Form 21 - 50M

CAROLINA POWER & LIGHT COMPANY
RALEIGH, NORTH CAROLINA 27602

COPY

June 5, 1970

Dr. Peter A. Morris, Director
Division of Reactor Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Re: Docket No. 50-261

Dear Dr. Morris:

Carolina Power & Light Company herewith transmits 80 copies of each of the following reports:

(1) "Tendon Analysis Report"
(2) "Likelihood and Consequences of Turbine Overspeed"
(3) "Additional Information Concerning Seismic Analysis of Class I Piping & Equipment"

These reports are submitted as additional information in support of our request for an operating license for H. B. Robinson Unit No. 2.

The Tendon Report is in response to your letter of May 14, 1970, requesting information on the difficulties experienced by the Company during the installation of the tendon system.

The turbine Overspeed Report contains details which were outlined to your staff and to the ACRS on April 10, 1970.

The Seismic Analysis Report contains information developed pursuant to the program outlined in our letter of April 6, 1970. As a result of this analysis, we are adding supports to all valve motor operators in Class I piping less than two inches in diameter. Four additional restraints are also being added to the auxiliary feed water system.

The report on the pipe failure incident is not yet completed and will be submitted as a separate transmittal.

Yours very truly,

J. A. Jones - Vice President
Assistant Manager
Engineering & Operating

JAJ/sb

In the Matter of)
)
CAROLINA POWER & LIGHT COMPANY) Docket No. 50-261
)
(H. B. Robinson Unit No. 2))

AFFIDAVIT OF J. A. JONES

I, J. A. Jones, being duly sworn, depose and state that I reside in Raleigh, North Carolina; that I am Vice President and Assistant Group Executive for Engineering & Operations, Carolina Power & Light Company, and am fully cognizant of the content of the attached documents entitled "Additional Information Concerning Seismic Analysis of Class I Piping and Equipment", "Likelihood and Consequences of Turbine Overspeed", and "Tendon Analysis Report", and that the contents of the same are true and correct to the best of my knowledge.

J. A. Jones

Subscribed and sworn to before me this 5th day of June, 1970, at Raleigh, North Carolina.

Notary Public

My commission expires:

Docket 50261--35

REC USAEC REG 6 . 70 . 50 261 . 1758

8 June 1970

H. B. ROBINSON UNIT NO. 2

ADDITIONAL INFORMATION CONCERNING

SEISMIC ANALYSIS OF CLASS I PIPING AND EQUIPMENT

This report contains information on the following seismic analysis subjects:

a. The effects of valve operators on Class I piping.

b. The effects of resonance with the structures on Class I piping.

c. The steps taken to assure that Class I equipment adequately meets seismic requirements.

TABLE OF CONTENTS

1.0 Effects of Valve Operators on Class I Piping

1.1 General

In the seismic design of Class I piping, valves including operators were treated as concentrated loads with the entire weight assumed to be massed at the centerline of the pipe. Piping systems that were statically analyzed by computer method (reference section 2.3.2.4) accounted for the weight effects of the valves as an additional load in the piping system for which stress values were calculated and restraints were placed as required. Piping systems that were analyzed by the simplified method (reference section 2.3.2.5) accounted for the weight effects of valves by shortening the span between restraints points so as not to exceed predetermined stress limits.

Although the total weights of valves were accounted for in the aforementioned analysis, the effects of the offset weight in the case of motor operated valves was not included. The additional stress effect due to offsetting the valve operator mass from the pipe centerline are considered insignificant except where large valve operators relative to pipe size are involved. In support of this design approach, an evaluation was performed to determine the threshold where this offset mass does produce a significant added stress (i.e., in addition to the stresses considered in the design) under seismic loading.

1.2 Method of Evaluation

Information was gathered from vendor's prints and contacts with valve manufacturers concerning weights and locations of center of gravity of motor and air operated valves ranging in size from 2 inches to 16 inches. It was found that, although operator weights vary according to pressure rating and closing time requirements, the center of gravity of the assembly is displaced approximately one-third of the height away from the centerline of the pipe toward motor.

Using the best available information for locating the center of gravity, a simple free body calculation was made to determine the stresses imposed on the pipe for each of the valves under investigation. For this calculation the statically applied weight load was multiplied by the distance of the center of gravity from the centerline of the pipe, and the resulting moment was then divided by the section modulus of the pipe. As an example, a 2 inch valve weighing 280 lbs. with its center of gravity displaced 15 inches from the centerline of the pipe resulted in a stress value of 4300 psi. The analytical model used assumes that the valve is anchored on one end only at the pipe to valve connection. This model is considered conservative because in actual practice the piping on both ends of the valve tend to resist rotation and, if equally restrained, the stress values at each end of the valve would vary by one half the total or 2150 psi.

SCH 160
Z = .979
$\frac{280 \times 15}{.979} = 4300$

Recognizing that the stress may not be divided by one half on both ends, a computer analysis was performed for an actual system with the most severely unbalanced end conditions that could be found in the plant. This configuration was found by reviewing piping drawings and a plant walk through. The system consisted of three nine foot long horizontal runs of 2 inch piping arranged one above the other, each end terminating in common risers that were restrained so as to resist rotation. The valves on each of the three lines were located one foot from one riser and eight feet from the other riser. (Reference Figure 1.2-1). The results of this analysis showed a maximum increase in stress of 2288 psi at the end of the valve that had the shorter run, whereas the free body calculation with stress equally divided at each end had indicated an increase of 2150 psi.

1.3 Results of Evaluation

The example cited above indicates that the free body calculations for a valve supported entirely on one end yields stress values (4300 psi) that are much too conservative. This is based on the reasoning that the piping on both ends of a valve will contribute resistance to rotation. Conversely, it is not conservative enough to assume that stress increase will be divided equally at both ends of the valve.

Results of the above example, although for an extreme case, show that the actual stress increased by 2288 psi whereas the equally divided stress value would indicate an increase of 2150 psi.

Considering that the actual value was about 6 percent higher than the estimated value, but also considering the severity of the end conditions for the case examined and the scarcity of similar configurations, it was concluded that the following criterion would apply:

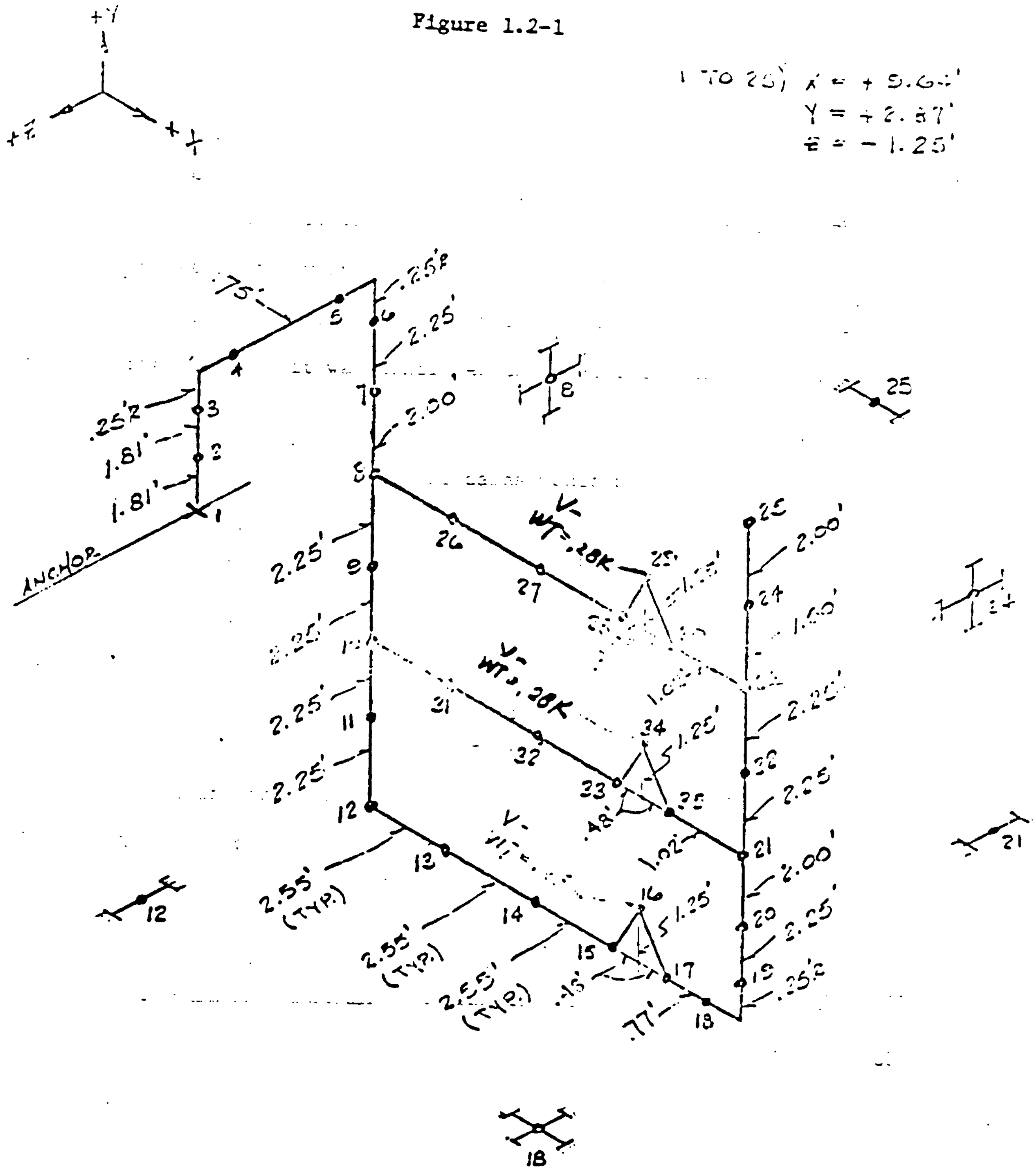
> The stresses for all cases would be determined using the analytical model where one end of the valve is fixed and the other end is free to move with the resultant stress being multiplied by 60 percent. The analytical model was normalized to a 1.0g loading for all cases.

Utilizing the aforementioned criterion, the added stress was obtained for various size valve and pipe schedules. A summary of results follows:

No. of Types of Valves Investigated*	Size Dia. (In)	Range of Pipe Schedule	Range of Stresses @ 60% of Total Stress
8	2	10 - 160	3600 - 1800
3	3	80 - 160	2400 - 1200
2	4	80 - 120	1200
1	10	140	480
1	16	100	420

*Included Air Operated and Motor Operated of different function situated on different pipe schedules.

Figure 1.2-1



H.B. ROBINSON

STUDY OF VALVE C_2

DR BY F. HEYDEN 3-13-70

2.1 Floor Response Spectra

Floor response spectra were generated for specified elevations of the containment, the containment internal structure, the auxiliary building and the class I bay of the turbine building as shown in figures 2.1-1 thru 2.1-21. These floor response spectra were generated by exciting the multidegree of freedom dynamic model of the buildings with the normalized time history forcing function acceleration which gives a ground response spectrum acceleration at least as large as the response spectrum acceleration defined in figure 5A.1-1 of the FSAR. The time history accelerations at each mass point of the building models were then used to construct a floor response spectrum for a one degree of freedom system which represents the maximum response of the equipment located at the mass point which represents the building elevation under consideration.

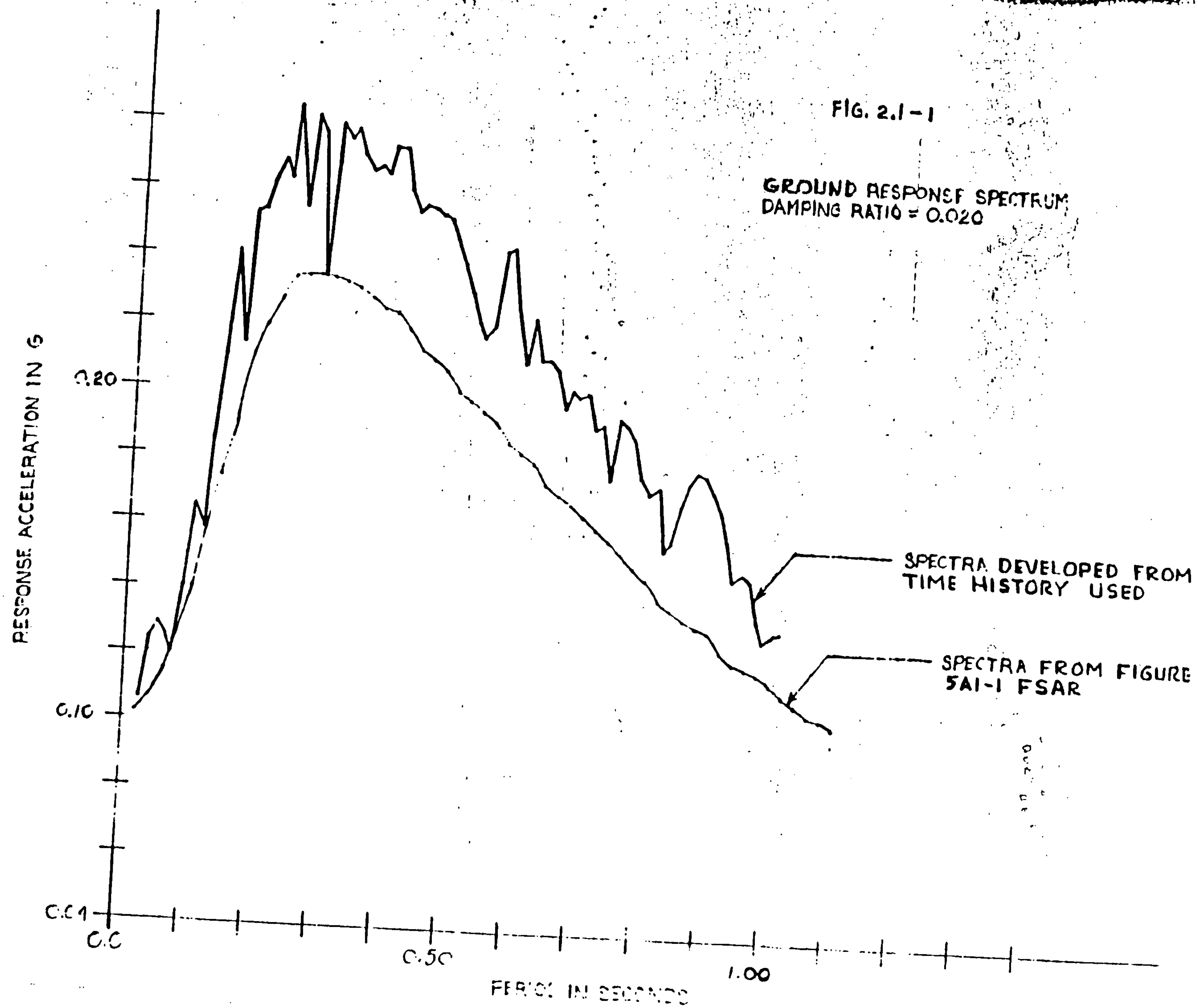


FIG. 2.1-1
GROUND RESPONSE SPECTRUM
DAMPING RATIO = 0.020
SPECTRA DEVELOPED FROM TIME HISTORY USED
SPECTRA FROM FIGURE 5A1-1 FSAR
RESPONSE ACCELERATION IN G
0.20
0.10
0.01
0.0
0.50
1.00

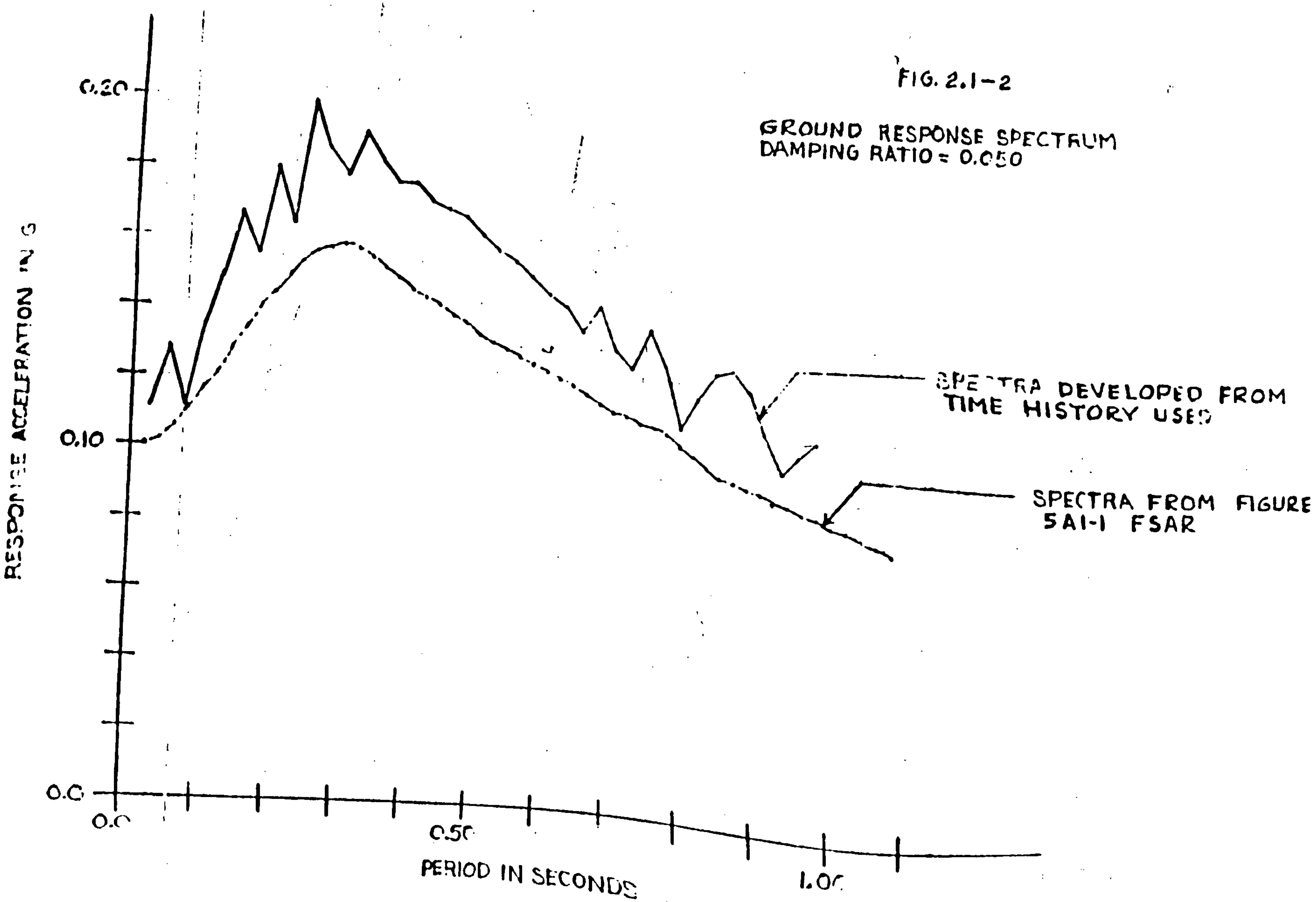


FIG. 2.1-2
GROUND RESPONSE SPECTRUM
DAMPING RATIO = 0.050
SPECTRA DEVELOPED FROM TIME HISTORY USED
SPECTRA FROM FIGURE 5A1-1 FSAR
RESPONSE ACCELERATION IN G
0.20
0.10
0.0
0.0
0.50
1.00
PERIOD IN SECONDS

FIG 2.1-2

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT NO 2
REACTOR INNER STRUCTURE
REACTOR CONTAINMENT
AUXILIARY BUILDING
ELEV. 226'-0" (GROUND)
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

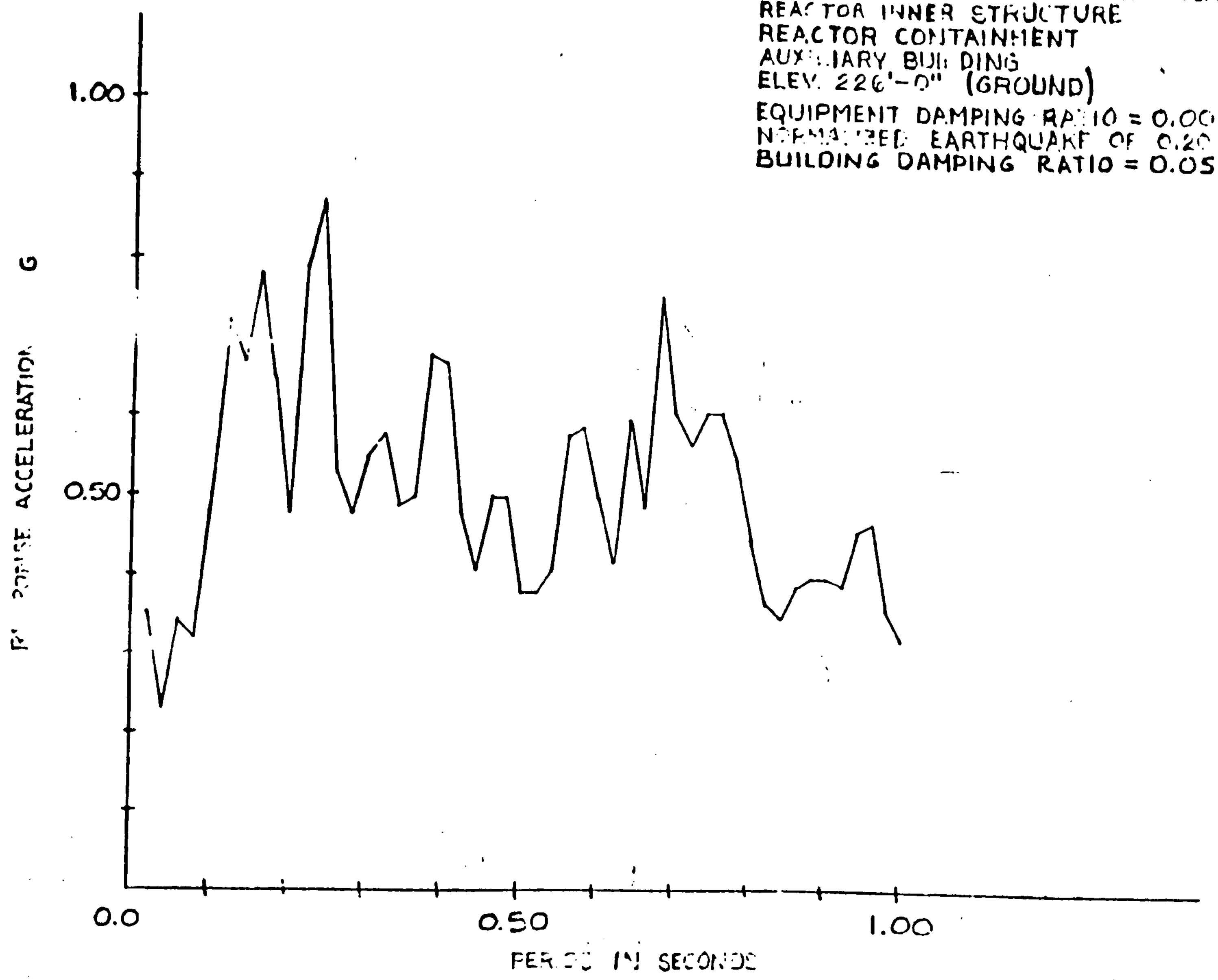


FIG. 2.1-4

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT-UNIT NO. 2
REACTOR INNER STRUCTURE
ELEV. 232'-6"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

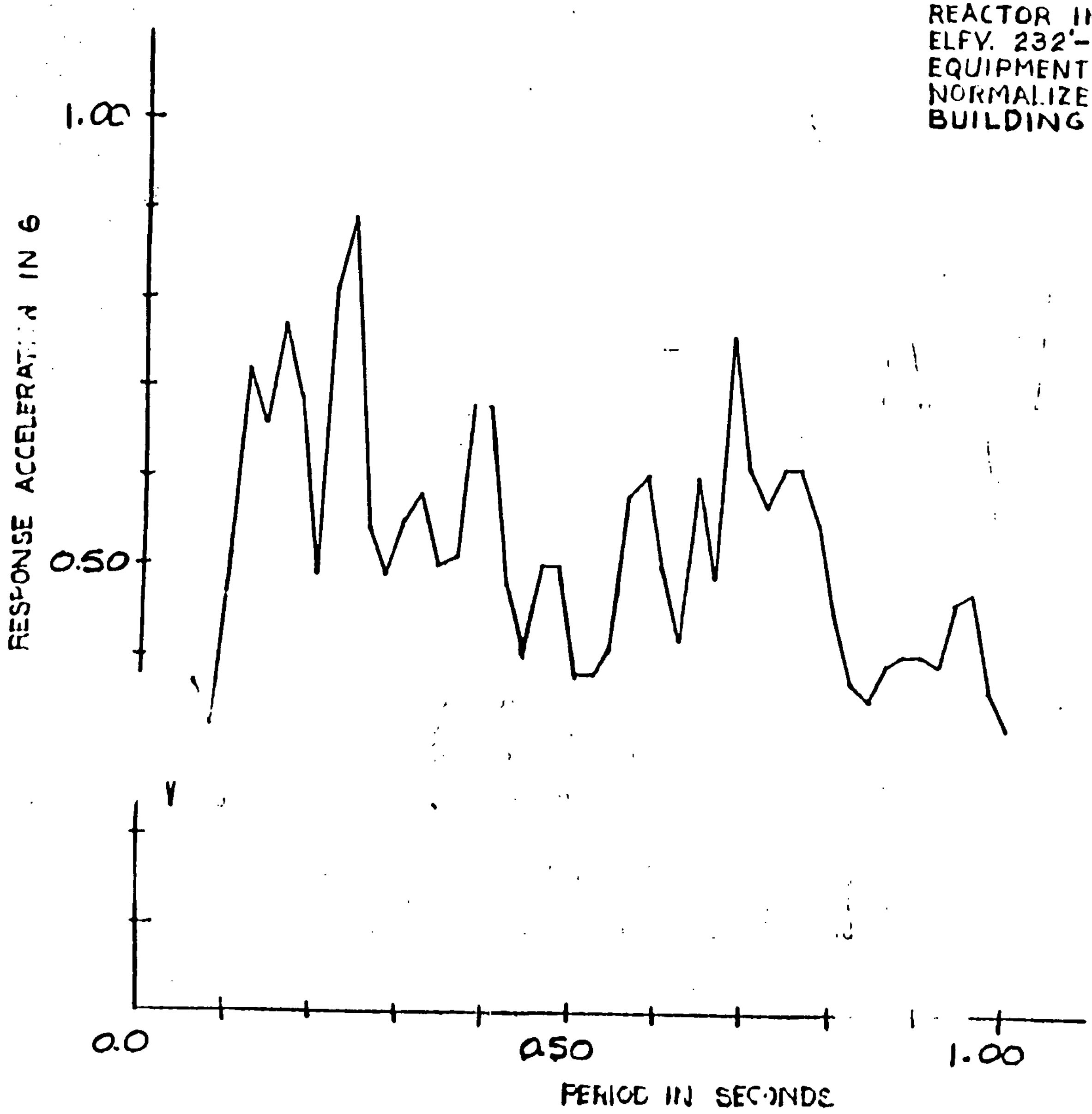


FIG. 2.1-5

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT—UNIT NO. 2
REACTOR INNER STRUCTURE
ELEV. 248'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

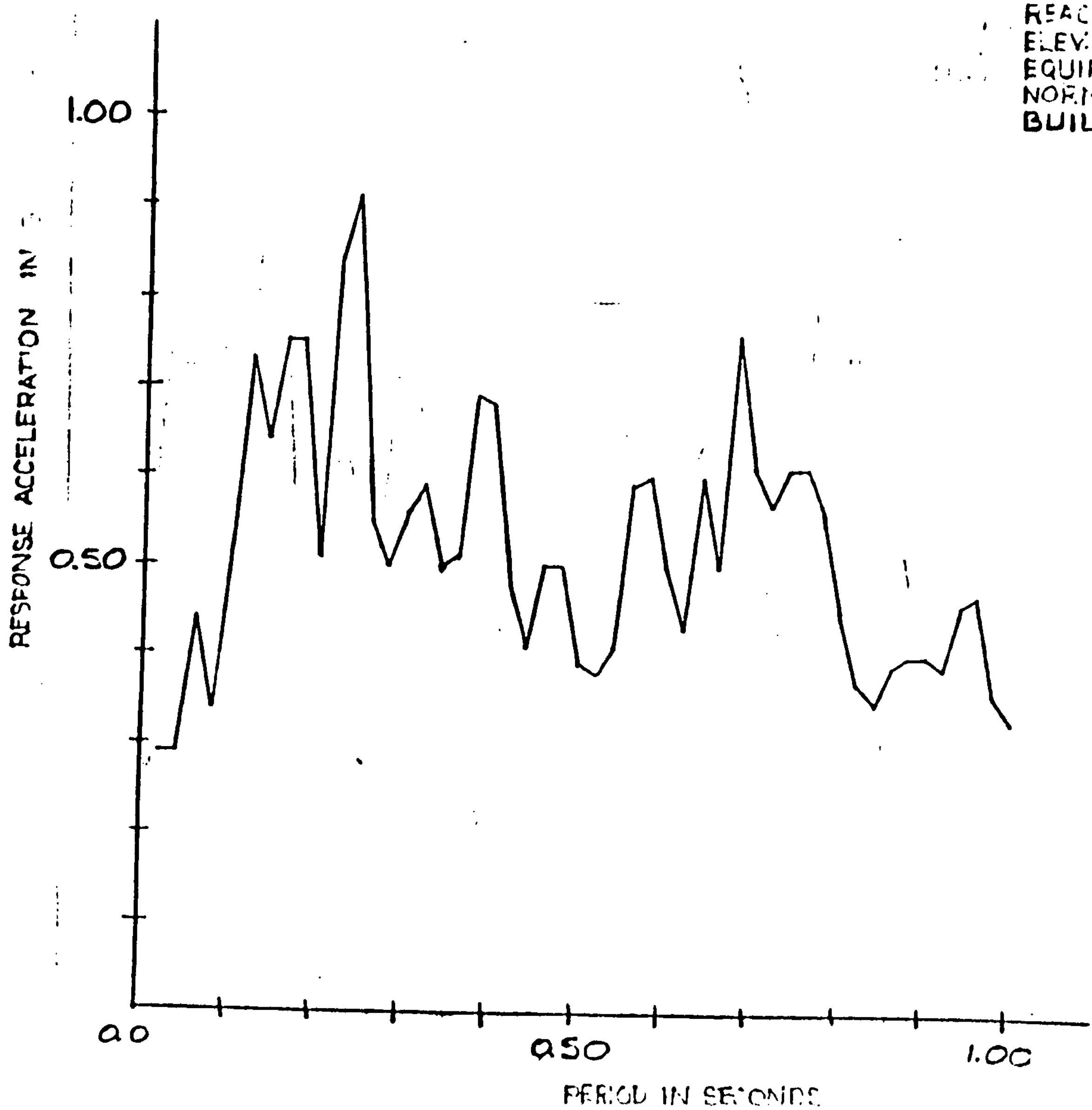


FIG. 2.1-6

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT - UNIT NO. 2
REACTOR INNER STRUCTURE
ELEV. 272'-6"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

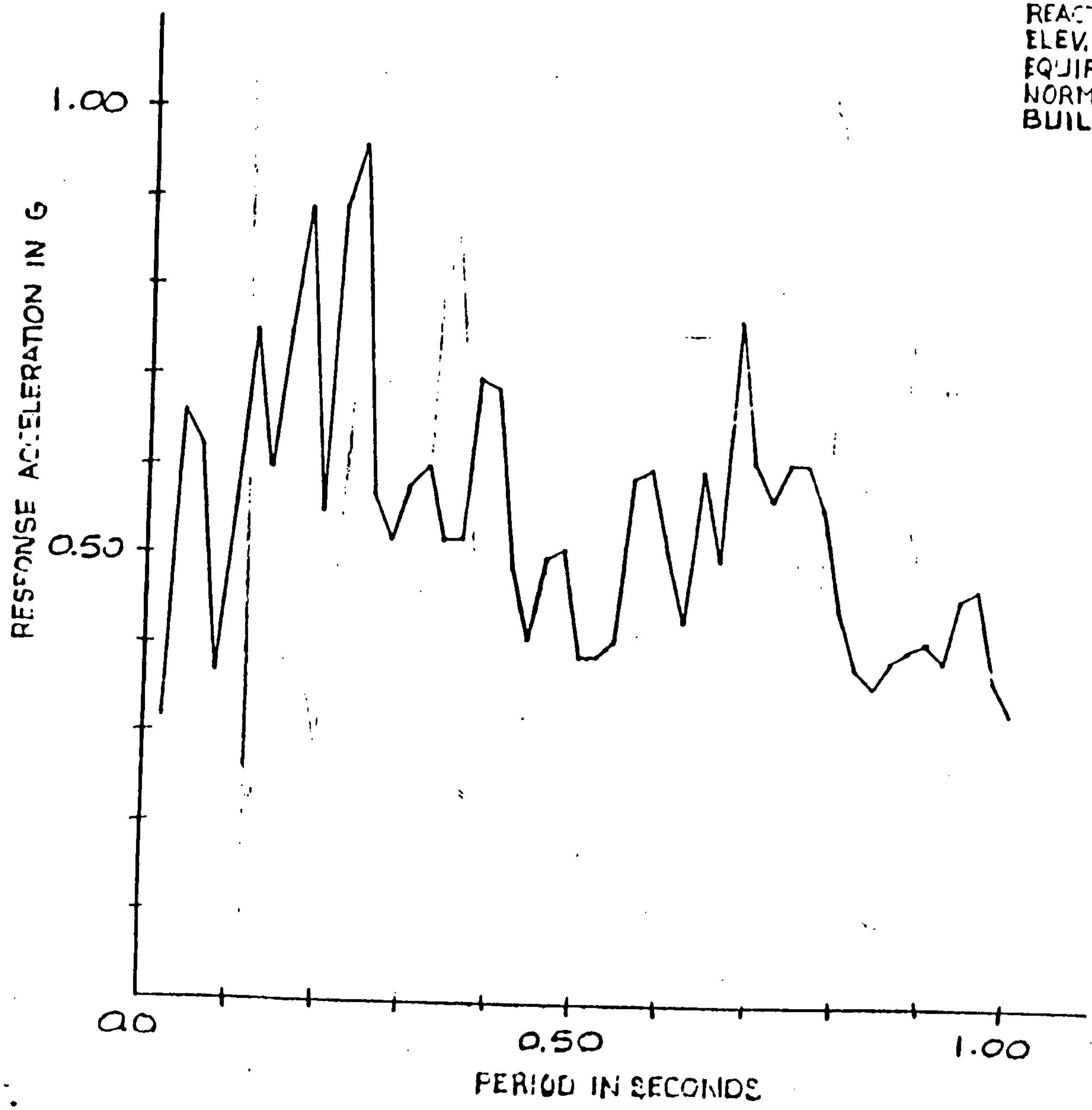


FIG. 2.1-7

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT — UNIT NO. 2
REACTOR INNER STRUCTURE
ELEV. 298'-6"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

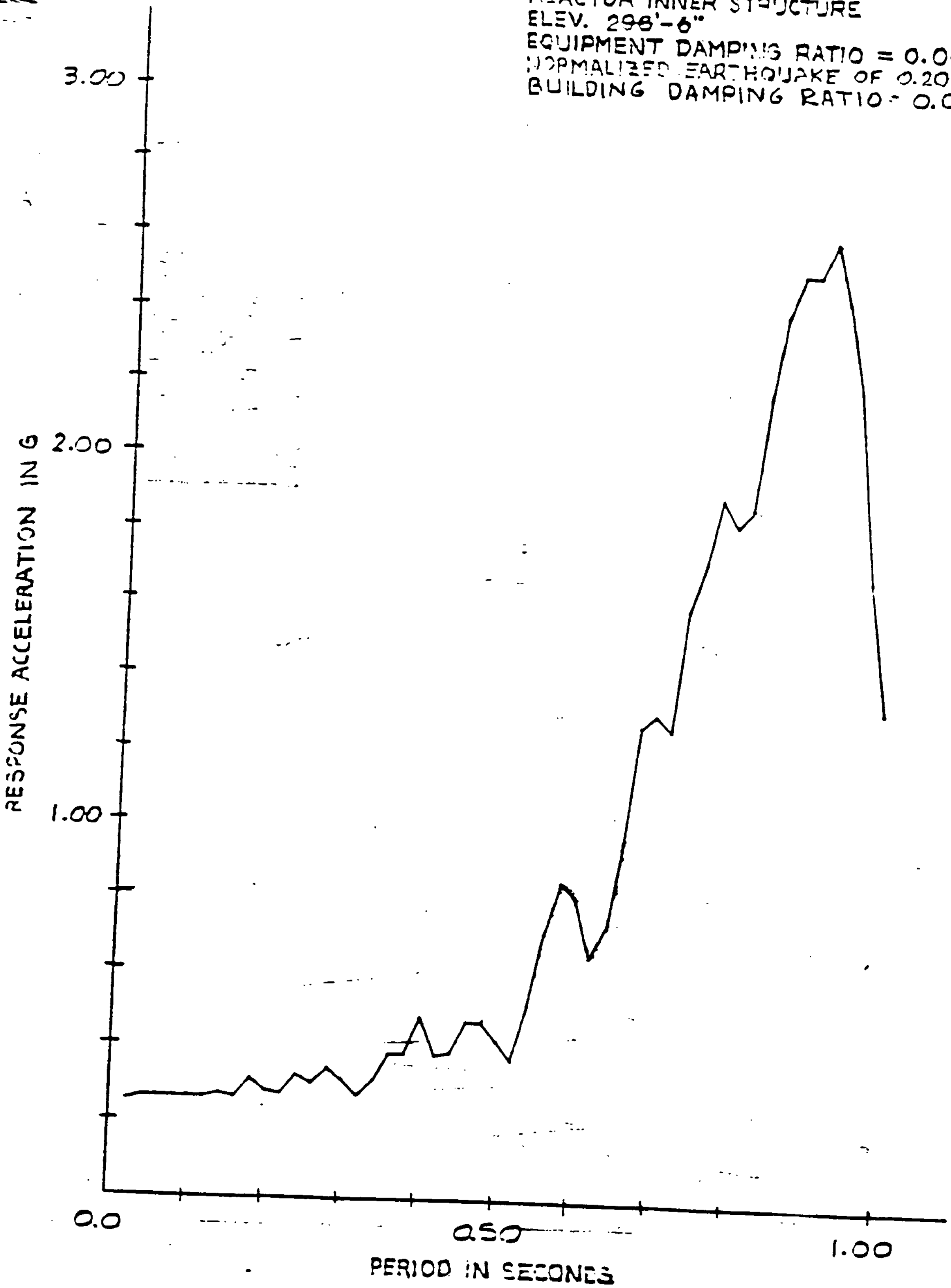


FIG. 2.1-B

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT Nº 2
AUXILIARY BUILDING-LONG DIRECTION
ELEVATION = 246'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

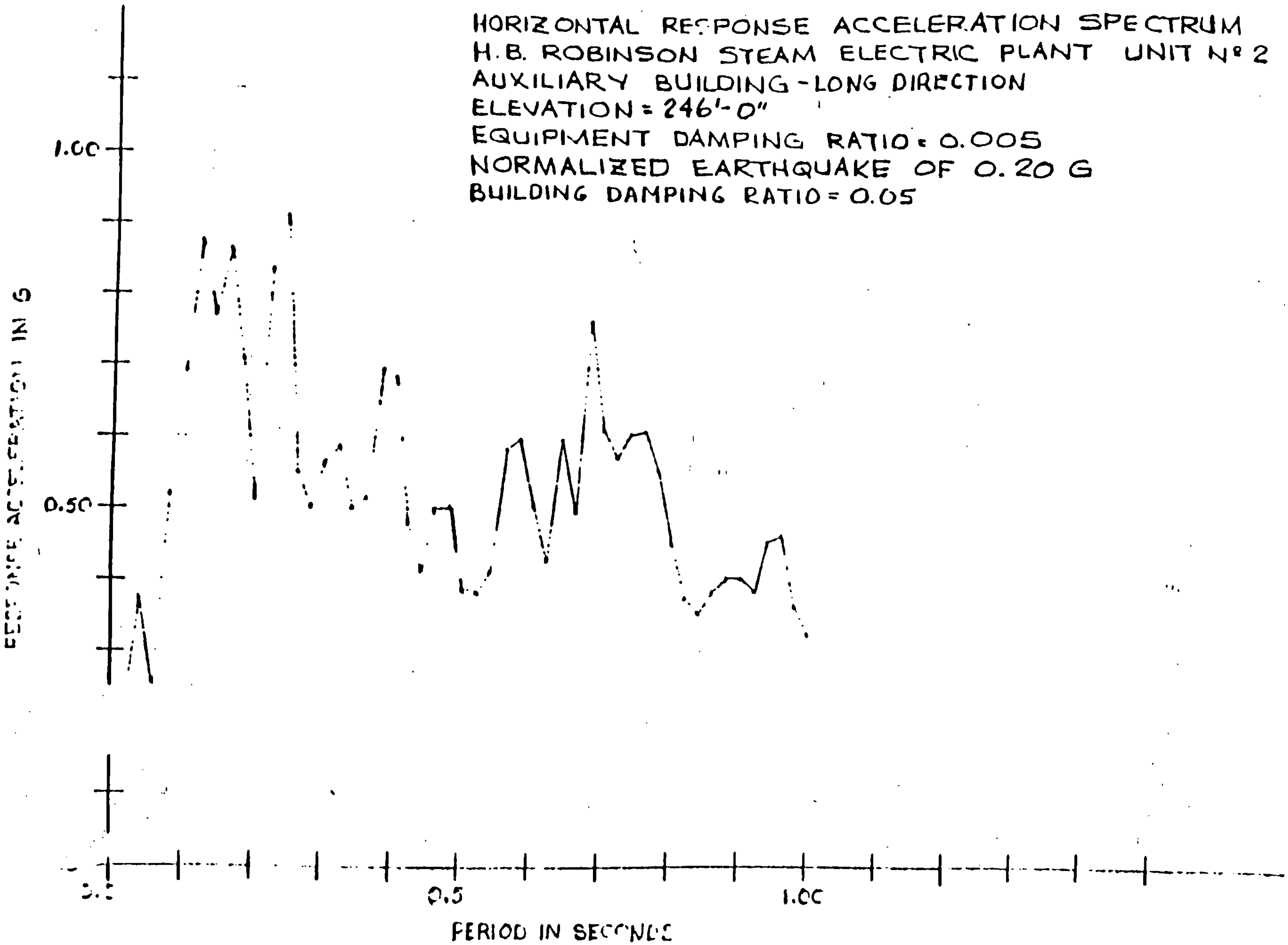


FIG. 2.1-9

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H. B. ROBINSON STEAM ELECTRIC PLANT UNIT № 2
AUXILIARY BUILDING - LONG DIRECTION
ELEVATION = 262'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

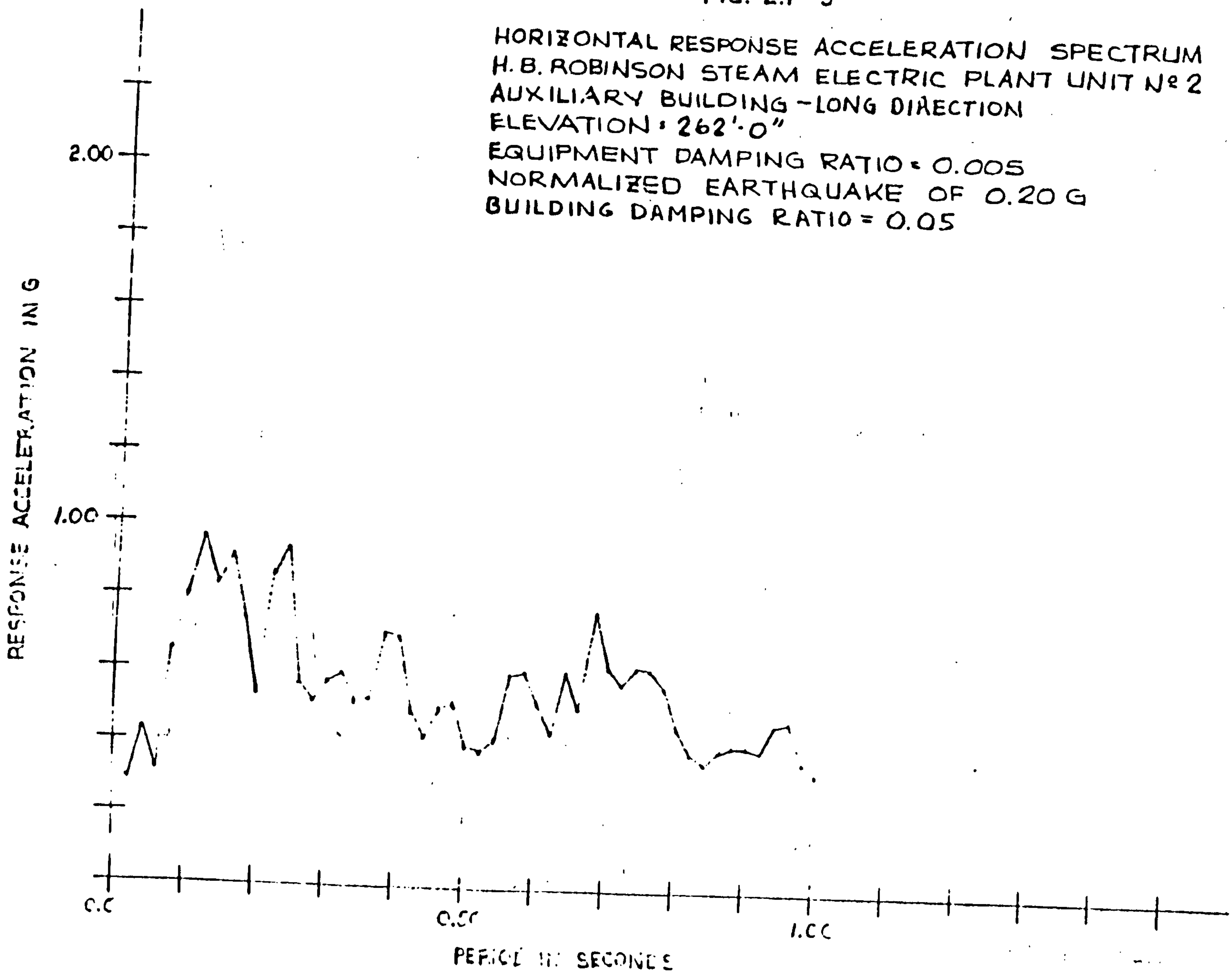


FIG. 2.1-10

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H. B. ROBINSON STEAM ELECTRIC PLANT UNIT Nº 2
AUXILIARY BUILDING - SHORT DIRECTION
ELEVATION: 246'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.05

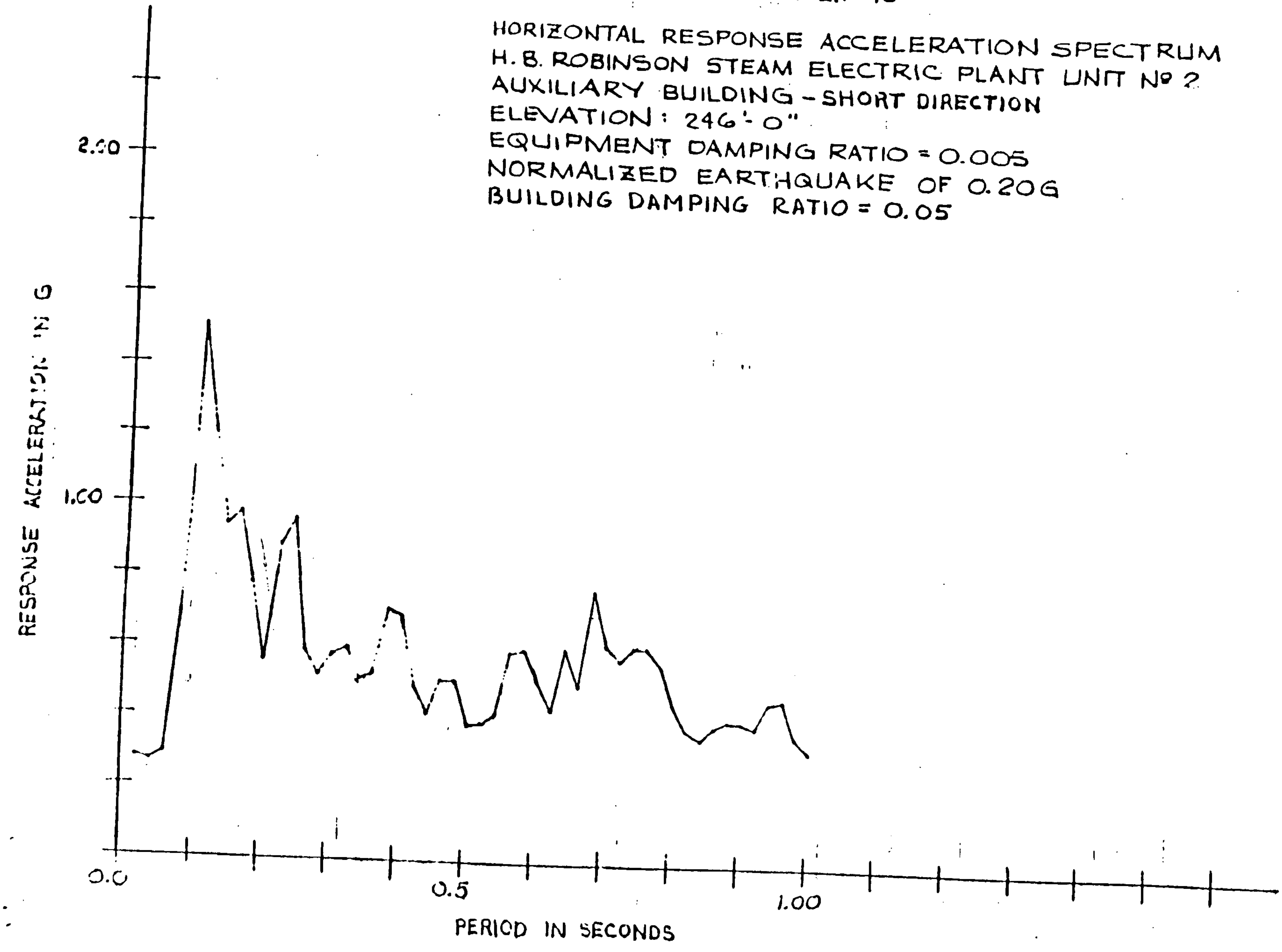


FIG. 2.1-11

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H. B. ROBINSON STEAM ELECTRIC PLANT UNIT Nº 2
AUXILIARY BUILDING - SHORT DIRECTION
ELEVATION: 262'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.05

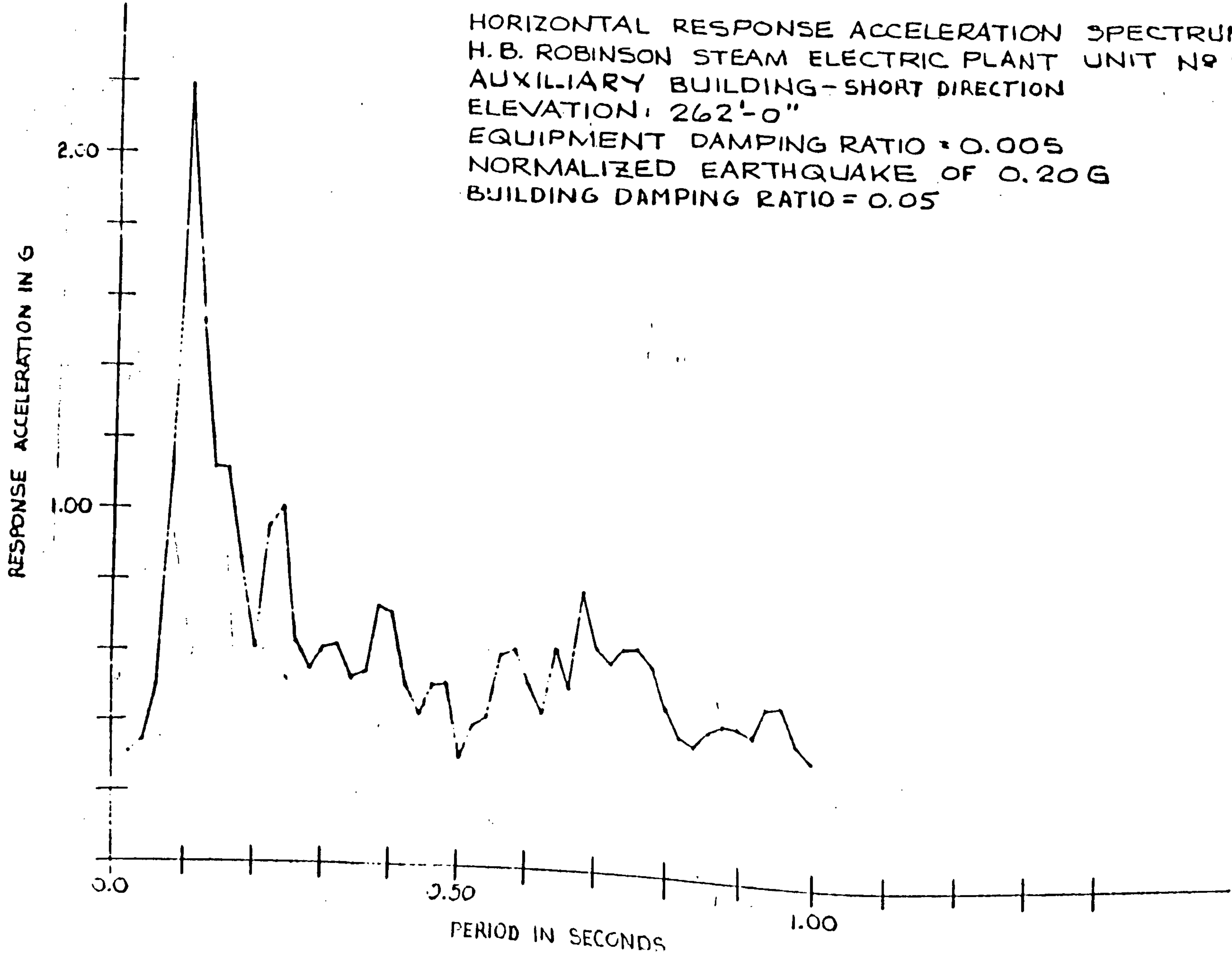


FIG. 2.1-12

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT Nº 2
REACTOR CONTAINMENT
ELEVATION: 289'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.05

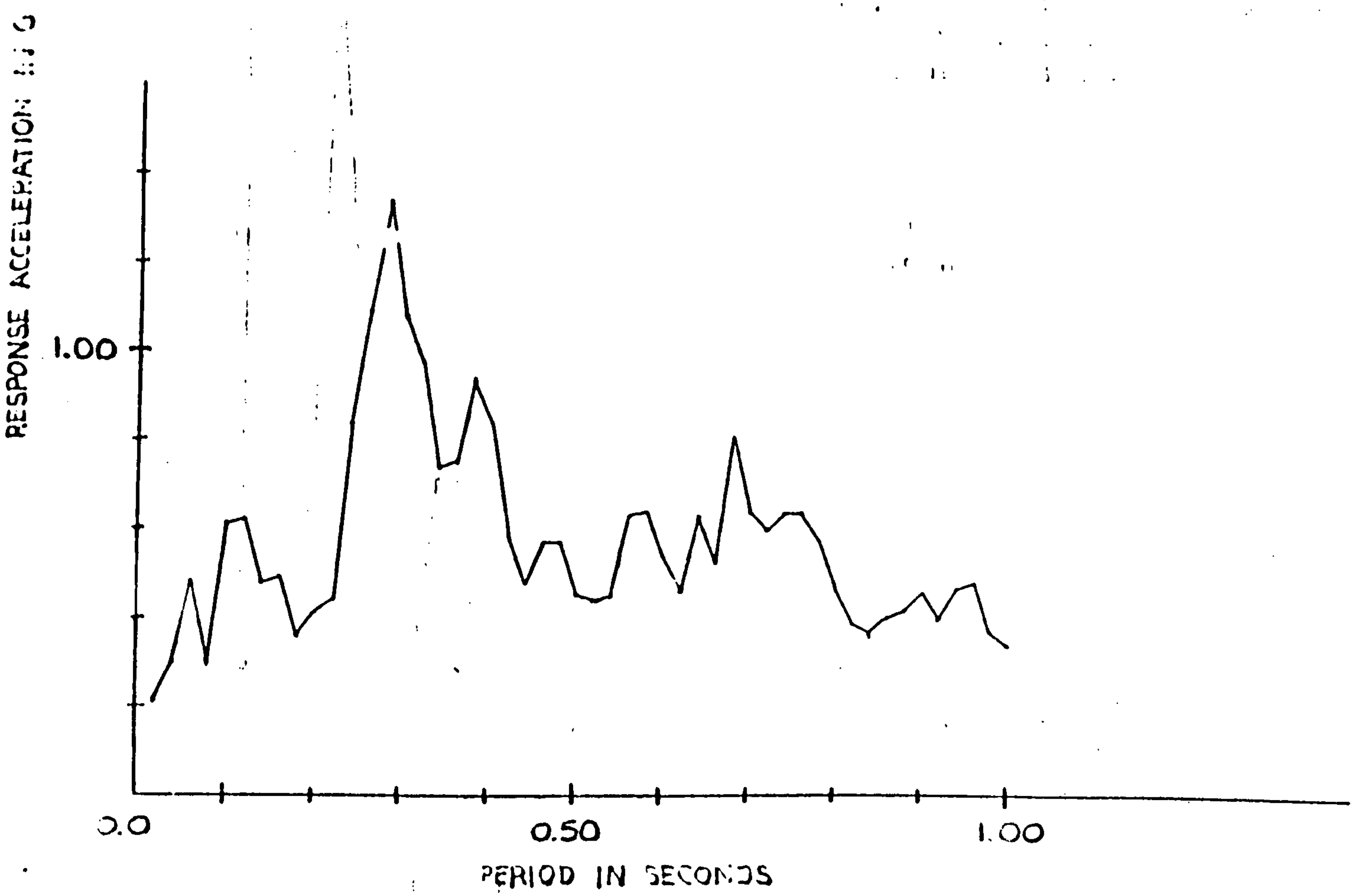


FIG. 2.1-13

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT № 2
REACTOR CONTAINMENT
ELEVATION: 352'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.05

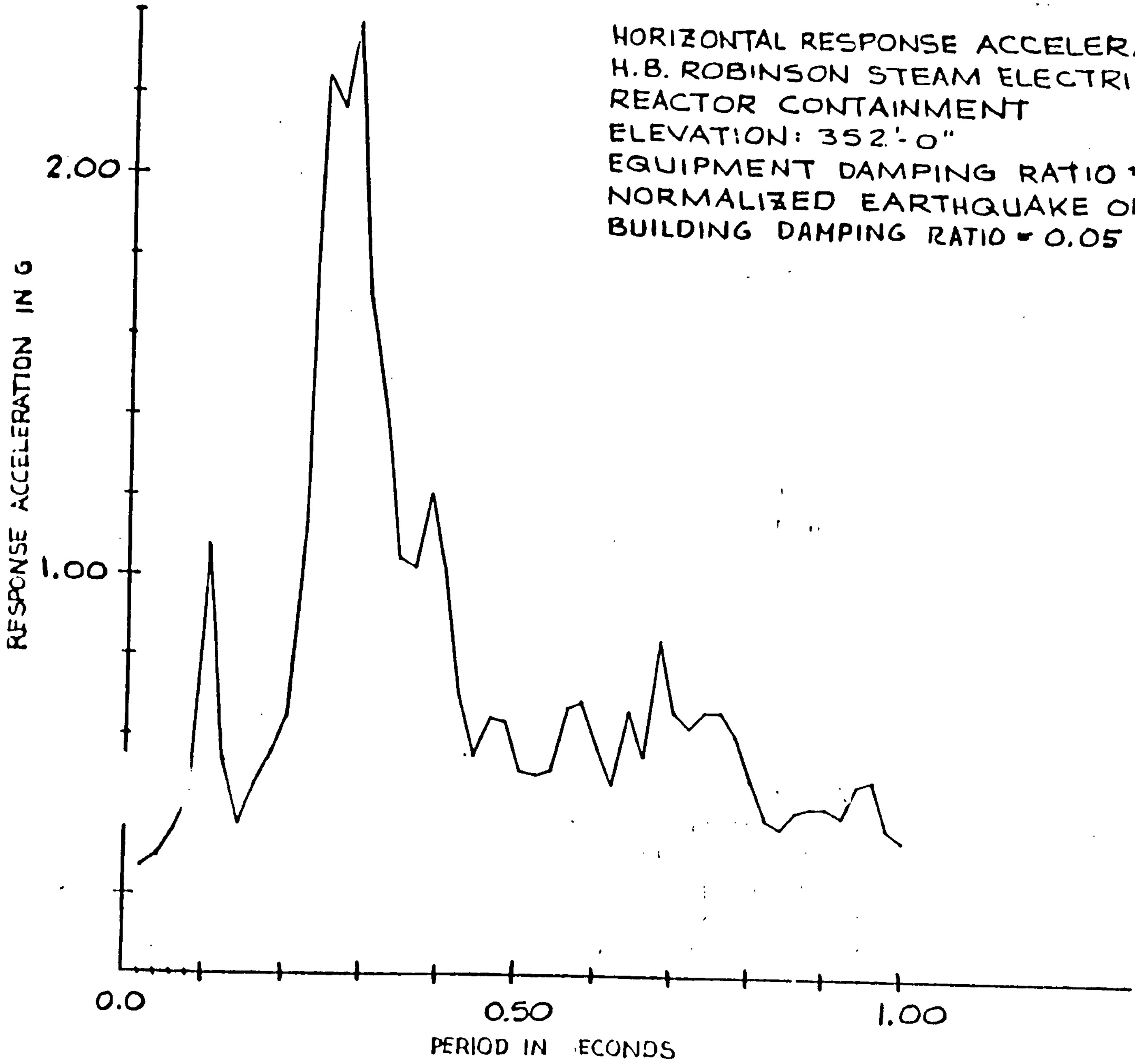


FIG. 2.1—14

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT No 2
REACTOR CONTAINMENT
ELEVATION: 401'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.05

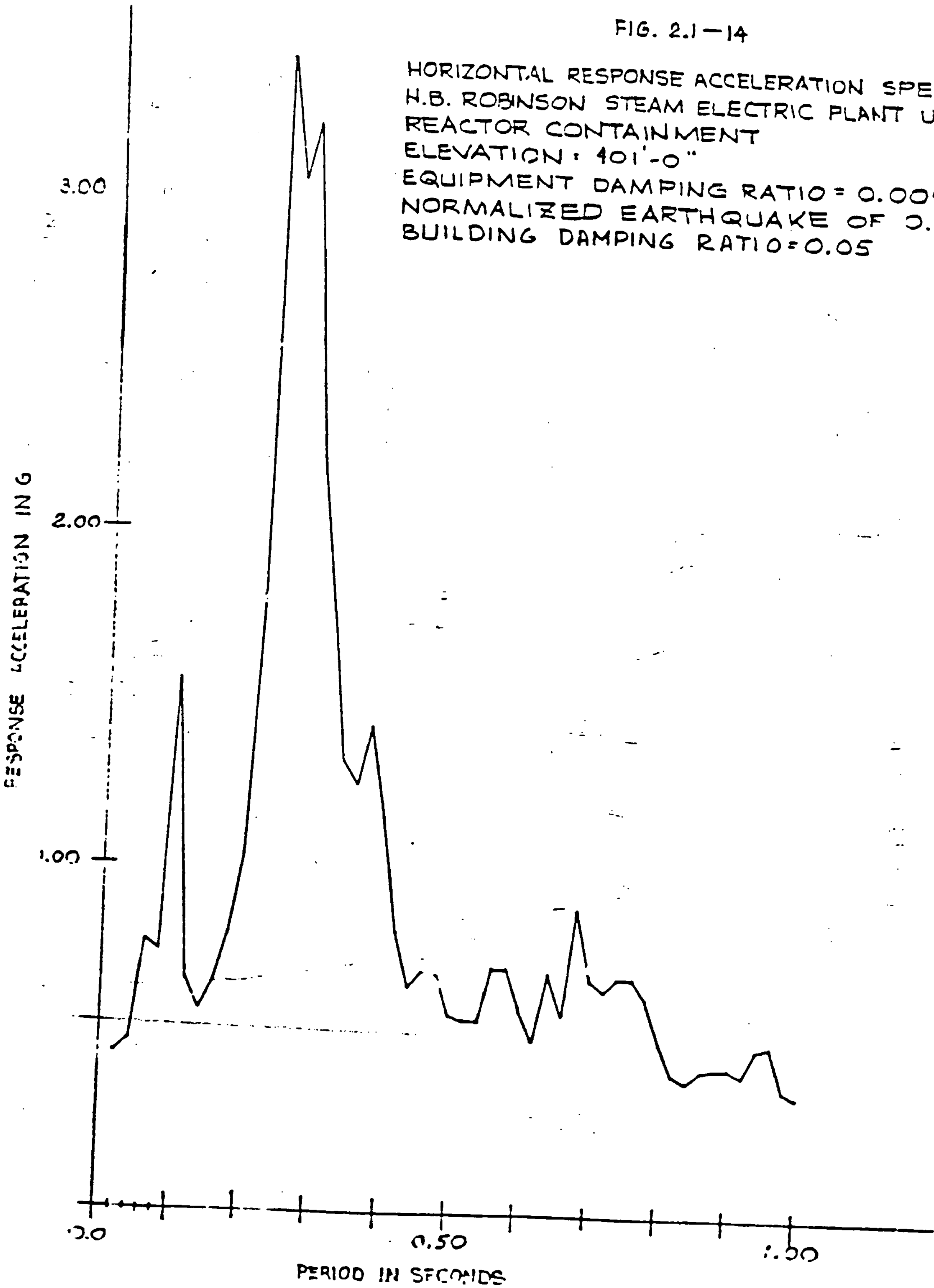


FIG. 2.1-15

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT - UNIT NO. 2
TURBINE BUILDING
ELEV. 224'-0" (GROUND)
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.02

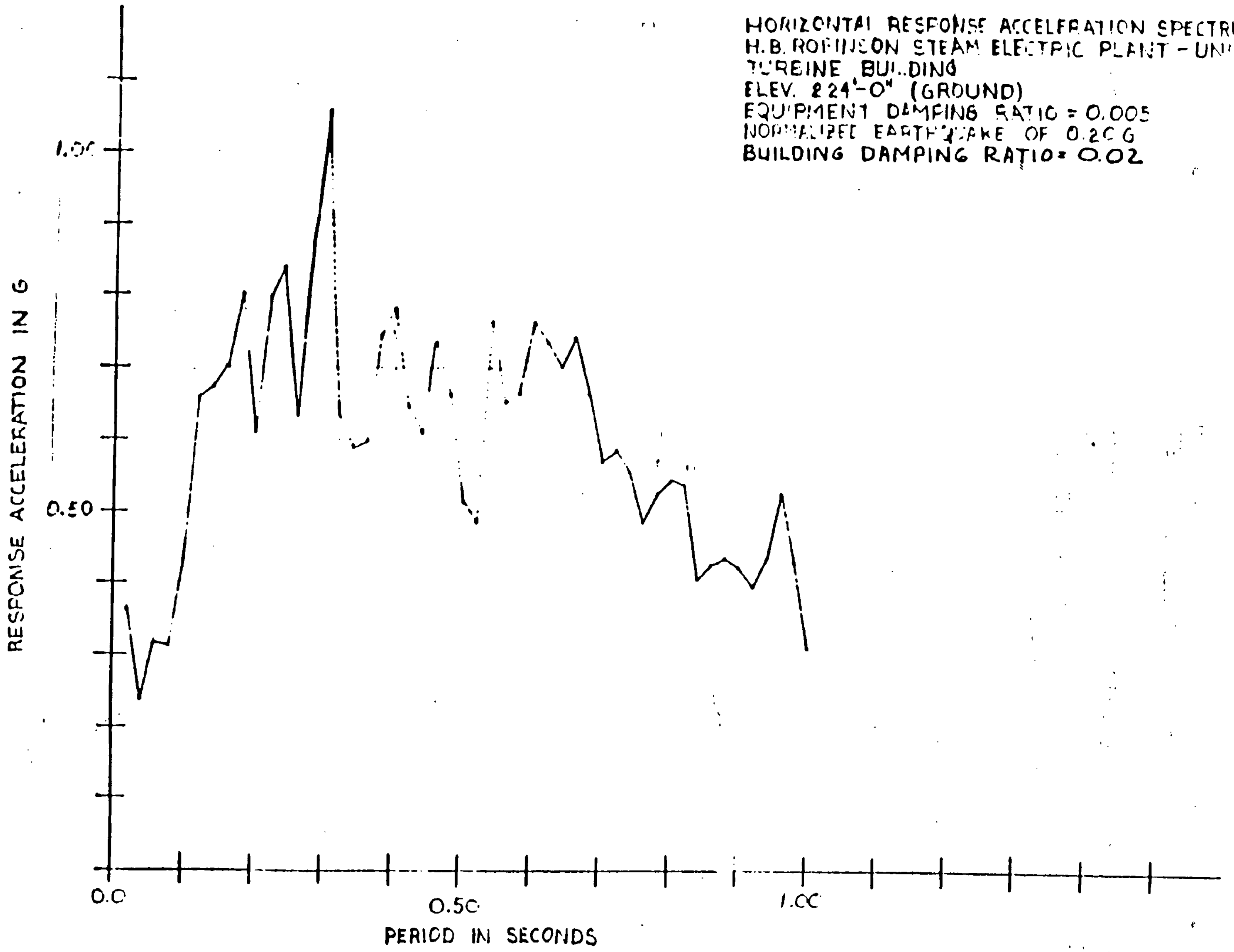


FIG. 2.1-16

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT—UNIT NO. 2
TURBINE BUILDING (NORTH-SOUTH)
ELEV. 242'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.02

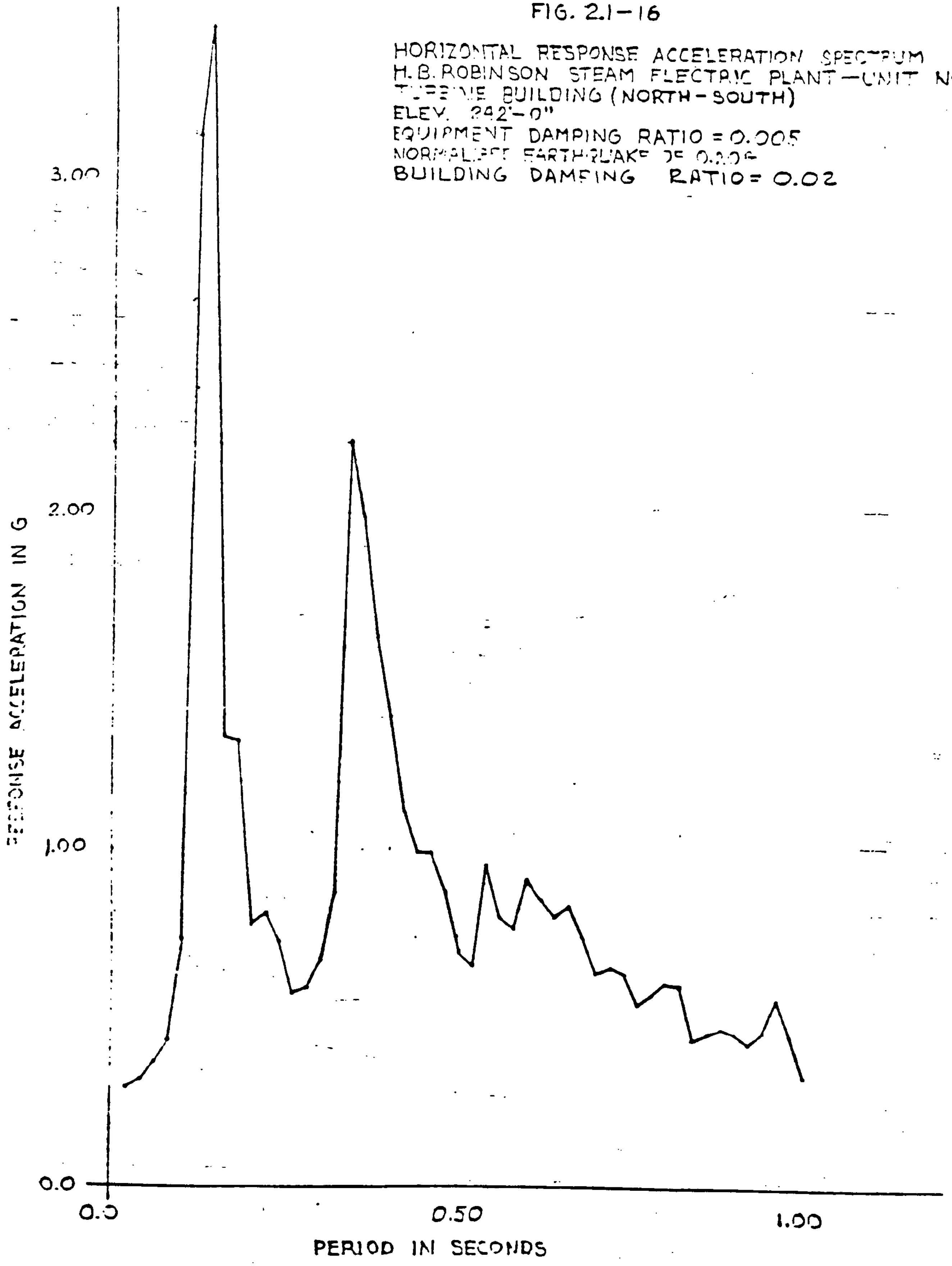
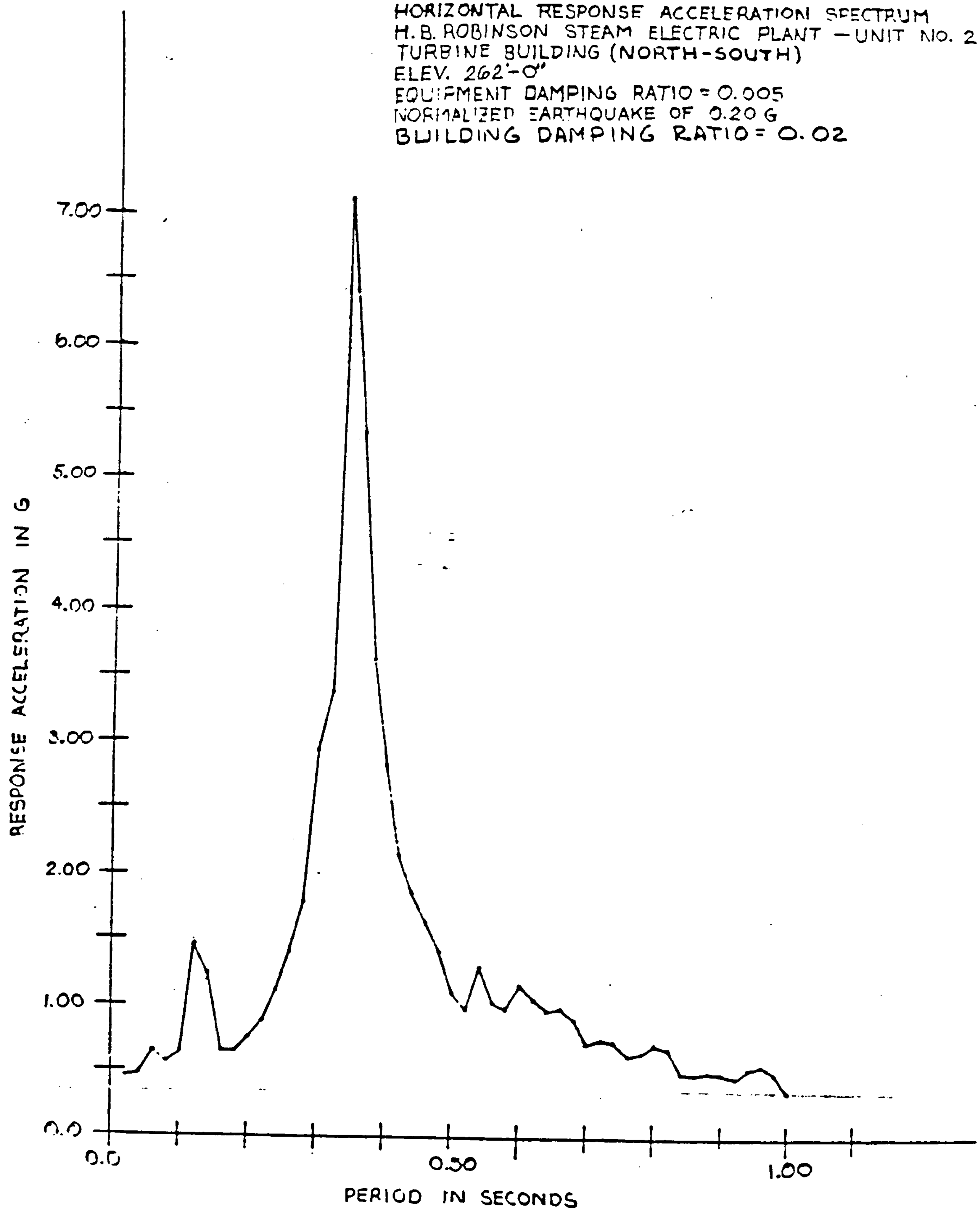


FIG. 2.1-17

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H. B. ROBINSON STEAM ELECTRIC PLANT — UNIT NO. 2
TURBINE BUILDING (NORTH-SOUTH)
ELEV. 262'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20 G
BUILDING DAMPING RATIO = 0.02



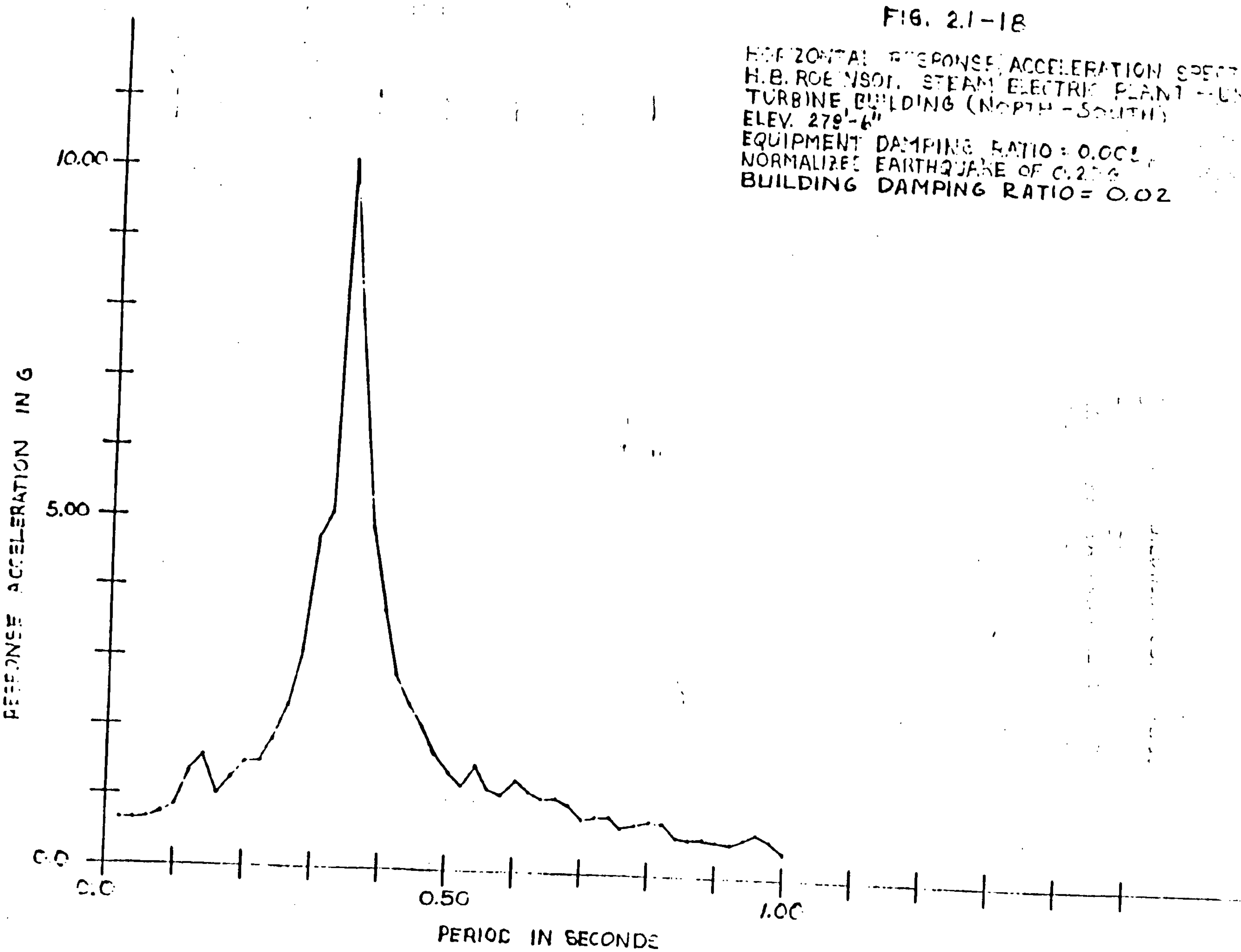


FIG. 2.1-18

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT - UNIT NO. 2
TURBINE BUILDING (NORTH-SOUTH)
ELEV. 279'-6"
EQUIPMENT DAMPING RATIO = 0.00[illegible]
NORMALIZED EARTHQUAKE OF 0.2 G
BUILDING DAMPING RATIO = 0.02

FIG. 2.1-19

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT No 2
TURBINE BUILDING (EAST-WEST)
ELEVATION: 242'-0"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.02

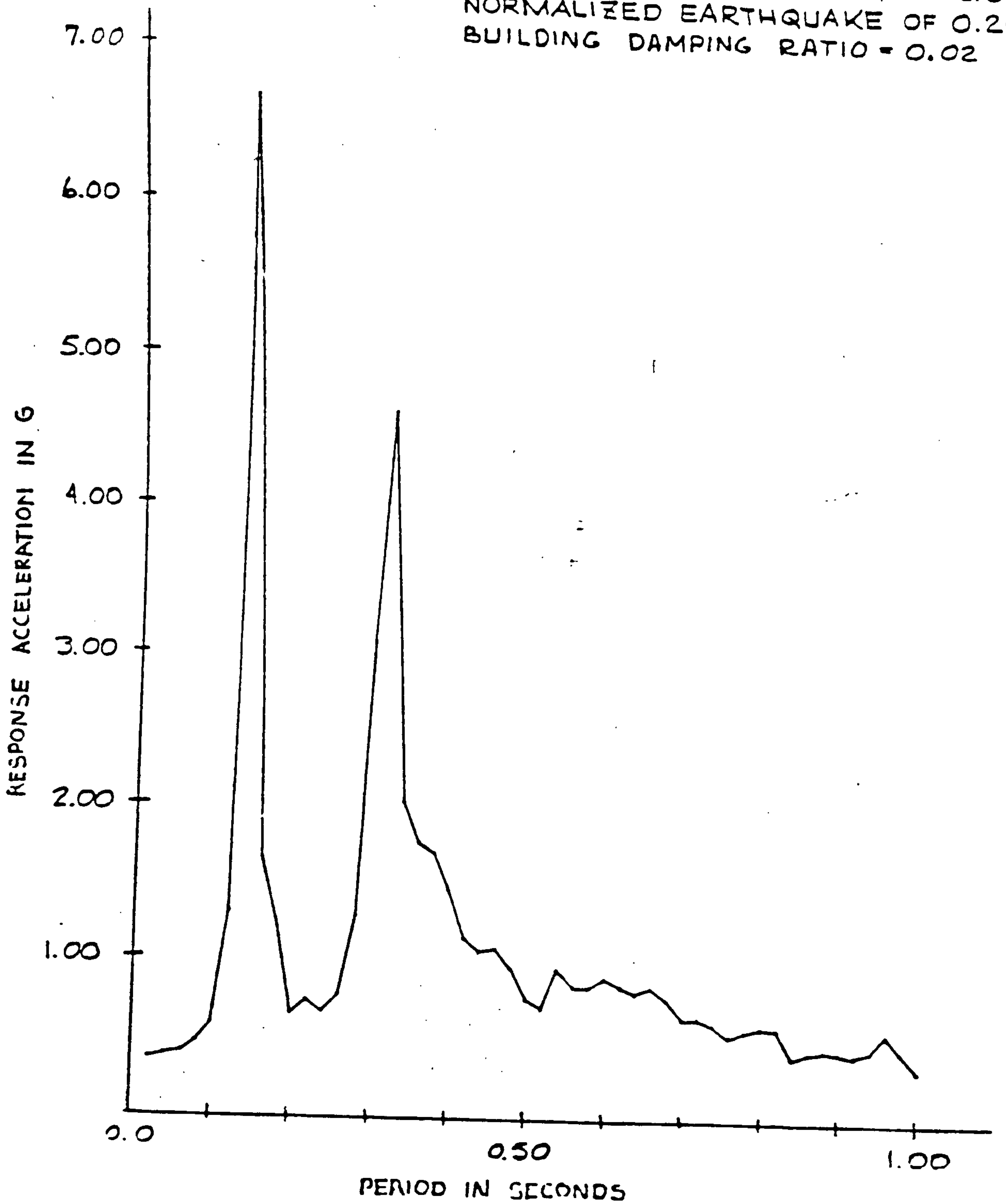
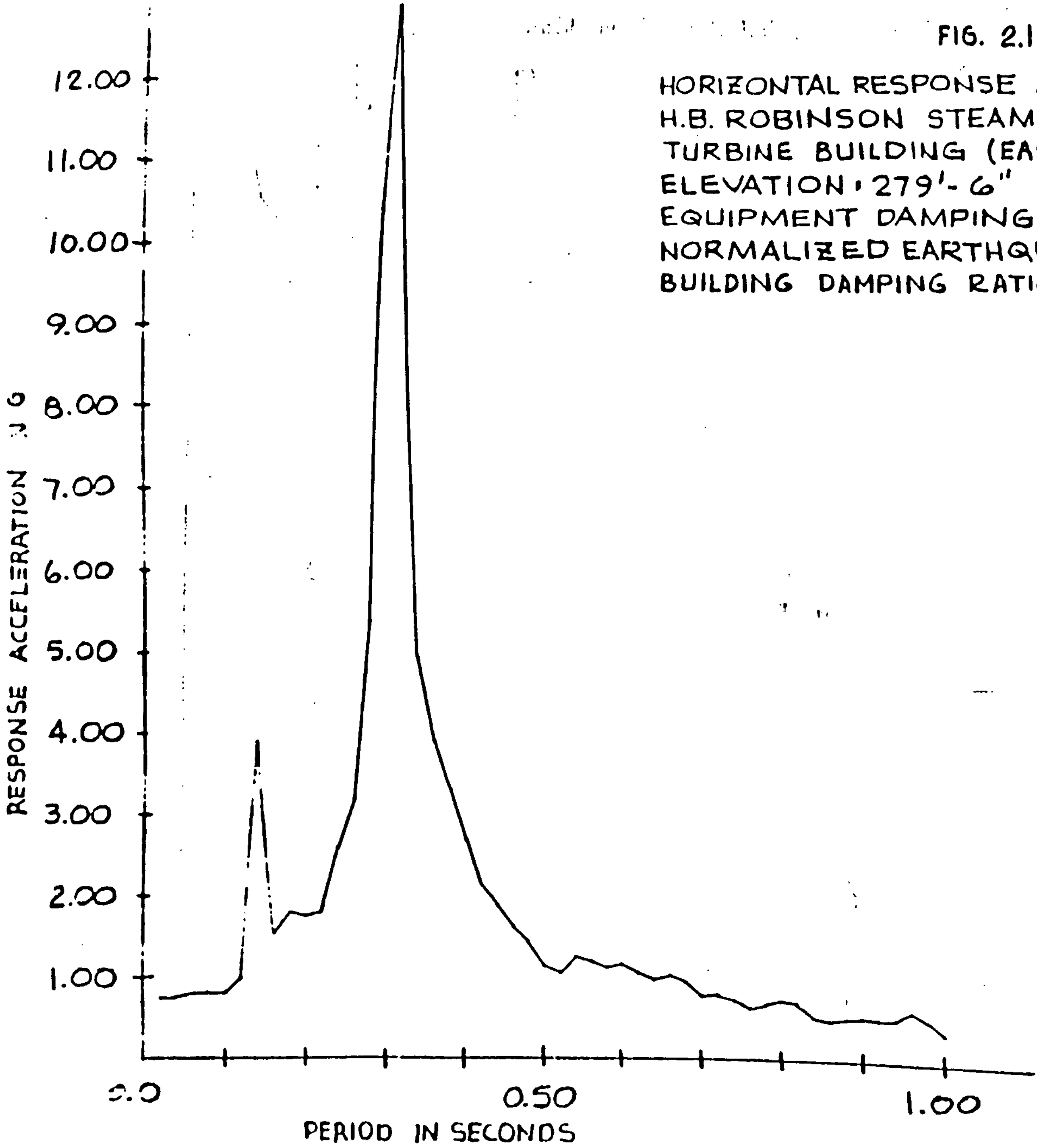


FIG. 2.1-21

HORIZONTAL RESPONSE ACCELERATION SPECTRUM
H.B. ROBINSON STEAM ELECTRIC PLANT UNIT № 2
TURBINE BUILDING (EAST-WEST)
ELEVATION : 279'-6"
EQUIPMENT DAMPING RATIO = 0.005
NORMALIZED EARTHQUAKE OF 0.20G
BUILDING DAMPING RATIO = 0.02



2.2 Reactor Coolant System Dynamic Analysis

This report describes the seismic pipe stress analysis for the reactor coolant loop (RCL). The completed analysis shows that the RCL piping will experience seismic stresses below allowables and therefore is adequate.

The maximum seismic stress occurs at the crossover leg/ reactor coolant pump suction nozzle interface and is 3184 psi which is below the allowable seismic stress.

This section contains:

1) A description of the system considered, and the mathematical model used.
2) The method of analyses.
3) A detailed description of the computer input constraint assumptions.
4) The resultant equipment support constraint loads under seismic conditions.
5) An isometric of the RCS.

2.2.1 CPL Reactor Coolant System Thermal and Seismic Analysis

1) The seismic analysis has been performed on the reactor coolant loop (RCL) which consists of the reactor vessel (RV), steam generator (SG), reactor coolant pump (RCP), the pipe connecting these components, and the large component supports. The components and piping are modeled as a system

of lumped masses connected by springs whose values are computed from elastic properties that are input. A simplified support model was arrived at by representing the structural support system as equivalent springs rather than as member beams and columns.

2) The analysis was performed using a proprietary computer code called WESTDYN. The code uses as input, system geometry, inertia values, member sectional properties, elastic characteristics, support and restraint characteristics, and the appropriate CPL seismic floor response spectrum for 0.5% critical damping. Both horizontal and vertical components of the seismic response spectrum are applied simultaneously. The seismic shock spectra were applied simultaneously along the Y and Z axis. Previous analysis indicate the Z direction to be the most critical horizontal direction for maximum pipe stress.

With this input data, the overall stiffness matrix [K] of the three dimensional piping system is generated (including translation and rotational stiffnesses). Zero rows and columns representing restraints are deleted, and the stiffness matrix is inverted to give the flexibility matrix [F] of the system.

$$[F] = [K]^{-1}$$

A product matrix is formed by the multiplication of the flexibility and mass matrices. This product matrix forms

the dynamic matrix, [D], from which the modal matrix is computed.

$$[D] = [F]\,[M]$$

The eigenvalues and eigenvectors representing the frequency and associated mode shape for each mode are generated using a modified Jacobi method.

$$(w^2\,[M] - [K])\,[X] = 0$$

From this information, the modal participation factor is combined with mode shapes and the appropriate seismic response spectrum values to give the structural response for each mode. Then the forces, moments, deflections, rotations, constraint reactions, and stresses are calculated for each significant mode. The modal stresses are then summed by the square root of the sum of the square method for each significant point in the system to determine the total stress.

3) The restraints, supports, and other constraints assumed for input into the seismic computer model are given below (see Page 11 for axis orientation).

SEISMIC

Reactor Vessel	The RV is rigid.
Steam Generator	The SG at the upper support point is permitted to translate along and rotate about the X, Y, and Z axis, but translations along X and Z are resisted by springs representing the upper support.

	The SG at the lower support point is permitted to translate along and rotate about the X, Y, and Z axis, but all movements are resisted by springs representing the lower support's stiffness.
Reactor Coolant Pump	The RCP is permitted to translate along and rotate about the X, Y, and Z axis, but all movements are resisted by springs representing the support's stiffness.

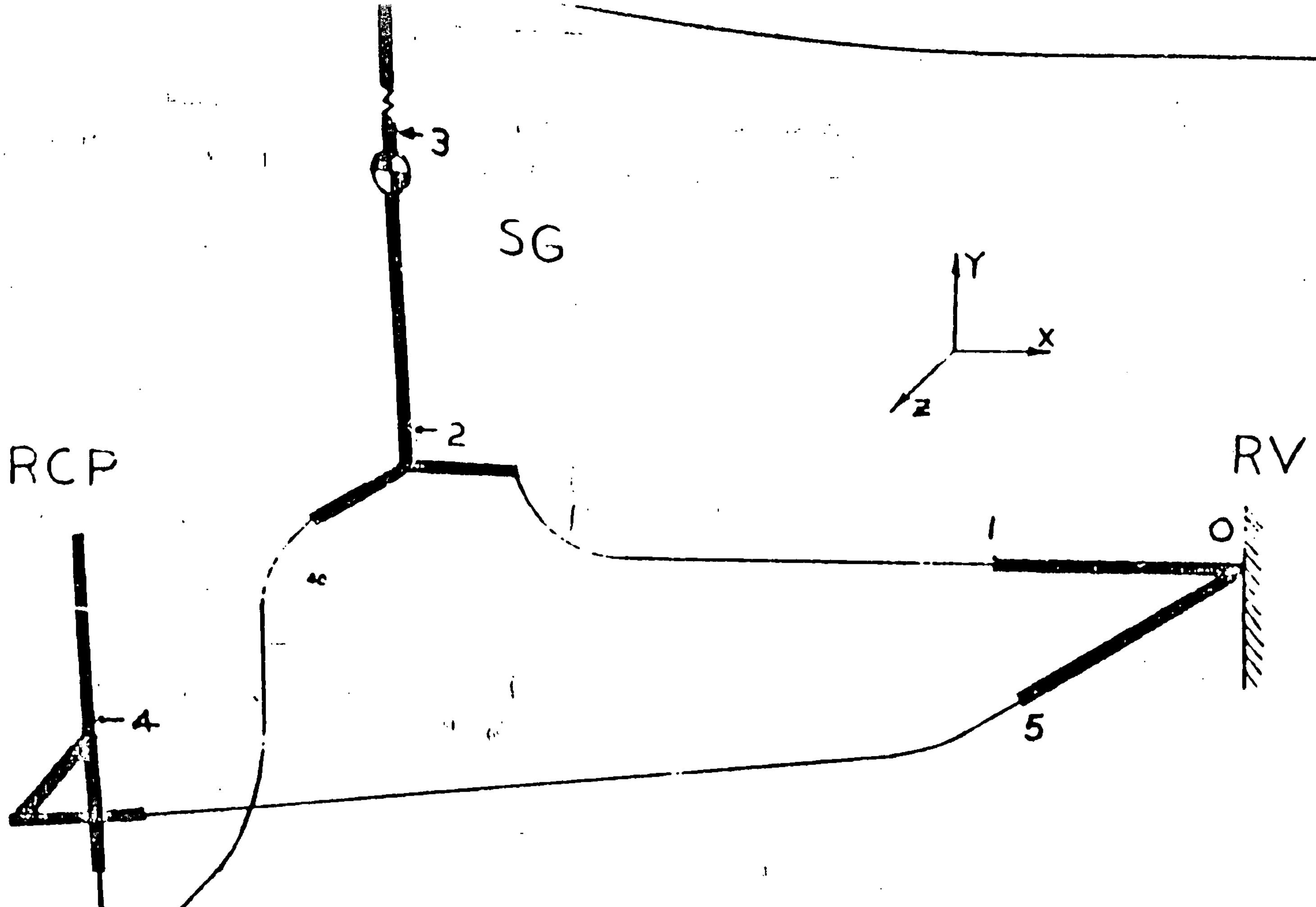
SKETCH SHEET

WESTINGHOUSE ELECTRIC CORPORATION

CPL - EQUIPMENT CONSTRAINT REACTIONS

	F_x	F_y	F_z	M_x	M_y	M_z
RV						
0	±83877	±101543	±12212	±14400834	±2630123	±14596880
SG						
2	0	±153909	±115475	±5752816	±2121616	±2357675
3	±4467	0	±244706	0	0	0
RCP						
4	±32663	±83775	±143892	±29659	±1109336	±706253

FORCES IN POUNDS, MOMENTS IN INCH-POUNDS
REACTIONS AT RV INCLUDE ALL THREE LOOPS



CPL Reactor Coolant Loop

2.3 Class I Piping Other Than Reactor Coolant

2.3.1 General

Although a seismic amplification factor was used in the design of all Class I piping, potential resonance response of the building and piping were not considered explicitly. This section contains an evaluation of the potential resonance effects (i.e., resonance between structures and piping) on Class I piping to assure that the design and/or the design amplification factor was adequate. The basis for this analysis follows:

For all Class I piping other than reactor coolant a resonance evaluation factor, K, was determined by dividing the peak accelerations of the floor response spectra by the acceleration used in the piping analysis. A modal contribution factor of 1.3 was used together with the resonance evaluation factor, K, to perform a stress evaluation as follows:

$$1.3\,K\,\sigma_S + \sigma_N \le \sigma_A \qquad (1)$$

where

σ_A = 1.8 times the allowable stress or yield stress, whichever is higher for code listed materials (ASA B31.1 or ASME Boiler & Pressure Vessel Section III) as recognized by ASME Boiler & Pressure Vessel Section III for emergency conditions. For materials not code listed, yield stress will be used (See FSAR Table 5A.3-1).

σ_S = seismic stress including effects of valve motors from design calculations.

σ_N = normal primary and bending stresses for loadings other than seismic, from design calculations.

In cases where the criterion of equation (1) is not met, a frequency check will be performed. A range of frequencies of interest was defined as follows:

$$0.5f_B \leq f_P \leq 2f_B \quad (2)$$

where,

f_B = the fundamental frequency of the building

f_P = the fundamental frequency of the piping

2.3.2 Description of Design Basis

The following is a general description of the design approach used for all Class I piping other than reactor coolant:

2.3.2.1 Method of Arriving at Static Coefficients

Class I piping is housed by and supported from the reactor inner structure, the reactor containment structure, the Class I bay of the turbine building and the reactor auxiliary building. A dynamic analysis was performed on these structures to determine the expected accelerations at various levels within the structure for both the operating basis and design basis earthquakes. Details of the dynamic analysis of Class I structures are continued in FSAR - Appendix 5A. In arriving at the static coefficients used for the design of piping systems, the horizontal acceleration values at the various levels of the structures were amplified by a ratio equal to the peak ground response for 0.5% damping as shown on the Housner curves divided by the ground acceleration. In our case the peak ground response is 0.96g for the 0.2 ground acceleration earthquake so that all building response accelerations were multiplied by a factor of 4.8.

2.3.2.3 Range of Static Coefficients for the Various Buildings

As explained previously, the seismic response of the structures were amplified by a factor of 4.8 for the static coefficients that were applied to the piping systems. For the design basis earthquake (0.2g ground acceleration) these amplified values of horizontal accelerations ranged as follows for the various structures:

Reactor Containment Structure

0.96g at El 226
3.00g at El 413

Reactor Inner Structure

0.96g at El 226
2.15g at El 275

Reactor Auxiliary Building

0.96g at El 226
1.65g at El 262

Turbine Building - Class I Bay

0.96g at El 226
1.85g at El 266

In all cases, the vertical acceleration applied to the piping was assumed to be two-thirds of the peak ground response acceleration for 0.5% damping, i.e., 0.32g for the operating basis earthquake and .64g for the design basis earthquake.

2.3.2.4 Computer Method of Static Analysis

For Class I system analyzed by this method, an isometric sketch was made from the piping drawings with mass points located at every tee and at the intersection of straight pieces and elbows. In addition, straight pieces were divided into as many mass points as necessary to assure adequate distribution of loading between support points with spans between mass points rarely exceeding ten foot lengths. This method accounted for the weight effects of valves as an additional load in the piping system for which stress values were calculated and restraints were placed as required. The valve loads were treated as concentrated loads acting on the centerline of the piping. A thermal analysis was then performed and after examining thermal displacements throughout the system, single or multi directional restraints were preli[illegible]rily located and the static analysis was perfo[illegible]

The s[illegible] analysis program uses the displacement method in wh[illegible]e equations of equilibrium at [illegible] junctions are solved simultaneously to obtain junction displacements, af[illegible] ich reactions at every point in the system are calcu[illegible]ed. Input data for the program includes weight per foot of pipe, fluid and insulation, weight of concentrated loads such as valves, static coefficients for the horizontal and vertical directions, and the location and direction of restraints. The computer output includes forces, moments and stresses (as per the Pressure

Piping Code, B31.1) at all points, displacements at all points, and forces on restraints and anchors.

The program multiplies the weight per foot of piping by the static coefficient and uses this adjusted weight unit to determine the virtual weight of each piece of pipe or concentrated load. Half the weight of each member is lumped at the end points and concentrated loads added as applicable. The program then calculates two sets of reactions for the system with loadings applied simultaneously first in one horizontal direction (X) and the vertical direction (Y), then in the other horizontal direction (Z) and the vertical direction (Y).

For each system, the results of the two combined horizontal-vertical analyses were evaluated and if the stress values were found excessive, restraints were added or relocated and the system reanalyzed both statically and thermally. Only in extreme cases where thermal considerations would not allow the use of positive restraints were hydraulic snubbers specified.

2.3.2.5 Simplified Method of Static Analysis

This method was used for the static analysis of relatively cold systems where thermal effects, although not ignored, were not a critical factor in the placement of restraints for seismic protection. The design basis was that restraints and supports be placed at close enough intervals so that seismic stresses would not exceed 5000 psi for the operational basis earthquake and 10,000 psi for the design basis earthquake.

For every size and schedule of pipes, filled with water and empty, and for the appropriate g loadings the maximum permissible span of straight, uniform pipe was established. These spans were determined on the conservative basis that supports act as pinned end joints for a uniformly loaded, simply supported beam rather than for a continuous beam. It is recognized that in the usual configuration of piping for large systems there are many deviations from the basic straight, uniform run of piping that must be considered in determining permissible span lengths. The effects of concentrated loads, branch connections, changes in pipe size, stress intensification factors, changes of direction, offsets, and various combinations of these effects were studied in detail. Correction factors were determined for each of these deviations which resulted in shortening the permissible span between restraint points for maintaining stress values within the preset limits.

As examples of correction factors:

The permissible span for straight, uniform run of 4" Sch 40 pipe filled with water with a static coefficient of 1.50g is 29.6 feet for a stress value of 10,000 psi. If a valve weighing 163 pounds was located anywhere within the restraint locations and with the center of gravity on the pipe centerline, the permissible span was reduced by an amount equivalent to the weight of valve (163 lbs.) divided by the weight per foot of piping (say 16.3 $\frac{\text{lbs.}}{\text{ft.}}$), resulting in a permissible span of 19.6 feet (29.6 feet minus 10 feet). This approach is conservative since the resulting span lengths are shorter than actually required for limiting stresses to specified values.

If the same 4" Sch 40 pipe had a reducer located between restraint points so that piping on either end reduced to 3" Sch 40, the permissible span for the smaller size line governed.

If between restraint points the piping configuration was such that the 4" Sch 40 pipe had both a valve located along the 4" piping and a 3" Sch 40 reducer, the permissible span was reduced first for the effect of the valve weight and again for reduced pipe size.

2.3.2.6 Systems Analyzed by Computer Method & Simplified Method

In all cases, systems that did not permit the use of the simplified method were analyzed by the computer method. Accordingly, systems were separated as per the following categories:

Computer Analysis

1 - Piping 2" and larger with temperature in excess of 212°F.

2 - Piping with temperature less than 212°F with significant movement due to expansion of equipment at connection nozzles.

3 - Piping with temperature less than 212°F located in the upper region of the reactor containment structure.

4 - Piping with temperature less than 212°F connected to piping of higher temperature that could not be logically analyzed except as part of the main system.

Simplified Analysis

For the most part, systems analyzed by this method were those of lesser anticipated stress levels consisting of piping 212°F or less and with relatively low seismic loadings. Systems, other than those analyzed by the computer method, 1-1/2" and over were analyzed by the simplified method.

Piping 1-1/4" and smaller that were field run (drains, vents, test lines and instrumentation lines) were seismically protected by specifying the maximum spacing between restraints such that stress values for straight runs of pipe would not exceed 10,000 psi for the 0.2g ground acceleration earthquake.

Although thermal expansion stress values are not identified in this report, it should be noted that:

1 - In all cases, thermal expansion stresses are within the Sa allowable of the Code for Pressure Piping, B31.1.

2 - In all cases, the sum of stresses due to internal pressure, weight and seismic loading for the operational basis earthquake is within 1.2 S_h (allowable stress in hot condition).

TABLE 2.3.3-1

FLOOR RESPONSE ACCELERATIONS FOR
H. B. ROBINSON STEAM ELECTRIC PLANT
(Carolina Power and Light Company)

Acceleration time history functions producing ground response curves used.

The response accelerations are for a normalized 0.2g earthquake and 1/2% piping damping.

Description		Maximum g Load	Building Damping
Auxiliary Building (1)			5%
	Ground El 226'	0.87	
	El 246.0'	1.51	
	El 262.0'	2.19	
Turbine Building - Class I Bay (1)			2%
	Ground El 224'	1.06	
	El 242.0'	6.67	
	El 262.0'	8.52	
	El 279.5'	12.90	
Reactor Containment			5%
	Ground El 226'	0.870	
	El 289'	1.34	
	El 352'	2.38	
	El 401'	3.40	
Reactor Inner Structure			5%
	Ground El 226'	0.870	
	El 232.5'	0.89	
	El 248.0'	0.91	
	El 272.5'	0.96	
	El 296.6'	2.62	

(1) Analysis for both directions of the building were performed and only maximum values are reported.

2.3.3 Seismic Amplification Factors and Building Frequency Factors

As part of the resonance evaluation, seismic g loading amplification factors were developed such that an analysis could be performed to determine the effects on piping should the piping be in resonance with the building. The amplification factor was determined as follows:

$$K = \frac{b}{a}$$

where,

b = peak acceleration at the floor where the Class I piping is located from floor response spectra (Reference Table 2.3.3-1).

a = Acceleration used in the piping analysis - Based on 0.1g or OBE.

For the evaluation, the amplification factor (K) for horizontal accelerations ranged as follows:

Reactor Containment Structure

1.81 at El 226
1.79 at El 401

Reactor Inner Structure

1.81 at El 226
0.67 at El 275

Reactor Auxiliary Building

1.81 at El 226 (.87 (Table 2.3.3-1)/1.81)/4.8 = .1 (Fig. 11 Appendix I)
2.74 at El 262

Turbine Building - Class I Bay

2.20 at El 226
9.00 at El 262

In addition, the fundamental frequency of each structure was found for the purpose of determining the potential for resonance between piping and the structures. The fundamental frequencies for each structure and the frequency band width follows:

		F_b CPS	Range $2F_b - .5F_b$ CPS
Reactor Containment Structure		3.83	7.6 - 1.9
Reactor Inner Structure		6.0	12.0 - 3.0
Reactor Auxiliary Building	Long	13.9	27.8 - 6.95
	Short	11.3	22.6 - 5.65
Turbine Building-Class I Bay	Long	3.16	6.32 - 1.58
	Short	2.91	5.82 - 1.45

2.3.4 Piping Evaluation

2.3.4.1 Systems Analyzed by Computer Method

The procedure used for evaluating the stress values for computer analyzed systems was as follows:

1 - For each system the various pipe sizes and wall thicknesses were listed in a table and identified by point numbers on the isometric sketches used for the analysis.

2 - The internal pressure and weight stresses were taken from the original evaluation and listed.

3 - The total allowable primary stress equal to 1.8 Sm was determined and the pressure and weight stresses were subtracted from the total allowable, the remainder thus being the stress value available for seismic loading.

4 - The K value for each point listed was determined by dividing the maximum acceleration of the appropriate floor response spectrum by the acceleration value used in the analysis. This ratio was then multiplied by the 1.3 modal participation factor.

5 - The higher of either the static X-Y or Y-Z stresses was multiplied by 1.3K, which represents the maximum potential stress value should the piping be in resonance with the supporting structure.

6 - The stress available for seismic loading (Item 3) was divided by the stress value for potential

resonance (Item 5), resulting in a "design evaluation factor." The "design evaluation factor" is a measure of design conservatism and indicates that if the factor is larger than 1.0 the piping does meet evaluation criteria.

Work sheets were compiled as per the above described procedure for every pipe size for each of the systems analyzed by the computer method. All piping systems, except for that piping contained in the Class I turbine bay were analyzed by the procedure and showed stress values which met acceptance stress criterion. As an example of the procedure used, refer to tables 2.3.3.1-1a and 1b where systems that indicated "design evaluation factors" of 1.25 or less were listed.

In the Class I turbine bay, a frequency evaluation was performed in lieu of a stress evaluation. The frequency evaluation consisted of determining the natural frequency of the piping (i.e., fundamental frequency) and comparing this value to the building's fundamental frequency ranges which are identified in section 2.3.3. The frequency analysis was performed by a computer method which provides the fundamental frequency of the system and normalized mode shape.

This evaluation showed that of the Class I systems located above ground level the following piping systems had fundamental frequencies which fell within the building frequency band:

a. Steam Driven AFWP Discharge to Main Feed System

b. FW Regulatory Valve Bypass #1, #2, & #3, S/G

Restraints were added to these systems to change their fundamental frequency such that it fell outside building fundamental frequency band. A summary of results follows:

Iso. No.	Line No.	Description	No. Restraints Added	System Fund. Freq. (CPS) Before	System Fund. Freq. (CPS) After	Building Resonance Band (CPS)
FDW-1	6"FW18, 4"FW25, 26,27	Steam Driven AFWP Discharge to Main Feed System	2	5.521 cps	7.720 cps	6.32 - 1.45
FDW-6	4FW 32, 33, 34	FW Regulatory Valve Bypass #1,#2,#3 S/G	3 (one per line)	5.807 cps	9.634 cps	6.32 - 1.45

After revising the system restraint design, the system thermal stress analysis was performed and all stresses were found to be within code allowables.

Table 2.3.3.1-1a

Pipe Evaluation For Computer Method

H. B. ROBINSON - CLASS I PIPING

Iso. No.	Line No.	Description	[illegible] & Sch.	[illegible]	Max. Oper. Temp.	Mat'l	A_F/A_M *	Press Stress	1.8 Sm	Avàil For Seismic	Analytical ** g Horiz/Vert.
CH-3	4CH74	Chem & Vol. Control Recirc Pump Disch	4"S[illegible]05	[illegible]	[illegible]30	A312 TP304	8.63	863	36000	33,637	.62/.32
SI-4	4SI110	High Hd. Pump Disc to Boron Tank	[illegible]	[illegible]	280	A312 TP316	2.61	3915	36000	30,585	.68/.32
SI-5	2SI20	High Hd. SI to Loop 3 Between HDR and MOV 868A	2"SCH805	1500	280	A312 TP316	2.00	3000	36000	31,500	.62/.32
SI-20	12AC3	RHR Ht. Exchg Bypass Line	12SCH405	350	380	A312 T304	7.76	2716	32472	28256	.48/.32

* AF/AM = Pipe flow area to metal area ratio

** The acceleration applied statically in the seismic analysis of Class I piping.

Table 2.3.3.1-1b

Pipe Evaluation For Computer Method

H. B. ROBINSON - CLASS I PIPING

Iso No.	Line No.	1.3 K*	Points On Iso.	Static X-Y	Static Y-Z	Maximum Static (X) 1.3 K	Design Evaluation Factor	Remarks
CH-3	4CH74	3.17	1-9	9,281	9,865	31,272	1.076	
SI-4	4SI110	2.89	56,55 86-159	8,923	5,311	25787	1.186	
SI-5	2SI20	3.17	13&30	6.861	7,720	24,472	1.287	
SI-20	12AC3	4.09	167-311	6,590	5,907	26,953	1.048	

*All lines are located between the ground floor (El. 226') and elevation 246' at the auxiliary building therefore, the floor response spectra g valve used was the value for elevation 246'.

2.3.4.2 Systems Analyzed by the Simplified Method

As described in section 2.3.2.5, the design basis for systems analyzed by the simplified method was that restraints and supports were placed at close enough intervals so that seismic stresses would not exceed 5000 psi for the operational basis earthquake and 10,000 psi for the design basis earthquake. An evaluation was performed for this method in a manner similar to that described in section 2.3.4.1 and the results are shown in table 2.3.4.2-1.

Table 2.3.4.2-1

PIPE EVALUATION FOR SIMPLIFIED METHOD

	1.8 Sm	Available * For Seismic	** Analytical g	Max. g (Fl/Resp.Sp.)	1.3K	Computed Stress	Computed Stress x1.3K	Desi Evalu Fact
Reactor Inner Structure								
Ground El 226'	35,000	29,000	.75	.87	1.51	5000	7550	3.84
El 232.5'	35,000	29,000	.75	.89	1.54	5000	7700	3.76
El 248.0'	35,000	29,000	.75	.91	1.58	5000	7900	3.67
El 272.5'	35,000	29,000	.75	.96	1.66	5000	8300	3.50
Reactor Auxiliary Building								
Ground El 226'	35,000	29,000	.75	0.87	1.51	5000	7550	3.84
El 246'	35,000	29,000	.75	1.51	2.62	5000	13,100	2.22

* The rational for the reduction of 6000 psi from the 1.8 Sm allowable stress was based on a weight stress value of 1500 psi and an internal pressure stress value of 4500 psi.

* The acceleration applied statically in the seismic analysis of Class I piping.

2.3.5 Valve Evaluation - Effects Of Valve Operators

For systems analyzed by the Computer method, the stress levels at all applicable valve locations were increased as described in Section 1.3 to account for the effect of the offset mass of the valve operators. Thus, by including the total stress (i.e., stress due to valve operators and normal piping stresses) in the evaluation described in Section 2.3.4.1, the potential effect of resonance was determined.

For systems analyzed by the simplified method, an overall evaluation was performed utilizing the information from Section 1.3. For this evaluation the worst stress condition (i.e., for a 2 inch valve) was assumed to apply in all cases. The results of this evaluation is shown in summary form on table 2.3.5-1.

As a result of the investigation of the effect on Class I piping due to valve operator offset weight (Reference Section 1.0) it was concluded that supports were required for the operators on valves less than 2 inches diameter. Therefore, supports are provided such that the following criteria are met:

1. Supports are provided at the valve body or operator in such a manner that the offset weight effect is essentially eliminated.
2. The support accepts all valve operator load when considering the appropriate seismic loading at the valve location.

Table 2.3.5-1

Valve Evaluation for Simplified Method

	1.8 Sm	Available* For Sesimic	Analytical** g	Max. g (Fl.Resp.Sp.)	1.3K	Computed Stress	Computed*** Stress x1.3K	Design Evaluation Factor
Reactor Inner Structure								
Ground El. 226.0'	35,000	29,000	0.75	0.87	1.51	7700	11,600	2.50
El. 232.5'	35,000	29,000	0.75	0.89	1.54	7700	11,800	2.45
El, 248.0'	35,000	29,000	0.75	0.91	1.58	7700	12,200	2.38
El. 272.5'	35,000	29,000	0.75	0.96	1.66	7700	12,800	2.28
Reactor Auxiliary Building								
Ground El 226'	35,000	29.000	0.75	0.87	1.51	7700	11,600	2.49
El. 246'	35,000	29,000	0.75	1.51	2.62	7700	20,200	1.44

* The rational for the reduction of 6000 psi from the 1.8 Sm allowable stress was based on a weight stress value of 1500 psi and an internal pressure stress value of 4[illegible]00 psi.

** The acceleration applied statically in the seismic analysis of Class I piping.

*** The maximum stress increase of 3,600 psi shown in section 1.3 was for 1.0g loading. Since the analysis was based on 0.75g loading this value becomes 2,700 psi, when adding this load to the basis 5000 psi loading it yields a total stress of 7,700 psi.

2.3.6 Safety Factors of Seismic Supports

Grinnell Company, Inc. of Providence, R. I., was selected for the design of seismic supports and restraints for this project. They have certified that their normal design of restraints incorporates a built-in basic safety factor of five. This factor varies, but mostly on the conservative side, because:

1 - In many cases, the loads on restraints are of such a small magnitude that in order to maintain uniform design standards, stock items for rods, clamps and associated hardware were used which were orders of magnitude heavier than required.

2 - Even for extreme cases where, for the total of thermal plus seismic loading, the allowable stress values for structural steel were extended to 1.33 times normal allowable stress limits, there exists a conservative safety factor, as shown by the following example: If a restraint was designed for a total force of 4000 lbs., 2000 lbs. due to thermal loading and 2000 lbs. due to seismic loading, it would be permissible to use structural steel for a normal allowable value of 3000 lbs., taking advantage of the 1.33 allowable increase for seismic loading. Due to the normal safety

factor of five, the force on the restraint can be increased to 15,000 lbs., before failure occurs, resulting in a total margin of 13,000 lbs. for seismic loading, which is equivalent to a safety factor of 6.5.

The codes and standards used in the design of hangers and restraints are:

a) Selection and application is in accordance with Manufacture Standardization Society MSS-SP-69

b) Materials and design is in accordance with Manufactures Standardization Society MSS-SP-58.

3.0 Class I Equipment

The purpose of this section is to identify the procedure used in the seismic design of Class I equipment to assure that the seismic requirements are met.

3.1 Seismic Criteria

Seismic requirements and design adequacy are determined as follows:

a) The horizontal seismic accelerations used are equal to or greater than the accelerations that occur at the equipment location (i.e., at the proper building elevation) as determined from the building dynamic analysis for the DBE.

b) The vertical seismic acceleration used are 2/3 of the value selected for horizontal acceleration.

c) The vertical and horizontal accelerations are assumed to act simultaneously.

This says vert. equip is 2/3 the curve & EL-pipe is 2/3 at ground!

d) Evaluate relative stiffness of the equipment and its support based on past experience with similar types of equipment. If the equipment is relatively rigid with a fundamental frequency above 15-20 cps then seismic design is performed by using a seismic g loading (ZPA) applied at the center of gravity of the equipment. This g loading corresponds to the combined mode g loading at the elevation of the building on which the equipment is supported. If the equipment is flexible, then a ratioed g (PEAK g) is applied at the center of gravity of the equipment. This g loading includes potential response of the equipment to building motion and the effects of both building and equipment damping.

3.2 Organizational Responsibilities

The seismic as well as all other design criteria for a particular piece of equipment is the responsibility of a cognizant design engineer who writes an equipment specification for purchase. In the specification, the cognizant engineer specifies the seismic requirements to be used by the designer.

The cognizant engineer has at his disposal specialist organizations who maintain expertise in seismic and dynamic design analysis for those cases where it is required to develop seismic design requirements or to review design adequacy.

The cognizant engineer is responsible to assure that the equipment supplied meets design requirements. The equipment supplied is evaluated by reviewing design drawings and in some cases, performing calculations independent of the vendors analysis.

Vendor shop and field construction audits are conducted to assure that the equipment is fabricated, installed and anchored in accordance with design requirements. These audits are conducted by QC inspectors, the cognizant engineer, and the resident field service engineers.

For a description of the functional integrity of the electrical racks, panels, etc., under earthquake conditions, refer to FSAR Amendment 10, Pages 7.5-13 through 15.

For equipment considered as relatively rigid (i.e. having a fundamental frequency above 15-20 cps) seismic design was performed using a seismic "g" loading applied at the equipment center of gravity. This is discussed in Section 3.0 of the report.

In light of the above, it can be concluded that Class I equipment will maintain both structural and functional integrity for the earthquake loadings associated with 0.2g ground acceleration.

H. B. ROBINSON UNIT NO. 2

ADDENDUM A

to

ADDITIONAL INFORMATION CONCERNING

SEISMIC ANALYSIS OF CLASS I PIPING AND EQUIPMENT

Class I equipment (flexible and rigid) have been evaluated to assure functional adequacy when considering potential equipment resonance with the building during earthquake conditions.

Electrical racks, panels, control boards, etc. fall in the category of flexible equipment. This equipment is located in the Auxiliary Building at or below elevation 258 ft. From Figures 2.1-10 and 2.1-11 of the report "Additional Information Concerning Seismic Analysis of Class I Piping and Equipment", the peak acceleration that a one-degree-of-freedom system in resonance with the building would experience is at elevation 258 ft. This peak acceleration is 2.0g for 0.2g ground acceleration with 0.5% of critical damping. For the minimum damping anticipated in this type of equipment, i.e., 1% of critical value, the peak acceleration is reduced to about 1.6g. This is the maximum equivalent static load that should be used to account for both floor acceleration and response spectra distortion.

When the equipment supports were designed, the equivalent static load was selected by accounting only for the floor acceleration. This means that a load of $\frac{0.30g}{0.20g} \times 0.69g = 1.05g$ was selected for equipment at or below elevation 258 ft. The design stresses were 2/3 of the material yield, e.g., 24,000 psi. Hence, the correct load of 1.6g would cause a maximum stress of $24{,}000 \times \frac{1.60g}{1.05g} = 36{,}500$ psi. The ultimate stress of this type of material is of the order of 70,000 psi. This gives a margin of 33,500 psi between the ultimate capacity and the maximum expected stresses.

For a description of the functional integrity of the electrical racks, panels, etc., under earthquake conditions, refer to FSAR Amendment 10, Pages 7.5-13 through 15.

For equipment considered as relatively rigid (i.e. having a fundamental frequency above 15-20 cps) seismic design was performed using a seismic "g" loading applied at the equipment center of gravity. This is discussed in Section 3.0 of the report.

In light of the above, it can be concluded that Class I equipment will maintain both structural and functional integrity for the earthquake loadings associated with 0.2g ground acceleration.