravity (signed) +
Nozzle (signed) +
0.67g Modified Housner Design Spectrum
Inertia (±)

Nozzle loads include gravity, thermal, hydraulic transients, seismic inertia, and seismic anchor motion effects. The seismic inertia and SAM loads will be combined by SRSS.

3.6 Valves

The design criteria for valves are developed for active and passive valves and for pressure and non-pressure retaining components.

3.6.1 Active Valves

The criteria are intended to ensure the structural integrity of the valve and its extended structure during and after a 0.67g Modified Housner Design Spectrum event. Seismic loads on the extended structure will be derived from valve accelerations, which will be calculated during the piping analyses.

Non-pressure retaining components, such as yoke legs, will be evaluated using Subsection NF of the ASME Code, 1983 Edition including Summer 83 Addenda [4]. All stresses in active valves will be limited to the elastic range. The Level C allowables of Subsection NF will be used, as they limit all primary stresses to below the yield point. The stress criteria for the non-pressure retaining parts are listed in Table 3.6-1.

Qualification of the valve body will be demonstrated by qualifying the welded joint between the valve body and the attached piping, including consideration of the appropriate stress concentration factors Pressure retaining parts of the extended structure will be evaluated using NC-3500 of the ASME Code [4]. Level C allowable stresses will be used and are summarized below.

Categogy	Stress Limit
Primary membrane stress	1.5 S
Primary membrane + bending stress	1.8 S

Pressure-retaining flanged connections are evaluated using the criteria of NC-3658 for Service Limit C.

The loads considered in the qualification of active valves are combined as shown below:

Design loads for valves = Gravity (signed) + Operational (signed) + 0.67g Modified Housner Design Spectrum inertia (±)

In the pressure-retaining components, operational loads include thrust loads due to valve actuations and pressure loads.

3.6.2 Passive Valves

The criteria for passive valves are intended to ensure the structural integrity of the valve and its extended structure during and after a 0.67g Modified Housner Design Spectrum event. The general qualification approach will be the same as that used for active valves, except that the allowable stresses will be increased.

Non-pressure retaining components will be evaluated using Subsection NF of the Code, 1983 Edition including Summer 83 Addenda, modified appropriately by Appendix F [4]. Table 3.6-1 shows the stress criteria for the non-pressure retaining parts.

Qualification of the valve body will be demonstrated by qualifying the welded joint between the valve body and the attached piping. This includes the consideration of the appropriate stress concentration factors. Other pressure-retaining parts will be evaluated using NC-3500 of the ASME Code [4]. Level D allowables will be used and will be summarized below:

Category	Stress Limit
Primary membrane stress	2.0 S
Primary membrane + bending stress	2.4 S

Pressure-retaining flanged connections will be evaluated using the criteria of NC-3658 for Level D Service Limits.

Design load for valves = Gravity (signed) + Operational (signed) + Modified Housner Design Spectrum inertia (±).

In the pressure-retaining components, the operational loads include thrust loads due to valve actuations and pressure loads.

3.7 Tanks

Design criteria for the Refueling Water Storage Tank is described in a separate report [17].

3.8 Penetrations

The design criteria for the containment penetrations ensure the adequacy of the penetration structures to act as pipe supports and to verify the structural integrity of the containment structure. The stresses in the penetration structure shall be reviewed against the applicable criteria for piping and pipe supports, as described in Subsections 3.1, 3.2 and 3.3. The stresses in the containment shall be reviewed against the criteria in the ASME B&PV Code, Subsection NE, 1980 Edition including Winter 1980 Addenda [3] for metal containment.

3.9 Electrical Raceways

The criteria for the evaluation of electrical raceways, which consist of cable trays and conduits, shall be based upon the RTS Design Criteria for SONGS-1 [8]. The applicable criteria in Sections 3.3 may alternatively be used to qualify raceway supports.

Table 3.1-1

GENERIC SUPPORT FLEXIBILITIES FOR VARIOUS PIPE SIZES

Pipe Diameter (inch)	Translational Flexibility (in/lb)
2-1/2	1.60×10^{-4}
3	1.11×10^{-4}
4	6.25×10^{-5}
6	2.78×10^{-5}
8	1.56×10^{-5}
10	1.00×10^{-5}
12	6.94×10^{-6}
14	5.10×10^{-6}
16	3.91×10^{-6}
18	3.08×10^{-6}
20	2.50×10^{-6}
24	1.74×10^{-6}
28	1.28×10^{-6}
30	1.11×10^{-6}

Table 3.3-1

DESIGN CRITERIA FOR PIPE AND EQUIPMENT SUPPORTS

Component Type	Stress Condition	Criteria
Structural Steel	Tension, Bending Shear Compression Web Crippling	1.30 x ASME Level D (1) 1.30 x ASME Level D (1) ASME Level D ASME Level D
Concrete Anchor Bolts	Shear, Tension, With Elliptical Interaction	F_u/F.S. where F.S. = 4 for wedge type = 5 for shell type (see note 2).
Catalog Items	All	Manufacturer's Load Capacity Data for Level D Service Conditions or Engineering Analysis with F.S. = 2 or Test Data with F.S. = 2.
Welds	All	ASME Level D

Where F_u = Ultimate strength at design temperature

F.S. = Factor of safety

Notes:

(1) On a case-by-case basis, 30 percent increase in yield stress may be used (see Section 3.3.1).

(2) On a case-by-case basis, F.S. less than 4 may be used (see Section 3.3.2).

Table 3.6-1

DESIGN CRITERIA FOR VALVE CAPACITY - NON-PRESSURE RETAINING PARTS

Component Type	Stress Condition	Active Valves	Passive Valves
Structural Elements (Yoke Legs)	Tension	ASME Level C	ASME Level D
	Bending	ASME Level C	ASME Level D
	Shear	ASME Level C	ASME Level D
	Compression	ASME Level C	ASME Level D
Bolting	Tension	ASME Level C	ASME Level D
	Shear	ASME Level C	ASME Level D
Welds	All	ASME Level C	ASME Level D

4.0 METHODOLOGY

4.1 Load Generation

The in-structure floor response spectra currently defined for the SONGS-1 structures (with the exception of the Reactor Building and Turbine Building) shall be used for subsystem analysis. For the Reactor Building and Turbine Building, the in-structure spectra shall be refined by using current SSI techniques. See also [25] for further discussion.

4.1.1 Input Time History

Three new artificial time histories shall be developed, one for each of the three mutually orthogonal earthquake directions. The time histories for the horizontal directions shall envelop the modified Housner Horizontal design spectrum (0.67g ZPA). The vertical time history shall envelop the modified Housner vertical design spectrum. The vertical spectrum ZPA is 2/3 of horizontal ZPA. The three time histories shall be statistically independent.

4.1.2 Soil-Structure Interaction

The SONGS-1 soil-structure interaction (SSI) analyses were based on the lumped parameter method, using frequency-independent soil springs. These analyses were performed in the 1975 to 1980 time frame. Since then, more refined SSI techniques have been developed.

For LTS, refined SSI analyses shall be performed to generate new floor response spectra. The SSI analyses shall be performed using available structural models which were used in previous SONGS-1 evaluations. For the SSI analysis of the Reactor Building, a frequency-domain, substructuring technique shall be used. The site-foundation system shall be modeled by a series of frequency-dependent impedance functions representing the stiffness and damping of the foundation site. Soil material damping (hysteretic) shall be limited to 8 percent. For the Turbine Building, a time-domain, modal superposition approach shall be used. Frequency-independent soil stiffness and damping coefficients, calculated for each individual footing of the Turbine Building or Pedestal mat, shall be used to represent the soil-foundation system. Composite modal damping shall be limited to 20 percent.

The three statistically independent free-field motions shall be applied simultaneously to the models, at the level of the foundation, both for surface-founded and embedded structures. Floor spectra shall be broadened to include variations in soil properties.

4.1.3 Direct Generation Method

For the Turbine Building in-structure spectra, correction factors shall be developed based on the direct generation method. These correction factors shall then be applied to the newly generated spectra. The objective of the correction factors is to modify the floor spectra such that the resulting response spectra strictly conforms with the required design spectra for SONGS-1, as specified by the Modified Housner Response Spectra. This is accomplished by:

1) Increasing the amplitude of the spectral ordinates for cases when the time history's spectral ordinates fall below the required design spectrum.

2) Removing the excess energy in the spectral ordinates for cases where the time history's spectral ordinates exceed the required design spectrum.

The correction factors are defined as the ratio of the spectral value obtained from using the design input spectra to the spectral value obtained from using the enveloping spectra corresponding to the free-field acceleration time history. Thus, the correction factors are a function of the dynamic characteristics of the structure (frequencies, mode shapes, mode participation factors), the "smooth" design input spectra and the artificial time histories spectra. The correction factors are frequency and damping dependent, i.e., a different factor shall be calculated for each frequency point and for each damping value.

4.2 Large Bore Piping Analysis Methods

Large bore piping analyses shall consider the effects of pressure, thermal, deadweight, hydraulic transients and seismic loadings. These loadings require consideration for pipe stress, pipe support loads, anchor loads and nozzle loads. A summary chart for piping analysis method is shown on Figure 4.2.

4.2.1 Linear Analysis Methods

In general, the envelope response spectra method shall be used. Should more precise analysis methods be warranted, then either the multiple level response spectra or time history methods shall be used. Similarity analysis may be used when justified, on a case-by-case basis.

4.2.1.1 Envelope Response Spectra Method

This method is the most commonly used method of piping analysis.

Mode/Direction Combinations

Modes shall be combined using any of the combination rules provided in Regulatory Guide 1.92 or by the Complete Quadratic Combination (CQC) technique. The three directions of earthquake motions shall be combined by SRSS, as per Regulatory Guide 1.92. A missing mass correction for modes in the rigid range shall be made.

The Complete Quadratic Combination (CQC) method is an accurate method to combine modal responses. The method is documented in [16]. The method has been validated by time history methods, and is found to give more accurate responses of closely spaced laterally-coupled modes than do the Regulatory Guide 1.92 methods. Higher modes in the rigid range of the input spectra are included using the missing mass correction.

Peak Shifting

The spectra peak shifting methodology, as outlined in Reference [7], and accepted in [2,6], may be adopted in this analysis.

Damping

PVRC recommended damping values, as outlined in Reference [9], and accepted in [2,6], shall be used in this analysis.

Seismic Anchor Motions

Seismic Anchor Motion (SAM) effects on pipe stresses shall be evaluated. SAM effects on pipe support loads shall be combined with inertia effects by the SRSS method.

4.2.1.2 Multiple Level Response Spectra Method

This method is a commonly used method of piping analysis. The method shall remove some conservatism introduced in the envelope response spectra method, when the input spectra at different levels in the structure have wide variations.

Mode/Direction/Level Combinations

Modes shall be combined using any of the combination rules provided in Regulatory Guide 1.92. The three directions of earthquake motions shall be combined by SRSS, as per Regulatory Guide 1.92. The pipe system responses due to individual levels of input motions shall be combined by absolute summation or SRSS, if it is shown that individual input motions are independent of each other. Independence shall be demonstrated by showing that the correlation coefficient for the input motions is between plus or minus 0.16. A missing mass correction for modes in the rigid range shall be made.

As an alternative to the above procedures, mode and level combinations may be combined using a random vibration method. This method uses correlation coefficients calculated from separate pipe and structure models to combine model and level responses. This technique has been validated by the multiple level time history technique.

Peak Shifting

The methodology described in Subsection 4.2.1.1 may be used.

Damping

The methodology described in Subsection 4.2.1.1 shall be used.

Seismic Anchor Motion

The methodology described in Subsection 4.2.1.1 shall be used.

4.2.1.3 Time History Method

General

In lieu of the response spectrum approach, time histories of support motions shall be used as excitation to the piping system. If the motions at the different support locations are distinct, multiple time histories shall be used to perform the analysis. The input motions shall include both acceleration and displacement motions of the supports.

Direction Combinations

The three directions of earthquake motions shall be combined by SRSS, as per Regulatory Guide 1.92.

Damping

The damping values in Regulatory Guide 1.61 shall be used.

4.2.1.4 Similarity Analysis Method

For piping systems which are similar to systems which have previously been evaluated, a similarity analysis shall be used to qualify the piping system. The similarity evaluation shall focus on pipe routing, pipe support scheme, and location of equipment. By evaluating the effect of minor changes between systems, the similarity analysis shall provide an economic means of evaluating the piping system.

4.2.2 Nonlinear Analysis Methods

4.2.2.1 Time History Method

General

The nonlinear time history analysis shall account for nonlinearities in the piping system due to material nonlinearity. The material nonlinearities are included for piping, pipe supports or support structures. Input time history motions are taken from appropriate locations of the structural analysis models.

Damping

The damping used in the nonlinearity analysis shall be Rayleigh type damping. The hysteretic behavior due to material yielding shall also be factored into the evaluation.

4.3 Small Bore Piping and Tubing

The small bore piping and tubing analysis shall be performed with walkdowns and chart methods. These methods shall also be verified by generic piping calculations and shall include the effects of anchor motions for support design [15].

As an alternative, small bore piping and tubing may be evaluated using the analysis methods described in Section 4.2.

4.4 Pipe Supports

Pipe supports shall be evaluated against the criteria in Section 3.3. If a support has yielded, the piping shall be reevaluated to determine whether it can maintain functionality. The adjacent supports shall be reevaluated to determine whether they can support the additional load.

Structures supporting more than one pipe shall be evaluated to withstand the total loads from all the pipes. For components loaded by more than one pipe, if predominent frequencies of different pipes in the vicinity of the support are at least 10 percent apart (similar to RG 1.92), then the support may be evaluated by considering the SRSS combination of seismic responses of different pipes. This method may also be applied in Sections 4.5, 4.6 and 4.9.

4.5 Structural Steel Members

The methodology used for RTS [10] shall be used to evaluate the structural steel members. The criteria described in Section 3.4 shall be used to qualify the components.

4.6 Mechanical Equipment

The evaluation of mechanical equipment (heat exchangers, pumps and filters) shall be performed using equivalent static analysis and dynamic analysis techniques.

For equipment connected to small bore piping for which computer analyses are not performed, hand calculations based on single span beam models and peak accelerations may be used.

4.7 Valves

Equivalent static analysis shall be performed to calculate stresses in critical sections of the valve based on the total loads (seismic, gravity and valve operation). The calculated stresses shall be compared to the allowables.

4.8 Tanks

The evaluation for the Refueling Water Storage Tank is described in a separate report [17].

4.9 Penetrations

The penetration components shall be evaluated using stress calculations which shall include textbook solutions, axisymmetric finite element or Bijlaard solutions.

4.10 Electrical Raceways

The methodology described in Reference [8] shall be used to evaluate the conduit and cable tray supports. Maximum support deflections shall be restricted to four inches to ensure circuitry continuity [11].

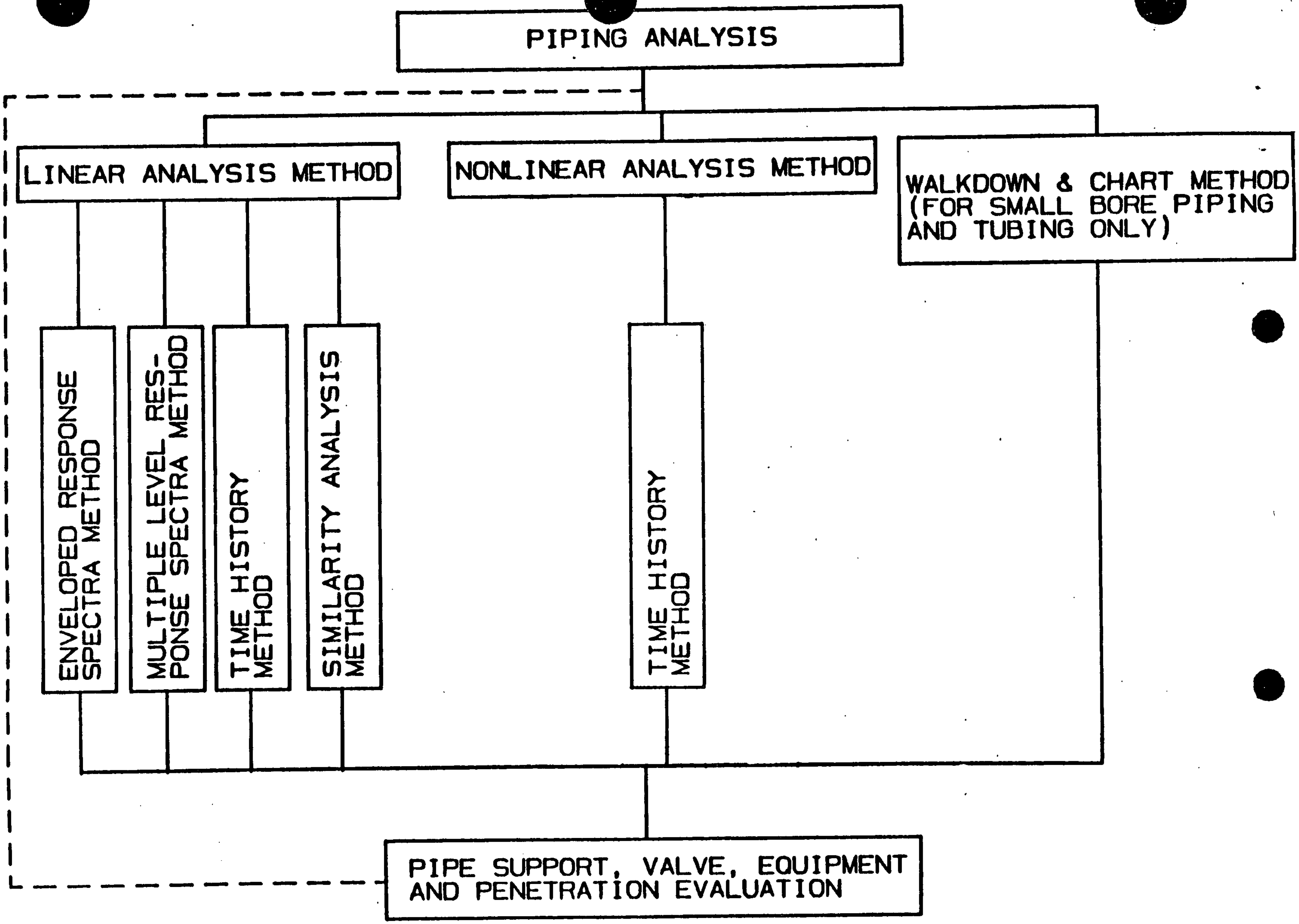

FIGURE 4.2 SUMMARY CHART FOR PIPING ANALYSIS METHOD

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