3.7a SEISMIC DESIGN

All systems and equipment of the NSSS are defined as either Seismic Category I or Non-Seismic Category I. The requirements for Seismic Category I classification are given in Section 3.2 along with a list of systems, components, and equipment which are so categorized.

All systems, components, and equipment related to plant safety are designed to withstand the potential safe shutdown earthquake and operating bases earthquakes.

The "Safe Shutdown Earthquake" is that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology, and seismology and specific characteristics of local subsurface material. It is that earthquake which produces the maximum vibratory ground motion for which Seismic Category I systems and components are designed to remain functional. These systems and components are those necessary to ensure:

(1) The integrity of the reactor coolant pressure boundary.

(2) The capability to shut down the reactor and maintain it in a safe shutdown condition.

(3) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guidelines exposures of 10CFR 50.67.

The "Operating Basis Earthquake" is that earthquake which, considering the regional and local geology, and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant. It is that earthquake which produces the vibratory ground motion for which these features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.

The seismic design of systems, components, and structures within the nuclear steam supply system (NSSS) scope of responsibility is presented in the following pages. The information presented in this section is intended to add to the information presented in Section 3.7b in order to better differentiate responsibilities in the seismic design of Susquehanna SES. As a result, not all subsections have a response but rather refer back to the corresponding subsection in Section 3.7b.

3.7a.1 SEISMIC INPUT

3.7a.1.1 Design Response Spectra

This subsection is covered in Subsection 3.7b.1.1.

3.7a.1.2 Design Time History

This subsection is covered in Subsection 3.7b.1.2.

3.7a.1.3 Critical Damping Values

The damping factors indicated in Table 3.7a-1 were used in the response analysis of various structures and systems, and in preparation of floor response spectra used as forcing inputs for piping and equipment analysis or testing. The values given in Table 3.7a-1 are less than or equal to those given in Regulatory Guide 1.61 and therefore are generally more conservative. See Note 1 on Table 3.7a-1 which describes the uses of higher damping values for piping systems.

3.7a.1.4 Supporting Media for Seismic Category I Structures

This subsection is covered in Subsection 3.7b.1.4.

3.7a.2 SEISMIC SYSTEM ANALYSIS

3.7a.2.1 Seismic Analysis Methods

Analysis of Seismic Category I NSSS systems and components is accomplished using the response spectrum or time-history approach. Either approach utilizes the natural period, mode shapes, and appropriate damping factors of the particular system. Certain pieces of equipment are analyzed statically by using 1.5 times the peak acceleration of the required response spectra. In some cases, dynamic testing of equipment is used for seismic qualification.

The time history analyses involve the solution of the equations of the dynamic equilibrium (Subsection 3.7a.2.1.1) by means of the methods discussed in Subsection 3.7a.2.1.2. In this case, the duration of motion is of sufficient length to ensure that the maximum values of response have been obtained.

A response spectrum analysis involves the solution of the equations of motion (Subsection 3.7a.2.1.1) by the method discussed in Subsection 3.7a.2.1.3.

3.7a.2.1.1 The Equations of Dynamic Equilibrium

Assuming velocity proportional damping, the dynamic equilibrium equations for a lumped mass distributed stiffness system are expressed in matrix form as:

$$[M]\{\ddot{u}(t)\}+[C]\{\breve{u}(t)\}+[K]\{u(t)\}=\{P(t)\} \qquad \text{Eq. 3.7a - 1}$$

where:

u(t)	=	time dependent displacement of non-support points relative to the supports
$\breve{u}$ (t)	=	time dependent velocity of non-support points relative to the supports
ü(t)	=	time dependent acceleration of non-support points relative to the supports
[M]	=	diagonal matrix of lumped masses
[C]	=	damping matrix
[K]	=	stiffness matrix
P(t)	=	time dependent inertial forces acting as non-support points.

3.7a.2.1.2 Solution of the Equations of Motion by Mode Superposition

The first technique used for the solution of the equations of motion is the method of Mode Superposition.

The set of homogenous equations represented by the undamped free vibration of the system is

$$[M]\{\ddot{u}(t)\} + [K]\{u(t)\} = \{0\} \qquad \text{Eq. 3.7a-2}$$

Since the free oscillations are assumed to be harmonic, the displacements can be written as

$$\{u(t)\} = \{\phi\} e^{iwt} \qquad \text{Eq. 3.7a-3}$$

where:

$\{\phi\}$	=	column matrix of the amplitude of displacements {u}
w	=	circular frequency of oscillation
t	=	time

Substituting Equation 3.7a-3 and its derivatives in Equation 3.7a-2 and noting that e^{iwt} is not necessarily zero for all values of t yields

$$[-o2\,[M] + [K]]\{\phi\} = \{0\} \qquad \text{Eq. 3.7a-4}$$

Equation 3.7a-4 is the classical algebraic eigen value problem wherein the eigen values are the frequencies of vibrations and the eigen vectors are the mode shapes, $\{\phi_i\}$.

3.7a.2.1.3 Analysis by Response Spectrum

As an alternative to the step-by-step mode superposition method described in Subsection 3.7a.2.1.2, the response spectrum method may be used. The response spectrum method is based on the fact that the modal responses can be expressed as a set of integral equations rather than a set of differential equations. The advantage of this form of solution is that for a given ground motion the only variables under the integral are the damping factor and the frequency. Thus, for a specified damping factor, it is possible to construct a curve which gives a maximum value of the integral as a function of frequency. This curve is called a response spectrum for the particular input motion and the specified damping factor. The integral has units of velocity; consequently, the maximum of the integral is called the spectral velocity.

Using the calculated natural frequencies of vibration of the system, the maximum values of the modal responses are determined directly from the appropriate response spectrum. The modal maxima are then combined as discussed in Subsection 3.7a.3.7.

The total seismic structural response is predicted by combining the response calculated from the two horizontal and the vertical analyses. When the response spectrum method is used, the methods for combining the loads from the three analyses is based on the method described in Subsection 3.7b.2.6.

3.7a.2.1.4 Support Displacements in Multi-Supported Structure

The Multi-Support dynamic analysis was not used during the original design of Susquehanna SES nor was this type of analysis a requirement of the construction permit. Other analytical methods are used to demonstrate the integrity of multi-supported structures during a postulated seismic event (for structures, see Subsection 3.7b.2.1). However, independent support motion analysis is used in conjunction with Regulatory Guide 1.61 damping as one of the acceptable alternative analytical methods during snubber elimination.

3.7a.2.1.5 Dynamic Analysis of Seismic Category I Structures, Systems, and Components

Time-History Techniques or the Response Spectrum Technique are used for the dynamic analysis of Seismic Category I structures, systems, and components which are sensitive to dynamic seismic events.

3.7a.2.1.5.1 Dynamic Analysis of Piping Systems

Each pipeline is idealized as a mathematical model consisting of lumped masses connected by elastic members. The stiffness matrix for the piping system is determined using the elastic properties of the pipe. This includes the effects of torsional, bending, shear, and axial deformations as well as change in stiffness due to curved members. Next the dynamic response of the system is calculated by using the response spectrum method of analysis.

The relative displacement between anchors is determined from the dynamic analysis of the structures. The results of the relative anchor point displacement are used for a static analysis to determine the additional stresses due to relative anchor point displacements.

3.7a.2.1.5.2 Dynamic Analysis of Equipment

Equipment is idealized as a mathematical model consisting of lumped masses connected by elastic members or springs. Analytical results for some selected large Seismic Category I equipment are given in Table 3.9-2.

When the equipment is supported at more than two points located at different elevations in the building, the response spectra for the most severe support point or spectra that envelope the response spectra of all support points is chosen as the design spectra.

The relative displacement between supports is determined from the dynamic analysis of the structure. The relative support point displacements are used for a static analysis to determine the additional stresses due to support displacements. Further details are given in the following subsection.

3.7a.2.1.5.2.1 Differential Seismic Movement of Interconnected Components

The procedure for considering differential displacements for equipment anchored and supported at points with different displacement excitation is as follows:

The relative displacements between the supporting points induce additional stresses in the equipment supported at these points. These stresses can be evaluated by performing a static analysis where each of the supporting point is displaced a prescribed amount. From the dynamic analysis of the complete structure, the time history of displacement at each supporting point is available. These displacements are used to calculate stresses by determining the peak modal responses. The stresses thus obtained for each natural mode are then superposed for all modal displacements of the structure by the SRSS method.

In the static calculation of the stresses due to relative displacements in the response spectrum method, the maximum value of the modal displacement is used. Therefore, the mathematical model of the equipment is subjected to a maximum displacement at its supporting points obtained from the modal displacements. This procedure is repeated for the significant modes (modes contributing most to the total displacement response at the supporting point) of the structure. The total stresses due to relative displacement is obtained by combining the modal results using the SRSS (Square Root of Sum of the Square) Method. Since the maximum displacement for different modes do not occur at the same time, the SRSS method is a realistic and practical method.

When a component is covered by the ASME Boiler and Pressure Vessel Code, the stresses due to relative displacement as obtained above are treated as secondary stresses.

3.7a.2.1.6 Seismic Qualification by Testing

For certain Seismic Category I equipment and components where dynamic testing is necessary to ensure functional integrity, test performance data and results reflect the following:

(1) Performance data of equipment which, under the specified conditions has been subjected to dynamic loads equal to or greater than those to be experienced under the specified seismic conditions.

(2) Test data from previously tested comparable equipment which, under similar conditions, has been subjected to dynamic loads equal to or greater than those specified.

(3) Actual testing of equipment in accordance with one of the methods described in Sections 3.9 and 3.10.

3.7a.2.2 Natural Frequencies and Response Loads

This subsection is covered in Subsection 3.7b.2.2.

3.7a.2.3 Procedure Used for Modeling

3.7a.2.3.1 Modeling Techniques for Seismic Category I Structures, Systems, and Components

An important step in the seismic analysis of Seismic Category I systems or structures is the procedure used for modeling. The systems or structures are represented by lumped masses, springs and dashpots idealizing the inertial, stiffness, and damping properties of the system. The details of the mathematical models are determined by the complexity of the actual structures and the information required for the analysis.

For information about modeling non-NSSS Seismic Category I structures, systems or components, see Subsections 3.7b.2.3 and 3.7b.3.3.

3.7a.2.3.2 Modeling of Reactor Pressure Vessel and Internals

The seismic loads on the reactor pressure vessel (RPV) and internals are based on a dynamic analysis of an entire RPV-Building Complex with the appropriate forcing function supplied at ground level. For this analysis, the models shown in Figure 3.7A-1 and the mathematical model of the building are coupled together.

This mathematical model consists of lumped masses connected by elastic (linear) members. Using the elastic properties of the structural components, the stiffness properties of the model are determined. The effects of both bending and shear are included. In order to facilitate hydrodynamic mass calculations, several mass points (fuel, shroud, vessel) are selected at the same elevation. The various lengths of control rod drive housings are grouped into the two representative lengths shown. These lengths represent the longest and shortest housings in order to adequately represent the full range of frequency response of the housings. The high fundamental natural frequencies of the CRD housings results in very small seismic loads. Furthermore, the small frequency differences between the various housings due to the length differences result in negligible differences in dynamic response. Hence, the modeling of intermediate length members becomes unnecessary. Not included in the mathematical model are light components such as jet pumps, in-core guide tubes and housings, sparger, and their supply headers. This is done to reduce the complexity of the dynamic model. If the seismic responses of these components are needed, they can be determined after the system response has been found.

The presence of a fluid and other structural components (e.g., fuel within the RPV) introduces a dynamic coupling effect. Dynamic effects of water enclosed by the RPV are accounted for by introduction of a hydrodynamic mass matrix, which will serve to link the acceleration terms of the equations of motion of points at the same elevation in concentric cylinders with a fluid entrapped in the annulus. The details of the hydrodynamic mass derivation are given in Reference 3.7a-1. The seismic model of the RPV and internals has two horizontal coordinates for each mass point considered in the analysis. The remaining translational coordinate (vertical) is excluded because the vertical frequencies of RPV and internals are well above the significant horizontal frequencies. Furthermore, all support structures, building and containment walls have a common centerline, and hence, the coupling effects are negligible. A separate vertical analysis is performed. Dynamic loads due to vertical motion are added to or subtracted from the static weight of components, whichever is the more conservative. The two rotational coordinates about each node point are excluded because the contribution of rotary inertia is

negligible. Since all deflections are assumed to be within the elastic range, the rigidity of some components may be accounted for by equivalent linear springs.

The shroud support plate is loaded in its own plane during a seismic event and hence is extremely stiff and therefore may be modeled as a rigid link in the translational direction. The shroud support legs and the local flexibilities of the vessel and shroud contribute to the rotational flexibilities and are modeled as an equivalent torsional spring.

3.7a.2.3.3 Comparison of Responses

The comparison between the calculated maximum seismic loads and the allowable loads in the RPV and internals is given in Table 3.7a-2.

3.7a.2.4 Soil Structure Interaction

This subsection is covered in Subsection 3.7b.2.4.

3.7a.2.5 Development of Floor Response Spectra

This subsection is covered in Subsection 3.7b.2.5.

3.7a.2.6 Three Components of Earthquake Motion

This subsection is covered in Subsection 3.7b.2.6

3.7a.2.7 Combination of Modal Responses

This subsection is covered in Subsection 3.7b.2.7.

3.7a.2.8 Interaction of Non-Category I Structures with Seismic Category I Structures

This subsection is covered in Subsection 3.7b.2.8.

3.7a.2.9 Effects of Parameter Variations on Floor Response Spectra

This subsection is covered in Subsection 3.7b.2.9.

3.7a.2.10 Use of Constant Vertical Static Factors

This subsection is covered in Subsection 3.7b.2.10.

3.7a.2.11 Methods Used to Account for Torsional Effects

This subsection is covered under Subsection 3.7b.2.11.

3.7a.2.12 Comparison of Responses

This subsection is covered under Subsection 3.7b.2.12.

3.7a.2.13 Methods for Seismic Analysis of Dams

This subsection is covered under Subsection 3.7b.2.13.

3.7a.2.14 Determination of Seismic Category I Structure Overturning Moments

This subsection is covered under Subsection 3.7b.2.14.

3.7a.2.15 Analysis Procedure for Damping

In a linear dynamic analysis, the procedure utilized to properly account for damping in different elements of a coupled system model is as follows:

(1) The structural damping of the various structural elements of the model are first specified. Each value is referred to as the damping ratio (B_j) of a particular component which contributes to the complete stiffness of the system.

(2) Perform a modal analysis of the linear system model. This will result in a modal matrix (ϕ) normalized such that $\phi_i^T K\phi_i = W_{i,}^2$ = W2i, where K is the stiffness matrix, W_i the circular natural frequency of mode i and ϕ_i^T is the transpose ϕ, which is a column vector of ϕ corresponding to the mode shape of mode i. Matrix ϕ contains all translational and rotational coordinates.

(3) Using the strain energy of the individual components as a weighting function, the following equation can be derived to obtain a suitable damping ratio (B_i) for the i^{th} mode.

$$B_j \frac{\sum_{j=1}^{N}\left[\phi_i^T B_j K_j \phi_i\right]}{W_i^2}$$

where

N	=	Total number of structural elements
ϕi	=	Mode shape for mode i (ϕ transpose)
B_j	=	Percent damping associated with element j

K_j = Stiffness contribution of element j

W_i = Circular natural frequency of mode i

3.7a.3 SEISMIC SUBSYSTEM ANALYSIS

3.7a.3.1 Seismic Analysis Methods See Subsection 3.7a.2.1

3.7a.3.2 Determination of Number of Earthquake Cycles

To evaluate the number of cycles which exist within a given earthquake, a typical boiling water reactor building-reactor dynamic model was excited by three different recorded time histories - May 18, 1940, El Centro NS component, 29.4 sec; 1952, Taft N69°W component, 30 sec; and March 1957, Golden Gate S80°E component, 13.2 sec. The model response was truncated such that the response of three different frequency bandwidths could be studied, 0^+-10 Hz, 10-20 Hz, and 20-50 Hz. This was done to give an approximation of the cyclic behavior expected from structures with different frequency content.

Enveloping the results from the three earthquakes and averaging the results from several different points of the dynamic model, the cyclic behavior as given in Table 3.7a-3 was formed.

Independent of earthquake or component frequency, 99.5% of the stress reversals occur below 75% of the maximum stress level, and 95% of the reversals lie below 50% of the maximum stress level. This relationship is graphically shown in Figure 3.7A-2.

In summary, the cyclic behavior number of fatigue cycles of a component during an earthquake is found in the following manner:

(a) The fundamental frequency and peak seismic loads are found by a standard seismic analysis.

(b) The number of cycles which the component experiences are found from Table 3.7a-3 according to the frequency range within which the fundamental frequency lies.

(c) For fatigue evaluation, one-half percent (0.005) of these cycles are conservatively assumed to be at the peak load 4.5% (0.045%) at three-quarter peak. The remainder of the cycles will have negligible contribution to fatigue usage.

The safe shutdown earthquake has the highest level of response. However, the encounter probability of the SSE is so small that it is not necessary to postulate the possibility of more than one SSE during the operating life of a plant. Fatigue evaluation due to the SSE is not necessary since it is a faulted condition and thus not required by ASME Section III.

The OBE is an upset condition and therefore, must be included in fatigue evaluations according to ASME Section III. Investigation of seismic histories for many plants show that during a 40 year life, it is probable that five earthquakes with intensities one-tenth of the SSE intensity, and one earthquake approximately 20% of the proposed SSE intensity, will occur. Therefore, the probability of even an OBE is extremely low. To cover the combined effects of these

earthquakes and the cumulative effects of even lesser earthquakes, one OBE intensity earthquake with 10 peak stress cycles is postulated for fatigue evaluation.

3.7a.3.3 Procedure Used for Modeling

3.7a.3.3.1 Modeling of Piping Systems

The continuous piping system is modeled as an assemblage of the beams. The mass of each beam is lumped at the nodes connected by weightless elastic member, representing the physical properties of each segment. The pipe lengths between mass points will be no greater than the length which would have a natural frequency of 33 Hz when calculated as a simply supported beam. All concentrated weights on the piping system such as main valves, relief valves, pumps, and motors are modeled as lumped masses. The torsional effects of the valve operators and other equipment with offset center of gravity with respect to center line of the pipe is included in the analytical model. If the torsional effect is expected to cause pipe stresses less than 500 psi, this effect may be neglected.

3.7a.3.3.2 Modeling of Equipment

For dynamic analysis, Seismic Category I equipment is represented by lumped mass systems which consist of discrete masses connected by weightless springs. The criteria used to lump masses are:

(1) The number of modes of a dynamic system is controlled by the number of masses used. Therefore, the number of masses is chosen so that all significant modes are included. The modes are considered as significant if the corresponding natural frequencies are less than 33 Hz and the stress calculated from these modes are greater than 10% of the total stresses obtained from lower modes.

(2) Mass is lumped at any point where a significant concentrated weight is located. Examples are the motor in the analysis of pump motor stand, the impeller in the analysis of pump shaft, etc.

(3) If the equipment has a free-end overhang span whose flexibility is significant compared to the center span, a mass is lumped at the overhang span.

(4) When a mass is lumped between two supports, it is located at a point where the maximum displacement is expected to occur. This tends to conservatively lower the natural frequencies of the equipment. Similarly, in the case of live loads (mobile) and a variable support stiffness, the location of the load and the magnitude of support stiffness are chosen so as to yield the lowest frequency content for the system. This is to ensure conservative dynamic loads since equipment frequencies are such that the floor spectra peak is in the lower frequency range. If such is not the case, the model is adjusted to give more conservative results.

3.7a.3.3.3 Location of Supports and Restraints

The location of seismic supports and restraints for Seismic Category I piping and piping systems components is selected to satisfy the following two conditions:

(1) The location selected must furnish the required response to control stress and/or strain within allowable limits.

(2) Adequate building strength for attachment of the components must be available.

3.7a.3.4 Basis of Selection of Frequencies

All frequencies in the range of 0.25 to 33 Hz are considered in the analysis and testing of structures, systems, and components. The frequency range of between 0.25 Hz and 33 Hz covers the range of the broad band response spectrum used in the design. If the fundamental frequency of a component is greater than or equal to 33 Hz, it is treated as rigid and analyzed accordingly. Frequencies less than 0.25 Hz are not considered as they represent very flexible structures and are not encountered in this plant.

3.7a.3.5 Use of Equivalent Static Load Method of Analysis

This subsection is covered under Subsection 3.7b.3.5.

3.7a.3.6 Three Components of Earthquake Motion

3.7a.3.6.1 Response Spectrum Method

The use of three components of earthquake motion was not a design basis requirement of the construction permit for this plant. The total seismic response is predicted by combining the response calculated from analyses due to one horizontal and one vertical seismic input. For this case, where the response spectrum method of seismic analysis is used, the basis for continuing the loads from the two analyses is given below:

(1) The peak responses of the different modes for the same earthquake excitations do not occur at the same time.

(2) The peak responses of a particular move due to earthquake excitations from different directions do not occur at the same time.

(3) The peak stresses due to different modes and due to different excitations may not occur at the same location nor in the same direction.

To implement the above, the two translation components of earthquake excitations are combined by summing the absolute sum of all responses of interest (e.g., strain, displacement stress, moment, shear, etc.) from seismic motion, the one horizontal (x or z) and one vertical direction (y), i.e., $|x+y|$ or $|y+z|$. The design is made for the larger of the two sums $|x+y|$ or $|y+z|$.

3.7a.3.6.2 Time History Method

The algebraic sum of contributions (to displacements, loads, stresses, etc.) due to the two earthquake components are calculated for each natural mode for each time interval of analysis. The time interval should be less than or equal to 0.2 of the smallest period of interest. The maximum of the algebraically summed values (displacements, loads, stresses) over all time intervals are the design displacements, accelerations, loads, or stresses.

The above method demonstrates the integrity of the Seismic Category I subsystems.

3.7a.3.7 Combination of Modal Responses

When the response spectra method of modal analysis is used, all modes are combined by the square root of the sum of the squares (SRSS) method. When the response spectra method of modal analysis is used for snubber elimination or other piping modifications, modal combinations shall be in accordance with Regulatory Guide 1.92 whenever Code Case N-411 or Regulatory Guide 1.61 is invoked for damping values.

3.7a.3.8 Analytical Procedure for Piping

The analytical procedures for piping analysis have been described in Subsection 3.7a.2.1.5.1.

3.7a.3.9 Multiply Supported Equipment Components with Distinct Inputs

The procedure and criteria for analysis has been described in Subsection 3.7a.2.1.5.2.

3.7a.3.10 Use of Constant Vertical Static Factors

This subsection is covered under Subsection 3.7b.3.10.

3.7a.3.11 Torsional Effects of Eccentric Masses

Torsional effects of eccentric masses are discussed in Subsection 3.7a.3.3.1.

3.7a.3.12 Buried Seismic Category I Piping Systems and Tunnels

This subsection is covered under Subsection 3.7b.3.12.

3.7a.3.13 Interaction of Other Piping with Seismic Category I Piping

When other piping is attached to Seismic Category I piping, the other piping is analytically simulated in a manner that does not degrade the accuracy of the analysis of the Seismic Category I piping. Furthermore, the other piping is designed to withstand the SSE without failing in a manner that would cause the Seismic Category I piping to fail.

3.7a.3.14 Seismic Analysis for Reactor Internals

The modeling of RPV internals has been discussed in Subsection 3.7a.2.3.2. The damping values are given in Table 3.7a-1. A comparison of responses is shown in Table 3.7a-2.

3.7a.3.15 Analysis Procedures for Damping

Analysis procedures for damping have been discussed in Subsection 3.7a.2.15.

3.7a.4 SEISMIC INSTRUMENTATION

This subsection is covered under Subsection 3.7b.4.

3.7a.5 REFERENCES

3.7a-1 L. K. Liu, "Seismic Analysis of Boiling Water Reactor," Symposium on Seismic Analysis of Pressure Vessel and Piping Components, First National Congress on Pressure Vessel and Piping, San Francisco, California, May 1971.

TABLE 3.7a-1

CRITICAL DAMPING RATIOS FOR DIFFERENT MATERIALS

Item	Percent Critical Damping	
	OBE Condition	**SSE Condition**
Reinforced concrete structures	2.0	5.0
Welded structural assemblies (equipment and supports)	1.0	2.0
Bolted or riveted structural assemblies	2.0	3.0
Vital piping systems	0.5	1.0
Drywell-Building (Coupled)	2.0	5.0
Reactor pressure vessel, support skirt, shroud head, separator and guide tubes	2.0	2.0
Control rod drive housings	3.5	3.5
Fuel	7.0	7.0
Steel frame structures	2.0	3.0

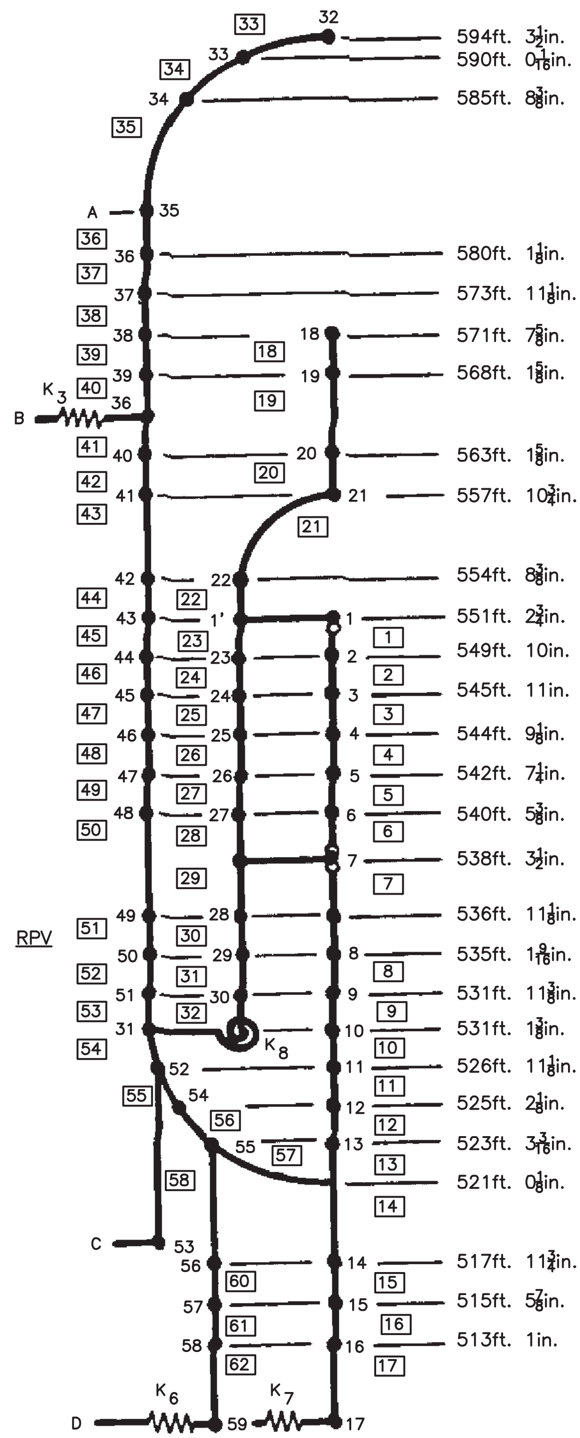
Other values may be used if they are indicated to be reliable by experiment or study.

NOTE: For snubber elimination or other piping modifications, damping values per Code Case N-411 or Regulatory Guide 1.61 may be applied. When either Code Case N-411 or Regulatory Guide 1.61 is invoked, modal combination for closely spaced modes per Regulatory Guide 1.92 shall be applied.

TABLE 3.7a-3

NUMBER OF DYNAMIC RESPONSE CYCLES EXPECTED DURING A SEISMIC EVENT

Frequency Band (Hz)	0+ - 10	10 - 20	20 - 50
Total Number of Seismic Cycles	168	359	643
Seismic Cycles 0.5% of Peak Loads to 75% of Peak Loads	0.8	1.8	3.2
Seismic Cycles 4.5% of Peak Loads to 75% of Peak Loads	7.5	16.2	28.9



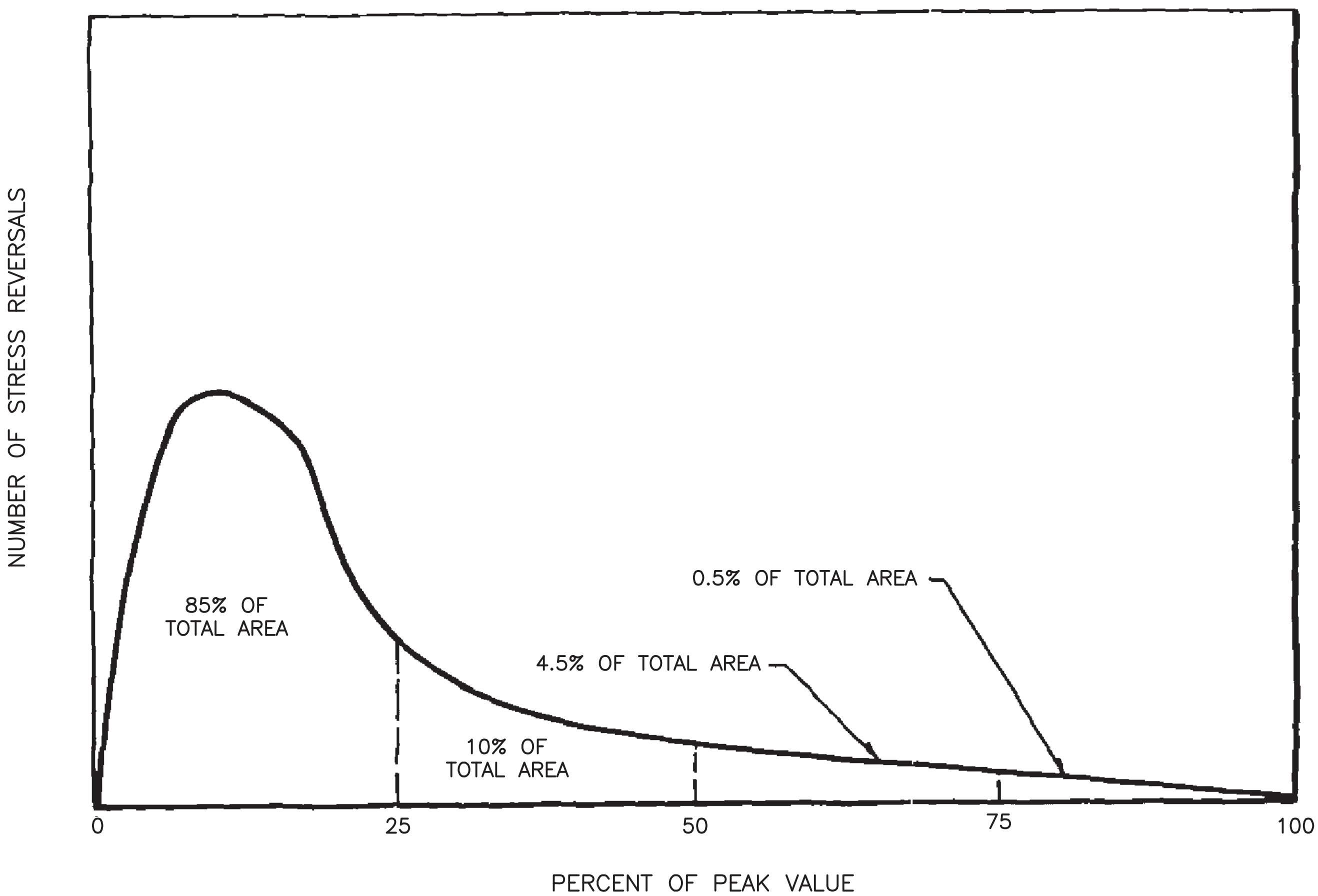
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR PRESSURE VESSEL
AND INTERNAL SEISMIC MODEL

FIGURE 3.7A-1, Rev. 47

Auto-Cad Figure Fsar 3_7A_1.dwg



FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DENSITY OF STRESS REVERSALS

FIGURE 3.7A-2, Rev. 47

Auto-Cad Figure Fsar 3_7A_2.dwg

3.7b SEISMIC DESIGN

This section describes the seismic design requirements and methods used for Susquehanna SES and the seismic design and analysis of non-NSSS equipment. Seismic design of NSSS equipment is described in Section 3.7a.

3.7b.1 SEISMIC INPUT

3.7b.1.1 Design Response Spectra

The site design response spectra for all rock founded structures except the Diesel Generator 'E' Building are illustrated on Figures 3.7B-1 and 3.7B-2 for the horizontal components of the Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) respectively. For the Diesel Generator 'E' Building, the horizontal site design response spectra are based on Regulatory Guide 1.60, Rev. 1 and are illustrated on Figures 3.7B-2 and 3.7B-4. The design earthquake is assumed to be the free field motion at the base mat of the structure without the effect of the structure. For all Seismic Category I structures founded on rock the maximum horizontal ground acceleration values are 5 and 10 percent of gravity for OBE and SSE respectively (refer to Subsections 2.5.2.6 and 2.5.2.7). However, Seismic Category I structures founded on soil, and the spray pond have been designed for maximum horizontal ground accelerations of 8 percent (OBE) and 15 percent (SSE) of gravity. The maximum ground displacement is taken proportional to the maximum ground acceleration. The displacement associated with a 1.0 gravity ground acceleration is set at 40 inches for all Seismic Category I structures except the Diesel Generator 'E' Building where it is set at 36 inches.

The base diagram of all design spectra consists of three parts: the maximum ground acceleration line on the left part, the maximum ground displacement line on the right part, and the middle part depends on the maximum pseudo-velocity.

For various damping values, the numerical values of design displacements and accelerations for the horizontal component design response spectra used for all Seismic Category I structures except the Diesel Generator 'E' Building are obtained by multiplying the values of the maximum ground displacement and acceleration by the corresponding factors given in Table 3.7b-1. Table 3.7b-2 provides the amplification factors for the horizontal and vertical design response spectra associated with the Diesel Generator 'E' Building.

The acceleration lines of the design response spectra are drawn parallel to the maximum ground acceleration line between the frequency lines of 6.67 cps (control point B of Figures 3.7B-1 and 3.7B-2) and 2 cps (control point C). The acceleration lines converge at the junction of the maximum ground acceleration line and the 33 cps frequency line (control point A). For frequencies higher than 33 cps, the maximum ground acceleration line represents the design response spectra. The displacement lines are drawn parallel to the maximum ground displacement line. The maximum pseudo-velocity is assumed to be constant. Lines were drawn parallel to the constant velocity lines connecting the acceleration lines at control point C and the displacement lines.

For all Seismic Category I structures except the Diesel Generator 'E' building, the design response spectra values for the vertical component of the earthquake are taken as 2/3 of the corresponding values of the horizontal component of the earthquake.

The site design spectra for all Seismic Category I structures except the Diesel Generator 'E' Building deviate from those suggested in Regulatory Guide 1.60. Figures 3.7B-88 through 3.7B-91 provide comparison of the two. The damping values for the NRC spectra are those specified by Regulatory Guide 1.61 for reinforced concrete structures.

Both the horizontal and vertical site design spectra for the Diesel Generator 'E' Building are based on Regulatory Guide 1.60, Rev. 1. The vertical ground acceleration values are the same as the horizontal ground acceleration values.

3.7b.1.2 Design Time History

A synthetic time history motion for all Seismic Category I structures, except the Diesel Generator 'E' Building, is generated by modifying the actual records of the 1952 Taft earthquake according to the techniques proposed in Reference 3.7b-1. Figure 3.7B-5 shows the normalized synthetic time history motion. The duration of the time history is 20 sec. The time interval of the time history is 0.005 sec.

Figures 3.7B-8 and 3.7B-9 show a comparison of the time history response spectra and the design response spectra for 2, 3, 5, and 7 percent damping values. The spectra are computed at the following frequency values (in cps):

0.2 to 1.0 (increment of 0.05)

1.0 to 10.0 (increment of 0.1)

10.0 to 30.0 (increment of 1.0)

Figure 3.7B-10 shows a comparison of the time history response spectra and the design response spectra for 2 and 5 percent damping values for a frequency range between 0.2 and 1.0 cps, with intervals of 0.0125 cps. All the above figures show that the time history response spectra envelop the design response spectra.

The synthetic time history motions for the Diesel Generator 'E' Building are generated from noise and are not based on actual earthquake recordings. Figures 3.7B-6 and 3.7B-7 show the horizontal and vertical synthetic time history motions, respectively. The duration of these time histories is 25 seconds. The time interval of these time histories is 0.01 seconds.
Figures 3.7B-11 through 3.7B-16 show a comparison of the time history response spectra and the design response spectra for the horizontal and vertical directions at 2, 5 and 7 percent damping values. The spectra are computed at the frequencies suggested in Standard Review Plan 3.7.1, July 1981. Figures 3.7B-11 through 3.7B-16 show that the time history response spectra meet the acceptance criteria described in the referenced Standard Review Plan.

3.7b.1.3 Critical Damping Values (Non-NSSS)

Table 3.7b-3 summarizes the damping values used on Susquehanna SES except for the Diesel Generator 'E' facility. They are expressed as a percentage of critical damping and are based on Reference 3.7b-2. For the Diesel Generator 'E' facility, the damping values are based on Regulatory Guide 1.61, Rev. 0 and are summarized in Table 3.7b-4.

The ESSW pumphouse, piping to the reactor building, the spray pond and the Diesel Generator 'E' fuel tank are some of the Seismic Category I structures and systems founded on soil. The equivalent spring constants and the soil damping coefficients used in the analysis of the ESSW pumphouse are shown in Table 3.7b-5. These values are based on formulae contained in Table 3-2 of Reference 03.7b-3. A lumped representation of soil structure interaction was used.

Soil structure interaction is also considered in the generation of the response spectra for the containment. As in the ESSW pumphouse, a lumped representation of the soil structure interaction is considered. Table 3.7b-5 shows the equivalent spring and damping coefficients used in the containment model.

3.7b.1.4 Supporting Media for Seismic Category I Structures

All Seismic Category I structures, with the exception of ESSW pumphouse, the spray pond, and its pipe supports, the Diesel Generator ‘E’ Fuel Oil Tank, miscellaneous structures and other buried pipes are founded on rock. For the structural analysis of the rock based structures, soil structure interaction is considered to be negligible due to the high stiffness of the rock, which has a modulus of elasticity of approximately 3.0×10^6 psi. However, the response spectra of the containment are derived from a model that considers the flexibility of the rock.

The properties of the rock and soil supporting the ESSW pumphouse are shown in Table 3.7b-6. Discussion of the embedment of structures in soil will be limited to the ESSW pumphouse, since all the other structures are founded on rock.

The ESSW pumphouse is 59 ft high and rests on a 64 ft x 112 ft reinforced concrete mat foundation. The embedment depth of the foundation is 29 ft. The depth of soil below the mat foundation varies from 35 to 60 ft. The soil is predominantly sand, gravel, cobbles, and boulders. Near the surface, the soil is primarily sand and sandy gravel. With increasing depth, the soil changes to more cobbles and boulders. Near bedrock, the soil is mostly cobbles and boulders.

The site geology is discussed in detail in Section 2.5.

3.7b.2 SEISMIC SYSTEM ANALYSIS

Section 3.2 identifies Seismic Category I structures, systems, and components. Seismic Category I structures are considered seismic systems and are discussed here. Seismic Category I systems and components are considered seismic subsystems and are discussed in Subsection 3.7b.3. Seismic systems are analyzed for both the OBE and SSE.

3.7b.2.1 Seismic Analysis Methods

The response spectrum method is used for seismic analysis of Seismic Category I structures. A description of the method is given in Section 4.2.1 of Reference 3.7b-3 for all Seismic Category I structures except the Diesel Generator 'E' Building where it is given in Section 6 of Reference 3.7b-21. Separate lateral and vertical analyses of structures are performed. The responses are then combined to predict the total response of the structure.

A time history analysis of the Seismic Category I structures is done to generate the response spectra at the various mass points of the model.

The mathematical models used for these analyses are lumped mass, stick models. The same models were used for both the response spectrum and time history analyses. The mathematical models of the reactor and control building are shown on Figures 3.7B-19, through 3.7B-21.

For all models, the masses are located at elevations of mass concentrations, such as floors and roofs. However, in the case of the containment which is a structure of continuous mass distribution, masses are lumped at variable intervals ranging from 6.6 feet to 15.7 feet along the containment shell and reactor pedestal. These methods of mass distribution are in accordance with the procedures of Section 3.2 of Reference 3.7b-3 to provide an adequate number of masses. The mathematical models of the containment are shown on Figures 3.7b-17 and 3.7-18.

The reactor and control buildings act as a single structure due to the monolithic construction. The entire reactor and control building structure is shown as a single unit in Figure 3.7B-22. Both the control building and the line 29 wall of the reactor building are connected to the P-line wall, which is common to both the reactor and control buildings. In the east-west direction, the control building and the line 29 wall are considered to respond as a single unit.

The horizontal mathematical models are shown on Figures 3.7B-19 and 3.7B-20. The sticks represent shear walls located at the base mat elevation in the reactor building in the direction of the earthquake motion. In the east-west model (Figure 3.7B-19), the control building is lumped entirely on the line 29 stick. The entire control building is considered to contribute to the stiffness of the line 29 stick. In the North-South direction (Figure 3.7b-20), the control building has its own stick connected to the P-line wall by springs.

The springs between the sticks represent the flexibility of the floor slab connecting each stick. Since these springs act in the direction of the earthquake motion, the model allows relative displacement between sticks. Figure 3.7B-21 shows the vertical earthquake model of the reactor and control buildings. The left stick represents the steel columns. The right stick represents the concrete walls of both the reactor and control buildings. The floors are represented by lumped masses and beam elements with the appropriate stiffness to capture the out of plane flexural vibration. Vertical translational coupling springs are provided to represent the coupling stiffness of the floor slab between the wall and column sticks. Mass numbers 8, 55, and 57 represent the fuel pool girder masses. Mass numbers 34, 35, 41, 43, 44, 46, 53 and 54 represent the floors between the fuel pool girders and columns/walls. Figure 3.7B-23 shows the correlation between the model mass points and the actual structure.

To more accurately determine the dynamic characteristics of the mathematical models the modulus of elasticity for concrete used in the analysis, is determined based on test results of concrete samples obtained from the plant site. The modulus value used is 720,000 ksf for all Seismic Category I structures except the Diesel Generator 'E' building where it was taken to be 518,400 ksf.

The seismic analysis of the Seismic Category I structures considers all modes whose frequencies are less than 33 cps. However, if a structure has only one or two modes with a natural frequency below 33 cps, then the three lowest modes are used. If a structure has three or less degrees of freedom, then all modes are considered in the analysis. For the Diesel Generator 'E' Building and its pedestal, all modes were considered.

The Seismic Category I structures are supported by continuous base mats; therefore, relative displacement of supports is not a consideration.

Nonlinear responses are not considered since the Seismic Category I structures are designed to remain elastic.

3.7b.2.1.1 Flexible Base and Fixed Base Containment Models

The original structural design of the containment was based uupon results obtained from a fixed base model of the containment. The fixed base model used a damping value of 5% of critical damping for all structural modes. The utilization of a fixed base model can be justified since the containment is founded on hard competent rock.

At a later date, a flexible base model of the containment was developed. The flexible base model of the containment is more realistic since it takes into account soil-structure interaction effects. The flexible base containment model used composite modal damping as described in reference 3.7b-3, (BC-TOP-4A, Rev. 3, Appendix D). Analyses were performed using the flexible base model to generate structural response spectra for evaluation of equipment, piping systems, etc.

Both models are fully in accordance with the requirements in Reference 3.7b-3, which has been approved by the NRC. For information regarding the comparison of results from the fixed base and flexible base models, see FSAR Section 3.7b.2.2.1, Revision 46 and previous revisions.

NSSS equipment qualified by GE used loads obtained from the fixed base model. All subsequent structural assessments have used loads derived from the more realistic flexible base model throughout. All future analyses shall use the loads derived from the more realistic flexible model. All remaining discussions regarding the containment presented in the FSAR are for the flexible base model.

3.7b.2.2 Natural Frequencies and Response Loads

The natural frequencies of the containment and the reactor and control building below 33 cps are shown in Tables 3.7b-7 and 3.7b-8 respectively. The first seven frequencies of the reactor and control building in the east-west direction are dependent upon the location of the reactor building cranes.

Some of the significant mode shapes of the containment and the reactor and control building are shown on Figures 3.7B-24 through 3.7B-39. The mode shapes for containment are for the horizontal and vertical directions. The reactor and control building mode shapes are for each of the three principal directions: east-west, north-south, and vertical. As with the frequencies, the first seven mode shapes of the reactor and control building in the east-west direction depend on the location of the cranes. Figures 3.7B-30 through 3.7B-34 show that it is the superstructure of the reactor building that is excited at these low frequencies. The location of the cranes is noted on the figures.

Figures 3.7B-40 through 3.7B-47 show the response displacements and accelerations of the containment for both OBE and SSE. The response of the reactor and control building is shown on Figures 3.7B-48 through 3.7B-59.

Response spectra at critical locations are shown on Figures 3.7B-60 through 3.7B-87. The curves are shown for each of the three principal directions at the damping values used for each design earthquake (see Subsection 3.7b.2.15 for further discussion of damping values). A brief description of the location of each series of curves is provided below with the corresponding figure numbers.

Figures 3.7B-60 through 3.7B-63	RPV Pedestal
Figures 3.7B-64 through 3.7B-69,	Refueling Area
Figures 3.7B-70 through 3.7B-81	Diesel Generator 'A-D' and 'E' Pedestals
Figures 3.7B-82 through 3.7B-87	Operating Floor of ESSW Pumphouse

3.7b.2.3 Procedure Used for Modeling

Seismic systems and subsystems were defined in Subsection 3.7b.2.

All equipment, components, and piping systems are lumped into the supporting structure mass except for the reactor vessel, which is analyzed using a coupled model of the containment structure and the reactor vessel (refer to Figures 3.7B-17 and 3.7B-18). See Section 3.2 of reference 3.7b-3 for the criteria of lumping the equipment, components and piping systems into the supporting structure mass.

Adequacy of the number of masses and degrees of freedom is discussed in Subsection 3.7b.2.1.

Each Seismic Category I structure is considered to be independent because of a gap between adjacent structures. For example, there is a 2 in. horizontal gap between the reactor and control building and the containment above the foundation mat.

To form these gaps rodofoam material (Ref. 3.7b-12) was used. Rodofoam was left in place in the following areas:

(1) Joints where the provided actual gap is 0.5 inch greater than that originally specified on the civil drawings.

(2) Joints where the interaction forces between structures due to presence of rodofoam cause insignificant effect on shear and moment.

3.7b.2.4 Soil Structure Interaction

All Seismic Category I structures, except the ESSW pumphouse and spray pond, are founded on rock. The seismic analysis of these structures is done assuming a fixed base. As stated in Subsection 3.7b.2.1, the containment response spectrum curves are generated from a flexible base model. The rock is assumed to be a homogeneous material comprising an entire elastic half-space. The soil springs and dampers used to represent the effect of the soil are discussed in Subsection 3.7b.1.3.

The ESSW pumphouse is supported by natural soil formation; consequently, soil structure interaction has been considered in the analysis of the pumphouse.Information regarding soil characteristics, foundation embedment, etc., is contained in Subsection 3.7b.1.4. The soil structure interaction analysis is performed using the lumped spring approach. The soil is considered a homogeneous material. The equivalent spring constants and the soil damping coefficients are discussed in Subsection 3.7b.1.3.

The seismic analysis of the spray pond is discussed in Subsection 2.5.5.

3.7b.2.5 Development of Floor Response Spectra

A time history analysis is used to develop the floor response spectra. The mathematical models used for this analysis are discussed in Subsections 3.7b.2.1, 3.7b.2.3, and 3.7b.2.4.

The floor response spectra for all Seismic Category I structures except the Diesel Generator 'E' Building are calculated at the frequencies listed in Table 5-1 of Reference 3.7b-3. For the Diesel Generator 'E' Building, the floor response spectra are calculated at the frequencies recommended in Regulatory Guide 1.122, Rev. 1. Structural frequencies up to 33 cps are used.

3.7b.2.6 Three Components of Earthquake Motion

Independent analyses are done for the vertical and two horizontal (east-west and north-south) directions. For design purposes, the response value used for all Seismic Category I structures except the Diesel Generator 'E' Building is the maximum value obtained by adding the response due to vertical earthquake with the larger value of the response due to one of the horizontal earthquakes by the absolute sum method. For the Diesel Generator 'E' Building, the responses due to three simultaneous orthogonal components of an earthquake are combined by the square root of the sum of the squares method per Regulatory Guide 1.92, Rev. 1.

3.7b.2.7 Combination of Modal Responses

The modal responses, i.e., shears, moments, deflections, accelerations, and inertia forces, are combined by either the sum of the absolute values method or by the square root of the sum of the squares method. When the latter method is used in all Seismic Category I structures except the Diesel Generator 'E' Building, the absolute values of closely spaced modes for each group are added first and then combined with the other modes or groups of closely spaced modes by the square root of the sum of the squares method. Two consecutive modes are defined as closely spaced when their frequencies differ from each other by 0.5 cps or less.

The definition for closely spaced modes was established for the Susquehanna Project in November, 1974 (Reference Question C-11 of PSAR Amendment #16.) It can be seen from Table 3.7b-7 that the natural frequencies of the containment are so widely spaced that they are not closely spaced modes based on the SRP definition for closely spaced modes. For the reactor and control buildings (see Table 3.7b-8) where frequencies are not widely spaced, the model responses are combined by the absolute sum method.

For the Diesel Generator 'E' Building, the total response is obtained by combining the absolute values of all closely spaced modal responses with the square root of the sum of squares of the remaining modal responses. Two consecutive modes are defined as closely spaced when their frequencies differ from each other by 10 percent or less (reference: Regulatory Guide 1-92).

3.7b.2.8 Interaction of Non-Category I Structures with Seismic Category I Structures

Non-Category I structures that are close to Seismic Category I structures, the turbine and radwaste buildings, have been designed to withstand an SSE. Dynamic analyses of these structures were done by the response spectrum method.

The remaining non-Category I structures were designed for seismic loads according to the UBC (Ref. 3.7b-4). The collapse of any of these remaining non-Category I structures will not cause the failure of a Seismic Category I structure.

Structural separations have been provided to ensure that interaction between Category I and non-Category I structures does not occur. The minimum separation at any point is maintained at one and a half times the absolute sum of the predicted maximum displacements of the two structures.

The rodofoam material that was used to form the separation gaps was left in place in some areas as mentioned in Section 3.7b.2.3.

3.7b.2.9 Effects of Parameter Variations on Floor Response Spectra

To account for variations in the structural frequencies owing to uncertainties in the material properties of the structure and to approximations in the modeling techniques used in the seismic analysis, the computed floor response spectra are smoothed and peaks associated with each of the structural frequencies are broadened. The parameters, which are considered variable, are the masses, the modulus of elasticity of the material, and the cross-sectional properties of the members. In addition, variation in the structural frequency is also taken into account because the base of the structures may not be fully fixed as assumed in the analysis.

Let

nf	=	Natural frequency of the building at a peak value of the floor response spectra
Δnf	=	Total variation in nf
Δnf_m	=	Variation in nf due to variation in the mass
Δnf_e	=	Variation in nf due to variation in the modulus of elasticity of the material
Δnf_s	=	Variation in nf due to variation in the cross-sectional properties of the members

A factor of 0.05 is used to account for the decrease in nf due to the possibility that the base of the structures may not be fully fixed.

Since it is highly improbable that the maximum variations in the individual parameters would occur simultaneously, Δ nf is determined by the square root of the sum of the squares of the individual variations as follows:

The maximum increase in nf is given by:

$+\Delta nf = [(\Delta nf_m)^2 + (\Delta nf_e)^2 + (\Delta nf_s)^2]\ 2$

$-\Delta nf = [(\Delta nf_m)^2 + (\Delta nf_e)^2 + (\Delta nf_s)^2 + (0.05)_2]\ 2$

For all Seismic Category I structures, except the Diesel Generator 'E' Building, the following values of $\pm\Delta nf$ are used:

$+\Delta nf = 0.12\ nf$

$-\Delta nf = -0.14\ nf$

For the Diesel Generator 'E' Building, the computed floor response spectra were smoothed and peak width associated with each structural frequency was increased by $\pm$15 percent.

3.7b.2.10 Use of Constant Vertical Static Factors

Constant vertical static factors are not used in the seismic design of Seismic Category I structures. The methodology used for the vertical seismic analysis is similar to the horizontal analysis.

3.7b.2.11 Methods Used To Account for Torsional Effects

Torsional effects for the diesel generator buildings and ESSW pumphouse are accounted as follows:

A static analysis was done to account for torsion on the Diesel Generator 'A-D' Building and ESSW pumphouse. For the ESSW pumphouse the eccentricity was determined by the distance between the center of mass and the center of rigidity of the structure. The inertia force from the response spectrum analysis was applied at the center of mass. The resulting torsional moment is equal to the inertial force multiplied by the eccentricity. The shear forces due to the torsional moment were then distributed to the walls. The torsional shear forces are distributed according to the method described in Section 3.4 of Reference 3.7b-5.

In the Diesel Generator 'A-D' Building, torsion is considered due to the eccentricity caused by the difference in rigidities of the east and west shear walls. The torsional shear forces are assumed to be taken entirely by east and west walls only.

For the Diesel Generator 'E' Building, the torsional effects due to its asymmetry are accounted for by lumping the floor masses at their respective center of gravity in the mathematical model of the building discussed in Section 3.7b.2.1. The stiffness matrix is calculated at these mass points and thus reflects the actual asymmetrical building configuration including the various wall openings. To account for accidental torsion, an additional torsional moment, produced by an eccentricity of ±5 percent of the maximum building dimension, is added to the gross torsional moment obtained from the dynamic analysis of the above mathematical model. The mathematical model of the diesel generator ‘E’ building is shown in Figure 3.7B-95.

Torsional effects are negligible for the containment because of the symmetry of the structure.

The reactor/control building is modeled for horizontal dynamic analysis as multiple sticks coupled by springs representing the shear stiffness of the floor slabs. Each stick represents a major structural shear wall. The mass and stiffness distribution of the structural walls is such that torsional effects are properly represented in the dynamic analysis.

Torsional effects for the Diesel Generator 'A-D' Building, ESSW pumphouse, and reactor/control building are also discussed in response to NRC questions 130.21 and 130.22.

3.7b.2.11.1 Torsional Analysis of Diesel Generator Building A-D and ESSW Pumphouse

During the dynamic analysis state, the inertia force at each mass was considered to be applied at the center of mass. However, since the center of rigidity does not coincide with the center of mass, there is torsion. The inertia force obtained from the dynamic analysis was used by multiplying it with the eccentricity (the distance between the center of mass and the center of

rigidity) to obtain the torsional moment. This moment was then distributed to the structural walls for assessment.

A minimum eccentricity of 5% was considered.

(i) The eccentricities of these structures were calculated.

(ii) The structures were represented by fixed base 3-D stick models with structural masses properly lumped at the calculated eccentricities, as shown in Figures 3.7B-93 and 3.7B-94.

(iii) Modal frequency analyses of the 3-D stick models were performed to determine the structure frequencies.

(iv) The frequencies determined are then compared with the corresponding frequencies associated with the fixed base models having zero eccentricities.

The results of comparison for the ESSW Pumphouse is shown on Table 3.7b-9 and for the Diesel Generator Building is shown on Table 3.7b-10. These results indicate that there are insignificant shifts in the structural frequencies by including the eccentricities in the dynamic analysis.

From the results of this study, it is concluded that the structures modeled by lumped stick models without the inclusion of eccentricities in the dynamic analysis is adequate for the prediction of desired structural responses.

Table 3.7b-11 shows the comparisons of torsional moments for SSE obtained from the studies made using 3-D stick model with the torsional moments used in the original analysis. Evaluation of the comparisons is shown as follows:

(1) Torsional moment used in the original design of ESSW Pumphouse is higher than the torsional moments computed from 3-D stick model results. Therefore, the original design is adequate.

(2) Torsional moments used in the original design of Diesel Generator building are lower than the torsional moments computed from the 3-D stick results. However, the stresses computed from the higher torsional moments result in a maximum shear stress of 16 psi which gives a maximum total shear stress of 74 psi due to torsion and direct shear, compared to an allowable of 126 psi. Thus, the original design of the diesel generator building is adequate.

3.7b.2.11.2 Torsional Analysis of the Reactor/Control Building

The torsional effect in the reactor/control building was considered in the dynamic analysis. Units 1 and 2 were considered simultaneously.

In the N-S direction, the eccentricity is larger than 5%. The N-S dynamic model presented on Figure 3.7B-20 consists of three sticks at each floor and the stiffness distribution of the structural walls are such that proper representation of the eccentricity is obtained. Therefore,

the torsional effect is properly accounted for in the dynamic analysis. The computed dynamic member forces and modal point responses were used for the assessment of structure and equipment.

In the E-W direction (see seismic model on Figure 3.7B-19), the eccentricity is less than 5%. However, a minimum eccentricity of 5% was considered by redistributing the masses. This was done for the assessment of walls.

3.7b.2.12 Comparison of Responses

Figures 3.7B-8 through 3.7B-10 (applicable for all Seismic Category I structures except the Diesel Generator 'E' Building) show that the response spectra of the time history envelop the design response spectra at all frequencies. The time history has been used to generate response spectra in the structures but has not been used to calculate forces in the structures. Response in typical Category I Structures, obtained from the response spectrum analysis compare closely with those obtained from time history analysis based on studies comparing displacements and accelerations obtained by the two methods, however there is some variation. Both methods are acceptable per Regulatory Guide 1.92 and Regulatory Guide 1.122.

The corresponding comparisons of the time history response spectra to the design response spectra for the Diesel Generator 'E' Building are provided in Figures 3.7B-11 through 3.7B-13 for the horizontal direction and Figures 3.7B-14 through 3.7B-16 for the vertical direction.

3.7b.2.13 Methods for Seismic Analysis of Dams

Dams are not provided on Susquehanna SES.

3.7b.2.14 Determination of Seismic Category I Structure Overturning Moments

For all Seismic Category I structures, except the Diesel Generator 'E' Building, the overturning moment is the sum of the moments at the base of each stick of the mathematical model. For each stick, the moment at the base is determined by combining the modal overturning moments. The moments are combined by the methods described in Subsection 3.7b.2.7. For the Diesel Generator 'E' Building, the total accelerations at each floor elevation, due to an earthquake component resulting from the modal combination described in Subsection 3.7b.2.7, are used to compute the overturning moment.

The components of the earthquake motion used are the same as those discussed in Subsection 3.7b.2.6.

Subsection 3.8.5 discusses the factor of safety against overturning for several loadings, which include seismic loads.

3.7b.2.15 Analysis Procedure for Damping

All Seismic Category I structures except the Diesel Generator 'E' Building consist of reinforced concrete and welded/bolted structural steel. Damping values for these materials are shown in Table 3.7b-3. However, in the seismic analysis of the structures, (except the Diesel Generator 'E' Building), damping values of 2 and 5 percent are used for OBE and SSE respectively for reinforced concrete, as well as welded/bolted structural steel. Therefore, analysis of composite modal damping is not necessary.

The Diesel Generator 'E' Building is constructed solely out of reinforced concrete. As shown in Table 3.7b-4, damping values of 4 and 7 percent are used for OBE and SSE, respectively.

All Seismic Category I structures except the ESSW pumphouse and spray pond and its pipe supports are founded on rock. Consequently, soil damping values are calculated for the ESSW pumphouse as described in Appendix D of Reference 3.7b-3.

The interaction damping values for the time history analysis of the containment are also calculated by the method described in Appendix D of Reference 3.7b-3.

3.7b.3 SEISMIC SUBSYSTEM ANALYSIS

As explained in Subsection 3.7b.2, this section discusses the seismic analysis of subsystems, i.e., equipment, piping, Class IE cable trays and supports for Seismic Category I HVAC ducts and cable trays.

3.7b.3.1 Seismic Analysis Methods

3.7b.3.1.1 Equipment

Seismic qualification of equipment is performed by using one of the following methods:

a) Analysis

b) Dynamic testing

c) Combination of analysis and dynamic testing

3.7b.3.1.1.1 Analysis

Seismic qualification of equipment is performed by analysis when the equipment can be adequately represented by a model and the analysis can determine its structural and functional adequacy. The analysis can either be an equivalent static analysis or a dynamic analysis.

Equivalent static analysis is described in Subsection 3.7b.3.5.

Dynamic analysis can be classified into three cases according to the relative rigidity of the equipment based on the magnitude of the fundamental natural frequency. Dynamic Analysis

refer to Seismic Loads only, a discussion of the Hydrodynamic Load can be found in DBD046, Sections 2.2.1.2 and 2.2.1.3.

For structurally simple equipment, which can be represented by one degree of freedom, the dynamic load consists of a static load obtained as the equipment mass multiplied by the acceleration corresponding to the equipment's natural frequency. If the fundamental frequency is not known, the peak acceleration from the response spectra is taken.

For rigid equipment having a fundamental frequency greater than 33 Hz, the dynamic load consists of a static load obtained as the equipment's mass multiplied by the acceleration corresponding to 33Hz.

For structurally complex equipment, which cannot be classified as structurally simple or rigid, the equipment is idealized by a mathematical model and dynamic analysis is performed using standard analytical procedures. An alternative method used for verifying structural integrity of members physically similar to beams and columns is the static coefficient method. In this method no determination of natural frequency is made. Dynamic forces are calculated as product of the mass and peak acceleration of response spectra multiplied by a static coefficient of 1.5.

Equipment damping values used are given in Tables 3.7b-3 and 3.7b-4.

3.7b.3.1.1.2 Dynamic Testing

Dynamic testing is performed when analysis is insufficient to determine either the structural or functional adequacy of the equipment or both. Typical test methods used are as follows:

a) Single frequency sine beat test

b) Single frequency dwell test

c) Multifrequency test

All seismic qualification tests subject the equipment to excitation for at least 30 seconds.

3.7b.3.1.1.3 Combination of Analysis and Dynamic Testing

Certain equipment is qualified by a combination of analysis and dynamic testing.

3.7b.3.1.2 Piping Systems

BP-TOP-1, Rev. 3 (Ref. 3.7b-6) describes the methods used for seismic analysis of piping systems found in all Seismic Category I structures, except the Diesel Generator 'E' Building. Reference 3.7b-6 is followed on Susquehanna SES with the following exceptions:

In seismic analysis the modal responses are combined by SRSS and lower damping values than specified in Reference 3.7b-6 are used. For snubber elimination or other piping

modifications, the combination of modal responses for closely spaced modes shall be in accordance with Regulatory Guide 1.92 whenever Regulatory Guide 1.61 or Code Case N-411 are used.

See Subsection 3.7b.3.7.

AEG-502, Rev. 0 (Ref. 3.7b-14) describes the methods used for seismic analysis of piping systems found in the Diesel Generator 'E' Building.

3.7b.3.1.3 Class IE Cable Trays

Cable trays are seismically qualified by one of two methods:

A. Capacity Evaluation Method which consists of the following:

   a) Calculation of the fundamental frequency of the cable tray based on the tray properties obtained from static tests

   b) Seismic load computation based upon the tray frequency, the possible support frequencies and the design spectra

   c) Calculation of the tray allowable capacity

   d) Evaluation of the tray capacity by interaction formulae

B. Static Analysis Method which consists of the following:

   a) Determine the maximum tray capacity in the two lateral directions by test

   b) Determine the maximum tray longitudinal capacity by analysis

   c) Calculate the maximum tray load by the equivalent static load method (discussed in Subsection 3.7b.3.5)

   d) Evaluation of the tray capacity by interaction formulae

3.7b.3.1.4 Supports for Seismic Category I HVAC Ducts

The supports of HVAC ducts are analyzed by the response spectrum method or by the equivalent static load method (discussed in Subsection 3.7b.3.5).

3.7b.3.1.5 Concrete Block Masonry Structures (Blockwalls)

The dynamic analysis of safety related concrete masonry blockwalls in Class I structures is performed by the response spectrum method. Response spectrum for the lower floor has been used for vertical motion and for walls, cantilevered from the floor. For horizontal motion, the acceleration of the lower floor or average of the lower and upper floor, whichever is greater, is

used in determining inertia loads. Frequency calculations for blockwalls supporting class I attachments or located in areas of class I equipment are based on either cracked section, partially cracked section, or uncracked section properties; whichever represents the condition based upon the calculated loads.

Partially cracked section analysis is based on the following AC1 318 (Ref. 10A of Table 3.8-1) formula:

I_e = $(M_{cr}/M_a)^3 I_g + (1 - (M_{cr}/M_a)^3) I_{cr}$

where,

I_e = effective moment of inertia of cracked Section

I_{cr} = moment of inertia of cracked Section

M_a = bending moment applied to the blockwall

I_g = Gross section moment of inertia (uncracked)

M_{cr} = cracking bending moment = $\frac{fr\ I_g}{Y_t}$

fr = modulus of rupture for masonry = 50 psi

modulus of rupture for concrete = $6\sqrt{f'_c}$ psi

Yt = distance from centroid axis of gross section to the extreme fiber in tension.

For assessing the effects of frequency variations on the responses, the variable items such as boundary conditions, mass, modulus of elasticity, cracking moment are considered. Damping values used are in accordance with Table 3.7b-3. The response of attachments to blockwalls is determined as described in Subsection 3.7b.3.1.1.1.

The three components of earthquake motion are combined in accordance with Subsection 3.7b.2.6.

3.7b.3.1.6 Supports of Seismic Category I Electrical Raceway Systems

This section defines the procedures used for the design of the supports of electrical raceway systems, i.e., cable tray, conduit, and wireway gutter systems, subject to the seismic and other applicable loads. The raceway support system usually consists of raceways, horizontal and vertical support members and lateral and longitudinal bracing members.

3.7b.3.1.6.1 Loading Combinations

The adequacy of raceway systems (except for cable tray supports installed during construction of the Diesel Generator 'E' facility) to withstand seismic and other applicable static loads is determined according to the loading combinations and allowable responses given below:

Equation	Condition	Load Combination	Allowable Response
1	Normal	D + L + SRV	F - See note 4
2	Normal/Severe	D + L + E	See Notes 2 & 4
(Equation 2 applies only to connections for fatigue considerations)			
3	Abnormal/Extreme	D + E' + SRV + LOCA	See Notes 2, 3, & 4

NOTES: 1. For notations, see Table 3.8-2.

2. The following equation is applicable for bending in overhead connections:

$$\frac{5n_{EQ}}{N_{OBE}} + \frac{n_{EQ}}{N_{SSE}} \leq 1.0$$

where:

n_{EQ} = Total number of load/stress cycles per earthquake.

N_{OBE} = Allowable number of load/stress cycles per OBE event.

N_{SSE} = Allowable number of load/stress cycles per SSE event.

3. The following criteria are used for checking the members. In no case shall the allowable stress exceed 0.90F in bending, 0.85F in axial tension or compression, and 0.50F in shear. Where the design is governed by requirements of stability (local or lateral buckling), the actual stress shall not exceed 1.5F.

4. Allowable shear and normal loads in connections are determined from the manufacturers' data or from code allowable stresses whichever is applicable. The allowable values are increased 50% for load combination equation 3.

The loading combinations and the allowable stresses for the design of cable tray supports installed during construction of the Diesel Generator 'E' facility are as follows:

Equation	Condition	Load Combination	Allowable Response
1	Normal	D + L	F
2	Normal/Severe	D + E	F
3	Abnormal/Extreme	D + E'	1.6F
The definition of terms D, L, E and E' are as per Table 3.8-2.			

3.7b.3.1.6.2 Analytical Techniques

One of three methods of analysis is used. Method 1 is a simplified method of analysis that determines the fundamental frequency of braced supports using two dimensional analysis. Frequencies are determined in each of three principal directions. Then loads are determined by taking the spectral accelerations multiplied by the mass; and stresses are determined from static analysis. All members and connections are checked using stress criteria.

Method 2 uses a three dimensional computer analysis and includes springs to represent joint stiffness. Response spectrum analyses are done to determine stresses and deformations. The number of stress cycles is determined by multiplying the time of maximum earthquake motion by the natural frequency of the system. The allowable number of cycles is taken from Reference 3.7b-8 for the joint rotations calculated. Only overhead connections are checked for fatigue since the test results (ref. 3.7b-8, pg. 7-19) demonstrate that failures occur only in overhead connections.

The basis for the design criteria and analysis method 2 is the "Cable Tray and Conduit Raceway Test Program" (references 3.7b-7 through 3.7-10).

Method 3 uses the equivalent static load method of analysis (as described in Subsection 3.7b.3.5). In this method, the acceleration response is assumed to be the peak of the response spectrum at the damping values described in Subsection 3.7b.3.1.6.3. Stresses are determined from static analysis. All members and connections are checked using stress criteria.

3.7b.3.I.6.3 Damping

A maximum damping of 7% of the critical is used for the design of all raceway systems. The test program demonstrates that for cable tray systems damping is, in general, much higher than 7%. Reference 3.7b-7 recommends using 20% but values up to 50% are reported. The recommended damping values, developed from the test program and based on lower bound values, are shown in Figure 3.7B-92. Damping is amplitude dependent, i.e., it increases with increasing amplitude of input motion. For conduit systems the damping increases with increasing amplitude, but is much lower than for cable tray systems. This 7% is a realistic value

for input motion exceeding 0.1g for conduit systems. Wireway gutters were not tested; however, the manner in which they are constructed - with more bolted connections and more cables than conduit - provides more damping mechanisms that are present in conduit systems so that 7% is a conservatively low damping value.

3.7b.3.1.6.4 Operating Basis Earthquake (OBE)

Except for cable tray supports installed during construction of the Diesel Generator 'E' facility, the OBE is considered in the load combinations only for the overhead connections which are checked for fatigue. The OBE stresses are not checked during design for two reasons: first, raceway systems do not fail in a brittle or catastrophic mode as demonstrated by the test program in which such failures did not occur and the electrical systems were able to continue to function in all cases. Thus, there is no need to limit the OBE stresses to the low levels usually used to preclude such failures. Second, the OBE stresses will always be less than the SSE stresses as demonstrated below.

In all cases the ZPA values are high enough to use 7% damping based on Figure 3.7B-92 since they all exceed 0.1g. A comparison of response spectra for corresponding damping values demonstrates that for all response spectra the OBE acceleration values are less than the corresponding SSE acceleration values. (See References 3.7b-8 and 3.7b-10) Thus, the OBE acceleration response and stresses are below the SSE acceleration response and stresses.

3.7b.3.2 Determination of Number of Earthquake Cycles

In general, the design of the equipment is not fatigue controlled because the equipment is elastic and the number of cycles in an earthquake is low.

Equipment that is qualified by analysis is designed to remain elastic during the earthquake. Any fatigue effects in tested equipment are accounted for by performing extended duration test on selected specimens. Consequently, the number of cycles of the earthquake has been accounted for.

In order to conduct a fatigue evaluation for nuclear Class I piping, the number of cycles for a given load set is obtained. This is done by considering ten maximum stress cycles per earthquake and five OBE's and one SSE to occur within the life of the plant.

3.7b.3.3 Procedure Used for Modeling

The models are developed to represent the equipment. Two or three dimensional models are used depending on the complexity of the equipment. The boundary conditions are modeled to reflect the in-plant mounting conditions. The equipment is represented by lumped mass models. Massless elastic members are used to connect the masses.

Supports for HVAC ducts are modeled as two or three dimensional (depending upon support complexity), lumped mass models. The masses are lumped at the center or at the corners of the ducts. The cable tray support analytical techniques are discussed in Subsection 3.7b.3.1.6.2.

Sections 2.0 and 3.0 of Reference 3.7b-6 discuss the techniques and procedures used to model piping other than the buried type.

3.7b.3.4 Basis for Selection of Frequencies

The natural frequencies of components are calculated. If the natural frequency of the component falls within the broadened peak of the response spectrum curve, then it is designed to withstand the peak acceleration.

3.7b.3.5 Use of Equivalent Static Load Method of Analysis

The equivalent static load method of analysis is used when the natural frequency of the equipment is not determined. If the equipment can be adequately represented by a single degree of freedom system, then the applied inertia load is equal to the mass of the equipment multiplied by the peak value of the response spectrum curve. If the equipment requires more than one degree of freedom for an adequate representation, then a factor of 1.5 is applied to the peak of the response spectrum curve.

Section 2.3.2 and Appendix D of Reference 3.7b-6 discuss the use of equivalent static load method of analysis as applicable to piping.

3.7b.3.6 Three Components of Earthquake Motion

For equipment, raceway, and HVAC duct supports, the three spatial components of the earthquake are combined by one of the following methods:

a. Absolute Sum

   Independent analyses are done for the vertical and two horizontal (east-west and north-south) directions. For design purposes, the response value used is the maximum value obtained by adding the response due to vertical earthquake with the larger value of the response due to one of the horizontal earthquakes by the absolute sum method.

b. Square Root of the Sum of the Squares

   Stress levels produced by the three individual accelerations (caused by the three spatial components of the earthquake) are combined by the square root of the sum of the squares method.

The criteria used for combining the results of horizontal and vertical seismic responses for piping systems are described in Section 5.1 of Reference 3.7b-6.

3.7b.3.7 Combination of Modal Responses

The modal responses of equipment (except the equipment in the Diesel Generator 'E' Building) are combined by the square root of the sum of the squares method. The absolute values of two

closely spaced modes are added first before combining with the other modes by the square root of the sum of the squares method. Two consecutive modes are defined as closely spaced when their frequencies differ from each other by 10 percent or less. For equipment located in the Diesel Generator 'E' Building, the modal responses are combined using the criteria presented in Regulatory Guide 1.92, Rev. 1.

Procedures given in Regulatory Guide 1.92 for combining modal responses, when closely-spaced modes are present, are not complied with in the seismic response spectra analysis for piping, except for piping within the Diesel Generator 'E' Building and as noted below. All modal responses are combined by square root of sum of squares (SRSS) in the response spectra method of modal analysis for seismic loading (OBE and SSE). Seismic response spectra used in the piping analysis corresponds to conservative damping values of 1/2% for OBE and 1% for SSE. For snubber elimination or other piping modifications, Regulatory Guide 1.92 is complied with in the seismic response spectra analysis of piping components for combining modal responses of closely spaced modes whenever Regulatory Guide 1.61 or Code Case N-411 damping values are used. The damping values used for the Diesel Generator 'E' facility are shown in Table 3.7b-4.

The procedures used in evaluating the piping system for hydrodynamic loads (SRV and LOCA) by response spectra method is in compliance with Regulatory Guide 1.92. The modal responses in this case are combined in accordance with section 5.2 of BP-TOP-1, Rev. 3, which has been accepted by the NRC staff, per the letter dated September 29, 1976, from Karl Kniel, Chief Light Water Reactors Branch No. 2, Division of Project Management to Burton L. Lex, Bechtel Power Corporation.

The criteria used for piping systems are described in Sections 5.1 and 5.2 of Reference 3.7b-6

3.7b.3.8 Analytical Procedures for Piping

The design criteria and the analytical procedures applicable to piping systems are as described in Section 2.0 of Reference 3.7b-6. The methods used to consider differential piping support movements at different support points are as described in Section 4.0 of Reference 3.7b-6.

3.7b.3.9 Multiple Supported Equipment and Components with Distinct Inputs

For cable trays and ducts whose supports have two distinct inputs, a response spectrum curve (or maximum acceleration) is used that envelops the curves (or accelerations) at the two locations. Section 4.0 of Reference 3.7b-6 discusses the methods used for the analysis of multiple supported piping systems.

3.7b.3.10 Use of Constant Vertical Static Factors

Constant vertical static factors are not used in the seismic design of subsystems.

3.7b.3.11 Torsional Effects of Eccentric Masses

The torsional effects of valves and other eccentric masses are considered in the seismic analysis of piping by the techniques discussed in Section 3.2 of Reference 3.7b-6.

3.7b.3.12 Buried Seismic Category I Piping Systems and Tunnels

Buried Seismic Category I piping has been analyzed and designed for seismic effects in accordance with Section 6.0 of Reference 3.7b-3, and Reference 3.7b-13 for the Diesel Generator 'E' facility.

The majority of the anticipated settlement due to static loading of the ESSW Pumphouse will have occurred prior to connecting the piping to the building. During a SSE event, the differential settlement between the pumphouse and the surrounding soil which supports the piping, will be less than one inch (see Subsection 2.5.4.7 for further discussion of settlements). This movement will be accommodated by the piping without exceeding code allowable stresses.

Tunnels on the Susquehanna SES are non-Seismic Category I.

3.7b.3.13 Interaction of other Piping with Seismic Category I Piping

The techniques used to consider the interaction of Seismic Category I piping with non-Seismic Category I piping are in Section 3.4 of Reference 3.7b-6. All piping in the Diesel Generator 'E' Building was analyzed to Seismic Category I requirements.

3.7b.3.14 Seismic Analysis for Reactor Internals

This subsection is covered under Subsection 3.7a.3.14.

3.7b.3.15 Analysis Procedure for Damping

In general, a single damping value, as shown in Table 3.7b-3, is used for the analysis of Seismic Category I subsystems. The critical damping value related to electrical raceway system is discussed in Subsection 3.7b.3.I.6.3.

For a structural system, located in the Diesel Generator 'E' Building and consisting of various components having different damping materials, composite modal damping is computed in accordance with Sheet 3.7.2.11, equation (4) of the Standard Review Plan.

3.7b.4 SEISMIC INSTRUMENTATION

3.7b.4.1 Comparison with NRC Regulatory Guide 1.12, Rev 1.

Unit 1 and Unit 2 containments are assumed to respond identically to a given earthquake. This is considered to be a reasonable assumption, since both are identically designed and built and founded on rock. For this reason, instrumentation redundancy between units was not employed; identical seismic instrumentation was not, in general, installed in both units. Foundation interaction was assumed to be negligible due to the high stiffness of the rock.

Equipment required by Regulatory Guide 1.12 for a Safe Shutdown Earthquake maximum ground acceleration of less than 0.3g was implemented. The characteristics of the seismic instrumentation specified for Susquehanna exceed the range, frequency and other performance requirements of Regulatory Guide 1.12. The equipment is shown on Dwg M-157, Sh. 2.

3.7b.4.1.1 Triaxial Time - History Accelerographs

Required:
1) one at the containment foundation
2) one on the containment structure

Actual:
1) Unit 1 containment foundation
2) Unit 1 containment structure, 74 feet directly above item 1).
3) Unit 2 containment foundation
4) ESSW pumphouse floor
5) Unit 1 reactor* boiler equipment
6) Unit 1 reactor building floor, near RHR pumps
7) Free field, near the Security Control Center. This unit is a combination, self-contained sensor-trigger-recorder. It is included even though not required by Regulatory Guide 1.12.
8) Standalone free field, near Secondary Alarm Station. This unit is a combination, self-contained sensor-trigger-recorder. It is included even though not required by Regulatory Guide 1.12.

3.7b.4.1.2 Triaxial Seismic Switches

Required: 1) Containment foundation

Actual: 1) Unit 1 containment foundation
2) Unit 2 containment foundation
3) ESSW pumphouse floor

3.7b.4.1.3 Triaxial Response Recorders

Required: 1) Containment foundation, with immediate control room indication
2) Nuclear boiler equipment or piping supports
3) Seismic Category I equipment supports or piping support outside the containment.
4) The foundation of a Seismic Category I structure where the response is different from that of the containment structure.

Actual: 1) Unit 1 containment foundation, with immediate control room indication.
2) Unit 1 reactor* equipment.
3) Floor mounting, near Unit 1 RHR pumps.
4) ESSW pumphouse floor, with immediate control room indication.
5) Unit 1 containment structure.
6) Unit 2 containment foundation, with immediate control room indication.

3.7b.4.2 Description of Instrumentation

The seismic instrumentation consists of tri-axial acceleration sensors, time history recorders, alarm module, and a computer for performing an automatic frequency domain comparison to OBE and SSE design limits. Each sensor is continuously monitored and a common trigger to activate recording for all sensors is activated if the signal from at least two trigger sensors exceeds a threshold concurrently for any axis.

The requirement that two trigger sensors exceed a threshold concurrently provides the system with the capability to distinguish a seismic event from a non seismic, local event.

The recorders are configured to capture pre-trigger and a post-trigger data to ensure the event is captured in its entirety. Data is recorded on non-volatile memory, which can store data from numerous trigger events. Upon completion of recording, the computer software downloads data from the recorders associated with locations used for OBE and SSE comparison and performs automatic analysis of this data (download and analysis typically completed within 5 minutes). If

---

* The actual location of this instrument is on the outside of the biological shield wall. It is located in the optimum location for measuring the input motion experienced by the reactor pressure vessel after properly taking into account accessibility for servicing, and functionality due to radiation levels.

the analysis determines the event is possibly seismic in nature an automatic comparison to OBE and SSE limits it performed and the results are indicated to the operator. The system performs self-diagnostics including computer failure monitoring which if not completed successfully will activate the fail safe trouble annunciator. Sound the seismic monitoring system external power be lost, an uninterruptable power supply is included which will run the system for greater than 25 minutes required by Regulatory Guide 1.12.

3.7b.4.3 Control Room Operator Notification

Activation of the common trigger for recording of all sensor locations is annunciated at the control room (OC653 panel) and also at the Seismic Warning Panel (OC696). Activation of the system trouble condition is annunciated at the control room (OC653 panel) and also at the Seismic Warning Panel (OC696) OBE or SSE exceeded is indicated at the Seismic Warning Panel (OC696) only.

3.7b.4.4 Comparison of Measured and Predicted Responses

The operator is provided with a procedure and predicted response curves, by which action to continue operation or shut down may be decided. The plant will be shut down following an earthquake if the vibratory ground motion exceeds that of the OBE. Operation will not resume until it has been determined through detailed inspections and analyses that no damage has been sustained.

3.7b.5 REFERENCES

3.7b-1 N.C. Tsai, "Spectrum Compatible Motions for Design Purposes," Journal of Engineering Mechanics Division, ASCE, Vol. 98, No. EM2, Proc, Paper 8807 (April 1972), pp. 345-356.

3.7b-2 N.M. Newmark, "Design Criteria for Nuclear Reactors Subject to Earthquake Hazards," Proc IAEA Panel on A Seismic Design and Testing of Nuclear Facilities, Japan Earthquake Engineering Promotion Society, Tokyo, Japan (1967).

3.7b-3 "Seismic Analyses of Structures and Equipment for Nuclear Power Plants," BC-TOP-4A, Rev 3, Bechtel Power Corporation, San Francisco, California (November 1974).

3.7b-4 Uniform Building Code (UBC), by International Conference of Building Officials, Whittier, California, 1970 Edition.

3.7b-5 A.T. Derecho, D.M. Schultz, and M. Fintel, "Analysis and Design of Small Reinforced Concrete Buildings for Earthquake Forces," Portland Cement Association (1974).

3.7b-6 "Seismic Analysis of Piping Systems," BP-TOP-1, Rev 3, Bechtel Power Corporation, San Francisco, California (January 1976).

3.7b-7 "Development of Analysis and Design Techniques from Dynamic Testing of Electrical Raceway Support Systems," Technical Report, July, 1979, Bechtel Power Corporation.

3.7b-8 “Cable Tray and Conduit Raceway Seismic Test Program-Release 4," Test Report #1053-21.1-4, Volumes 1 and 2, December 15, 1978, ANCO Engineers, Inc.

3.7b-9 "Hatago, P.Y., Reimer, G.S., "Dynamic Testing of Electrical Raceway Support Systems for Economical Nuclear Power Plant Installations," presented at the February 4-9, 1979 IEEE-PES.

3.7b-10 "Cable Tray and Conduit Raceway Seismic Test Program-Release 4," Addendum to Test Report #1053-21.1-4, Volume 3, May 1980, ANCI Engineers, Inc.

3.7b-11 Cable Tray Qualification Data for the Susquehanna Steam Electric Station Units 1 and 2. Specification 8856-E-132, November 29, 1976, Husky Products, Inc.

3.7b-12 Rodofoam II manufactured by W. R. Grace & Co. or equivalent equal.

3.7b-13 M. A. Igbal and E. C. Goodling, "Seismic Design of Buried Pipes," presented at the 2nd ASCE Specialty Conference on Structural Design of Nuclear Plant Facilities at New Orleans, Louisiana, December, 1975.

3.7b-14 "Seismic Analysis of Piping Systems in Nuclear Power Plants," AEG-502, Rev. 0, Gibbs and Hill, Inc., New York, New York (June 1981).

3.7b-15 "Design Response Spectra for Seismic Design of Nuclear Power Plants," US NRC Regulatory Guide 1.60 Rev. 1 (December 1973).

3.7b-16 "Damping Values for Seismic Design of Nuclear Power Plants," US NRC Regulatory Guide 1.61 (October, 1973).

3.7b-17 "Combining Modal Responses and Spatial Components in Seismic Response Analysis," US NRC Regulatory Guide 1.92, Rev. 1 (February 1976).

3.7b-18 "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components," US NRC Regulatory Guide 1.122, Rev. 1 (February 1978).

3.7b-19 "Standard Review Plan 3.7.1," US NRC NUREG-0800 (July 1981).

3.7b-20 "Standard Review Plan 3.7.2," US NRC NUREG-0800 (July 1981).

3.7b-21 "Diesel Generator 'E' Building Seismic Analysis," Calculation Number SE-DB-1C, Rev. 1.

TABLE 3.7b-1

AMPLIFICATION FACTORS FOR GROUND SPECTRA*

Percent of Critical Damping	Acceleration	Displacement
0.0	5.2	2.0
0.5	4.7	1.8
1.0	4.2	1.6
2.0	3.5	1.5
3.0	3.0	1.2
5.0	2.1	1.1
7.0	1.5	1.0

* For all seismic Category 1 structures except the Diesel Generator 'E' Building

TABLE 3.7b-2

AMPLIFICATION FACTORS FOR DIESEL GENERATOR 'E' BUILDING'S GROUND SPECTRA

HORIZONTAL DESIGN RESPONSE SPECTRA				
Percent of Critical Damping	Amplification Factors for Control Points			
	Acceleration		Displacement	
	A(33Hz)	B(9Hz)	C(2.5Hz)	D(0.25Hz)
0.5	1.0	4.96	5.95	3.20
2	1.0	3.54	4.25	2.50
4	1.0	2.92	3.50	2.20
5	1.0	2.61	3.13	2.05
7	1.0	2.27	2.72	1.88

VERTICAL DESIGN RESPONSE SPECTRA				
Percent of Critical Damping	Amplification Factors for Control Points			
	Acceleration		Displacement	
	A(33Hz)	B(9Hz)	C(3.5Hz)	D(0.25Hz)
0.5	1.0	4.96	5.67	2.13
2	1.0	3.54	4.05	1.67
4	1.0	2.92	3.34	1.47
5	1.0	2.61	2.98	1.37
7	1.0	2.27	2.59	1.25

TABLE 3.7b-3

DAMPING VALUES FOR NON-NSSS MATERIALS*
(PERCENT OF CRITICAL DAMPING)

Structure of Component	OBE	SSE
Welded steel structures	2	5
Bolted steel structures	3	5
Reinforced concrete structures	2	5
Concrete masonry structures		
Uncracked	2	2
Partially Cracked	4	7
Cracked	4	7
Piping systems	0.5	1
Equipment	0.5	1

*Notes

1. For seismic design of all non-NSSS safety related structures, piping systems and equipment, except those associated with the Diesel Generator 'E' Facility
2. Higher damping values are used if justified.
3. For snubber elimination or other piping modifications, damping values per Code Case N-411 or Regulatory Guide 1.61 may be applied to piping systems. When either Code Case N-411 or Regulatory Guide 1.61 is invoked, modal combinations for closely spaced modes per Regulatory Guide 1.92 shall be applied.

TABLE 3.7b-4

DAMPING VALUES FOR DIESEL GENERATOR 'E' FACILITY
(Percent of Critical Damping)

Structure or Component[3]	Operating Basis Earthquake (OBE)[1]	Safe Shutdown Earthquake (SSE)
Equipment and large-diameter piping systems [2,4], pipe diameter greater than 12 in	2	3
Small-diameter piping systems [4], diameter equal to or less than 12 in	1	2
Welded steel structures	2	4
Bolted steel structures	4	7
Reinforced concrete structures	4	7

1 In the dynamic analysis of active components as defined in U.S. NRC Regulatory Guide 1.48, these values should be used for the SSE.

2 Includes both material and structural damping. If the piping system consists of only one or two spans with little structural damping, use values for small-diameter piping.

3 If the maximum combined stresses due to static, seismic, and other dynamic loading are significantly lower than the yield stress and 1/2 yield stress for SSE and OBE, respectively, in any structure or component, damping values lower than those specified above should be used for that structure or component to avoid underestimating the amplitude of vibrations or dynamic stresses.

4 Damping values per Code Case N-411 may be applied to piping systems.

TABLE 3.7b-5

STRUCTURE FOUNDATION INTERACTION COEFFICIENTS

Structure	Motion	Equivalent Spring Constant	Equivalent Damping Coefficient
ESSW Pumphouse	Transitional	EW 1.97+6 k/ft(1) NS 1.97+6 k/ft	3.31+4 k-sec/ft 3.31+4 k-sec/ft
	Rocking	EW 6.1+9 kft/rad NS 2.94+9 kft/rad	3.77+7 k-ft-sec/rad 2.10+7 k-ft-sec/rad
	Vertical	1.81+6 k/ft	5.22+4 k-sec/ft
Containment	Translational	4.07+7 k/ft	1.89+5 k-sec/ft
	Rocking	7.96+10 k-ft/rad	6.16+7 k-ft-sec/rad
	Vertical	4.78+7 k/ft	3.27+5 k-sec/ft

(1) 1.97+6 = 1.97×10^{6}

TABLE 3.7b-6

PROPERTIES OF FOUNDATION MEDIA FOR CONTAINMENT AND ESSW PUMPHOUSE

	Containment (rock)	ESSW Pumphouse (soil)
Density (pcf)	140	130
Shear modulus (psi)	1.15 (10^5)	6.1 (10^4)
Shear wave velocity (fps)	6200	1480

TABLE 3.7b-7

NATURAL FREQUENCIES OF CONTAINMENT BELOW 33 CPS*

Mode No.	Frequency (CPS)	
	Horizontal	Vertical
1	4.99	16.19
2	8.01	20.95
3	16.12	38.24
4	19.83	
5	23.89	

* The frequency of 38.8 cps is included in the table because three modes are used in the vertical analysis.

TABLE 3.7b-8

NATURAL FREQUENCIES OF THE REACTOR AND CONTROL BUILDING BELOW 33 CPS

Mode No.	Frequency (CPS) E-W	N-S	Vertical
1	2.23	3.92	4.43
2	2.51	4.53	6.21
3	3.49	4.72	6.80
4	4.31	5.98	7.50
5	4.77	12.0	7.85
6	6.14	12.5	7.99
7	6.23	13.5	8.89
8	11.26	14.0	9.20
9	11.33	16.7	9.56
10	11.96	22.6	9.88
11	12.81	23.0	10.17
12	13.17	23.6	10.96
13	17.81	28.2	11.01
14	21.74	29.8	11.09
15	21.95		11.58
16	23.19		11.80
17	24.37		14.24
18	25.31		14.33
19	26.22		15.53
20	26.91		16.14
21	27.87		19.71
22	28.65		20.76
23	30.65		21.36
24	30.81		23.66
25			26.18
26			26.75
27			27.77
28			29.86
29			30.11
30			32.58

TABLE 3.7b-9

ESSW PUMPHOUSE : FREQUENCIES WITH AND WITHOUT ECCENTRICITIES

(SEE FIGURE 3.7B-125)

Mode #	Frequencies (cps)	
	With Eccentricity	Without Eccentricity
1	13.93	13.94
2	18.05	18.06
3	28.94	28.97
4	38.83	40.01

TABLE 3.7b-10

DIESEL GENERATOR A-D BUILDING
FREQUENCIES WITH AND WITHOUT ECCENTRICITIES

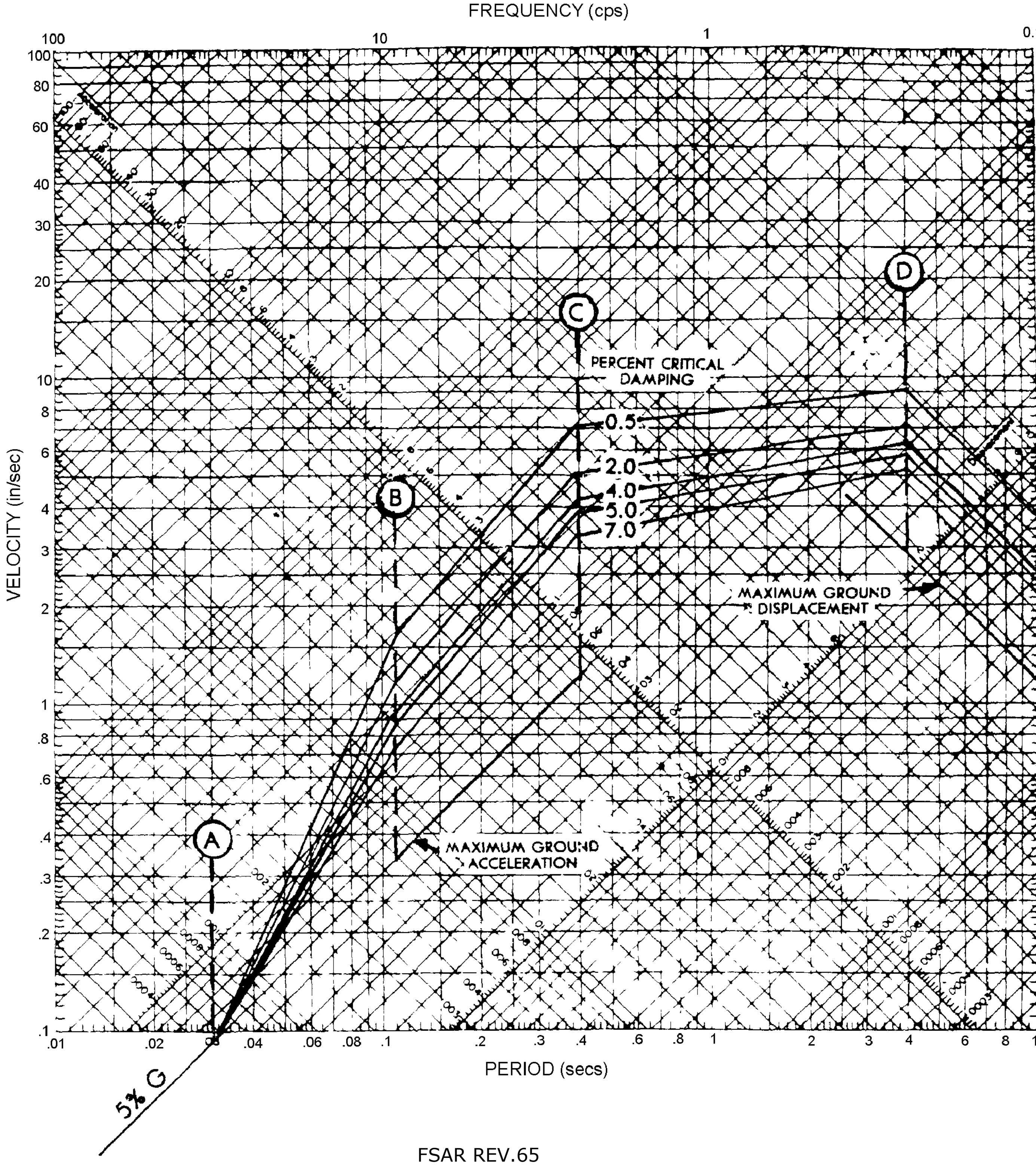
(SEE FIGURE 3.7B-126)

Mode #	Frequencies (cps)	
	With Eccentricity	Without Eccentricity
1	8.86	8.96
2	9.65	9.71
3	22.56	23.42
4	31.69	32.04
5	33.45	33.66

TABLE 3.7b-11

COMPARISONS OF TORSIONAL MOMENTS BETWEEN ORIGINAL DESIGN AND THE VALUES COMPUTED FROM THE RESULTS OF 3-D STICK MODEL

Building	Torsional Moment (k.ft.)	
	Original Design	3-D Stick Model
ESSW Pumphouse	24,440	11,780
Diesel Generator A-D Building El. 677'-0"	29,420	46,400
Diesel Generator A-D Building El. 710'-9"	23,450	34,900



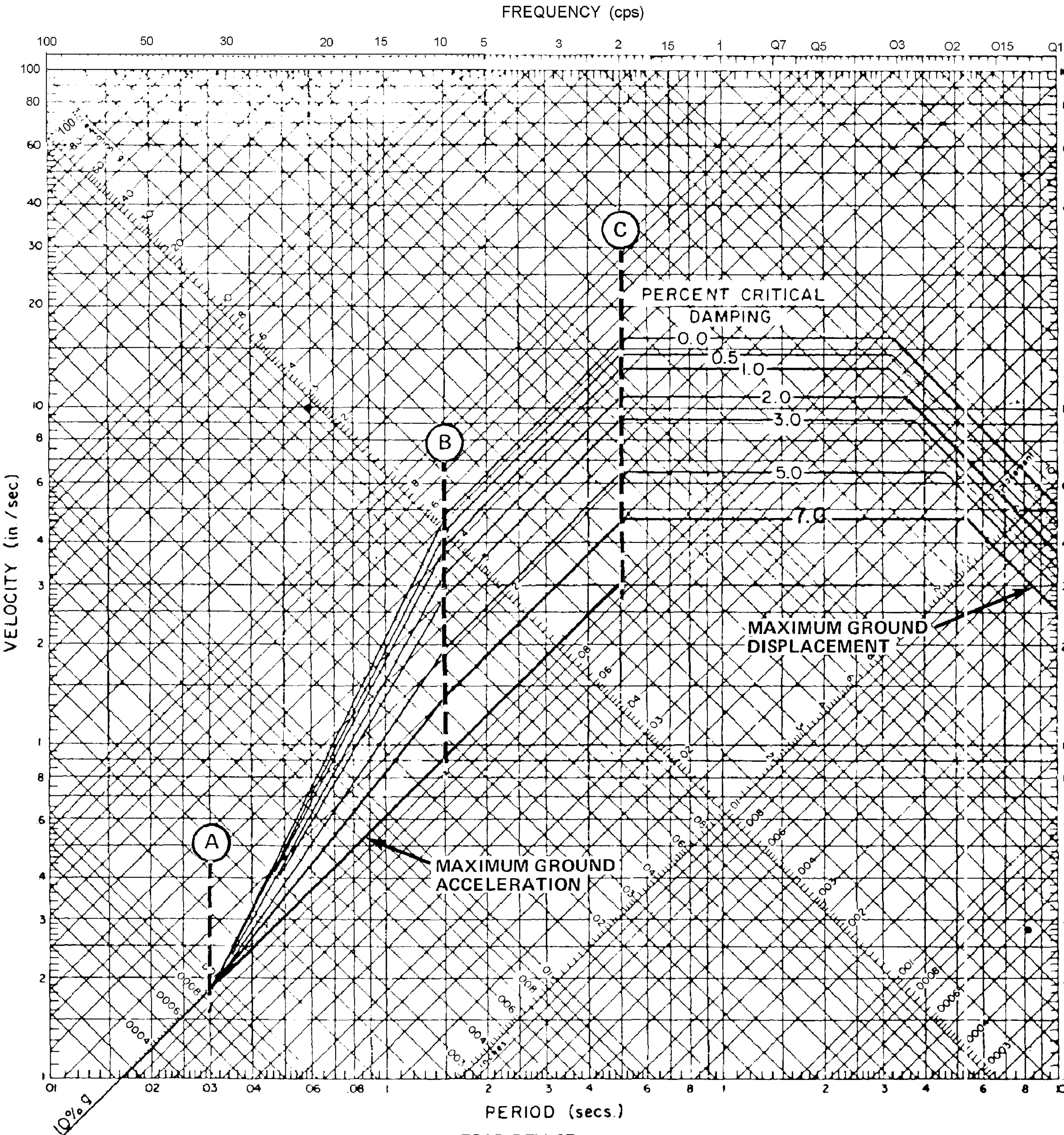
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
DESIGN RESPONSE SPECTRA
OPERATING BASIS EARTHQUAKE
HORIZONTAL COMPONENT

FIGURE 3.7B-2, Rev. 55

Auto-Cad Figure Fsar 3_7B_2.dwg



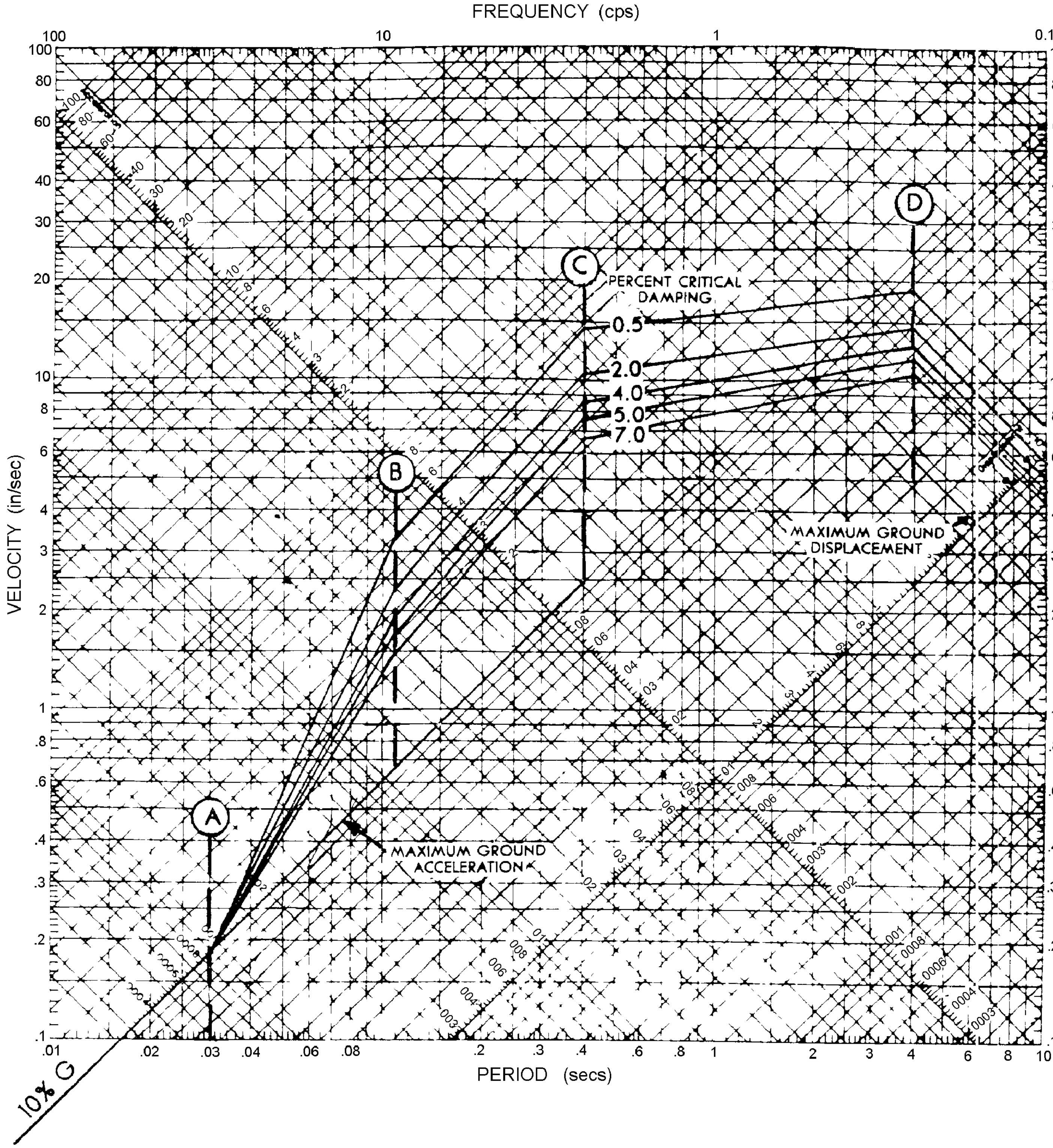
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DESIGN RESPONSE SPECTRA
SAFE SHUTDOWN EARTHQUAKE
HORIZONTAL COMPONENT

FIGURE 3.7B-3, Rev. 55

Auto-Cad Figure Fsar 3_7B_3.dwg



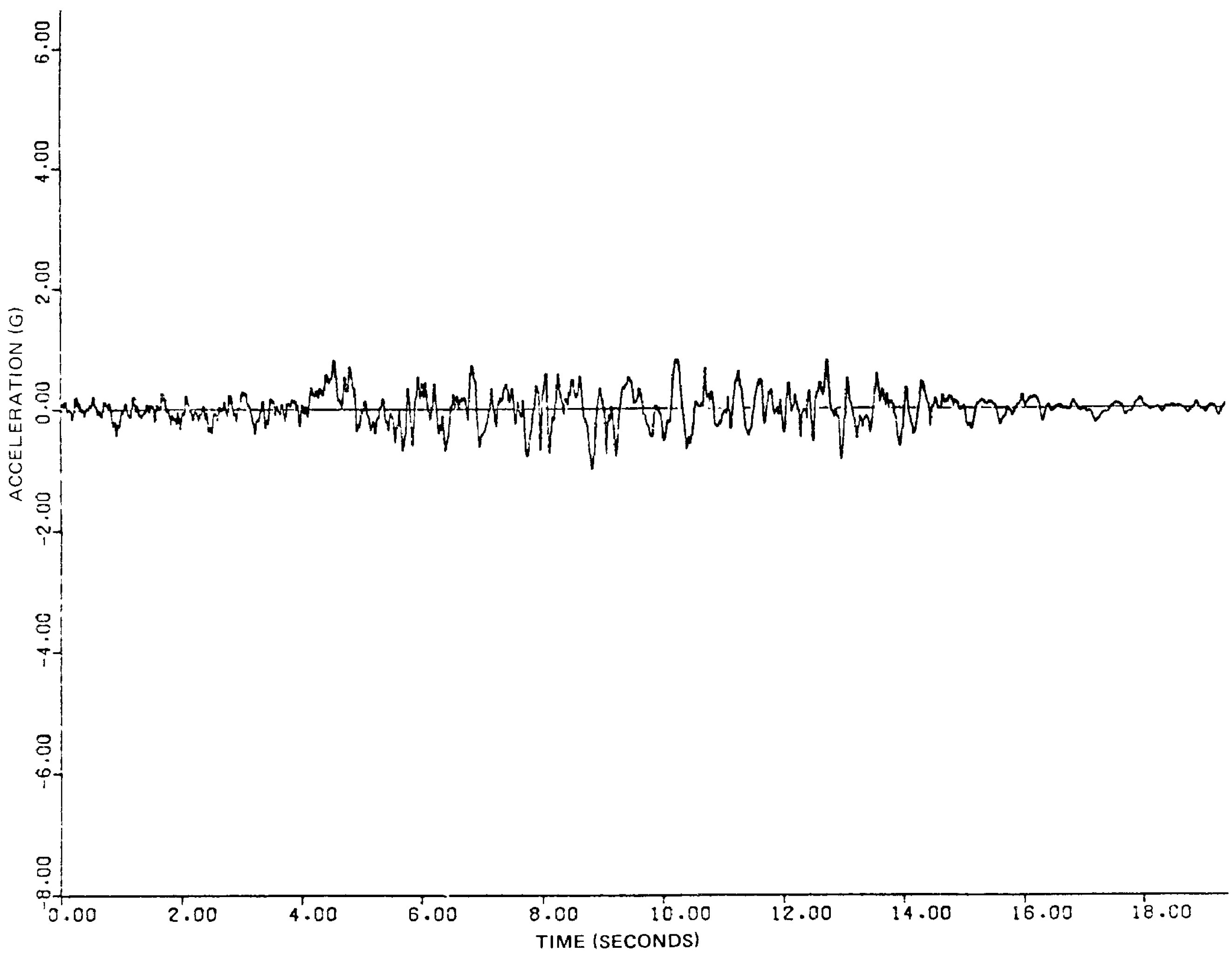
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING'S
DESIGN RESPONSE SPECTRA
SAFE SHUTDOWN EARTHQUAKE
HORIZONTAL COMPONENT

FIGURE 3.7B-4, Rev. 55

Auto-Cad Figure Fsar 3_7B_4.dwg



* FOR ALL SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING.

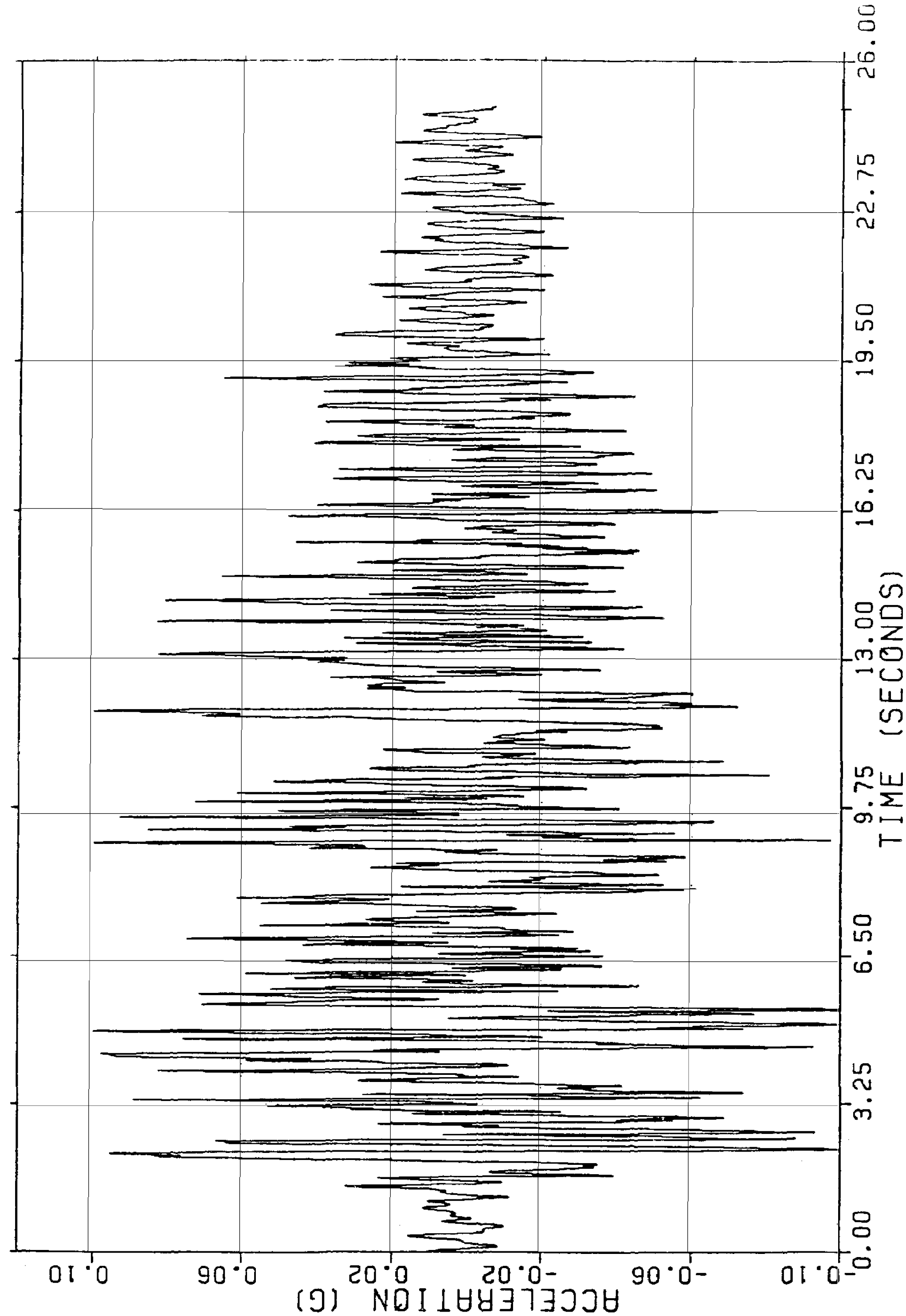
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

SYNTHETIC TIME HISTORY*
NORMALIZED TO 1G

FIGURE 3.7B-5, Rev. 55

Auto-Cad Figure Fsar 3_7B_5.dwg



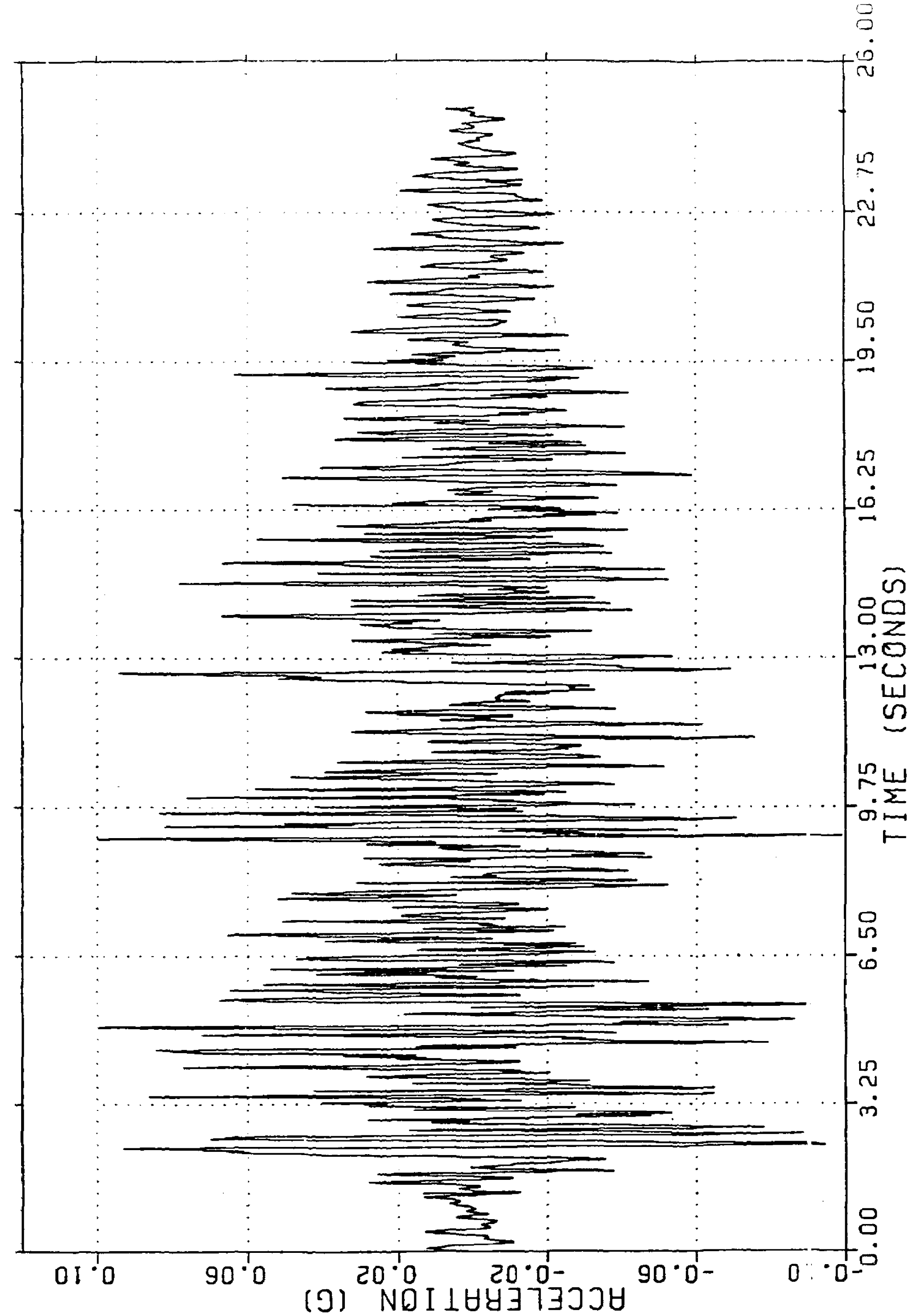
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
HORIZONTAL SYNTHETIC TIME
HISTORY NORMALIZED TO 0.1G

FIGURE 3.7B-6, Rev. 55

Auto-Cad Figure Fsar 3_7B_6.dwg



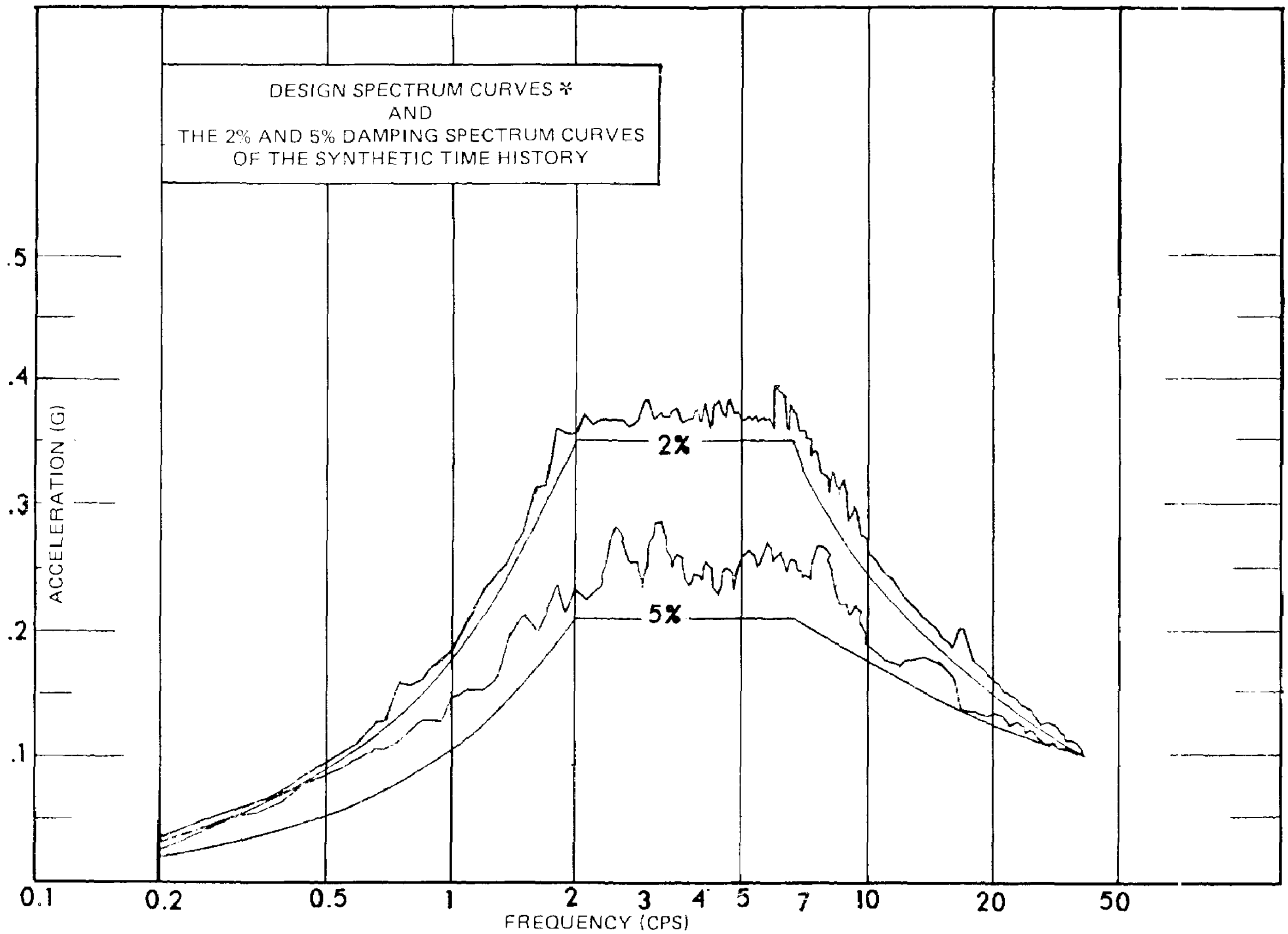
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
VERTICAL SYNTHETIC TIME
HISTORY NORMALIZED TO 0.1G

FIGURE 3.7B-7, Rev. 55

Auto-Cad Figure Fsar 3_7B_7.dwg



* SSE HORIZONTAL COMPONENT FOR ALL ROCK FOUNDED SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING.

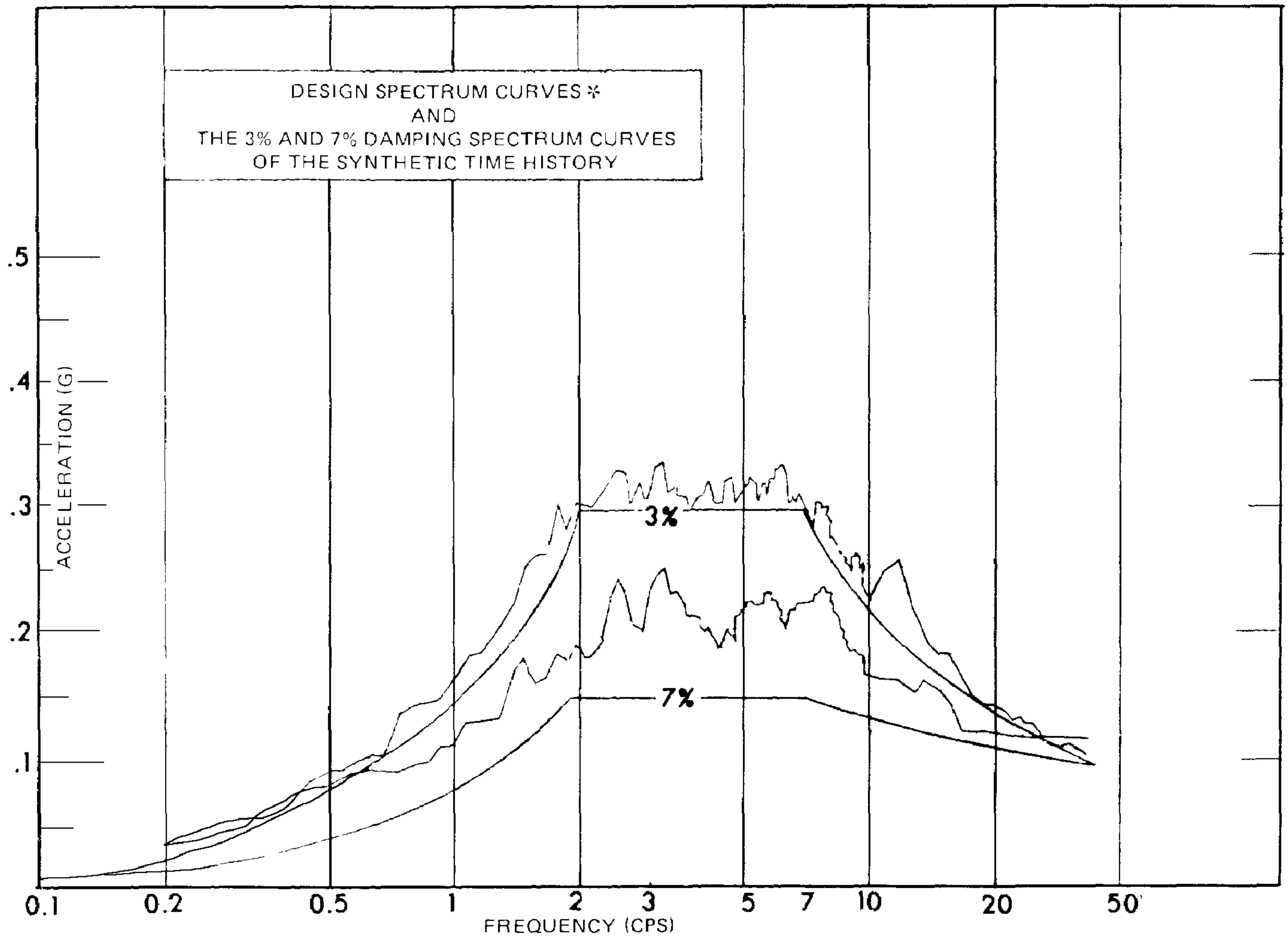
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF TIME HISTORY
RESPONSE SPECTRA AND
DESIGN RESPONSE SPECTRA
2% AND 5% DAMPING (0.2-30 CPS)

FIGURE 3.7B-8, Rev. 55

Auto-Cad Figure Fsar 3_7B_8.dwg



* SSE HORIZONTAL COMPONENT FOR ALL ROCK FOUNDED SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING.

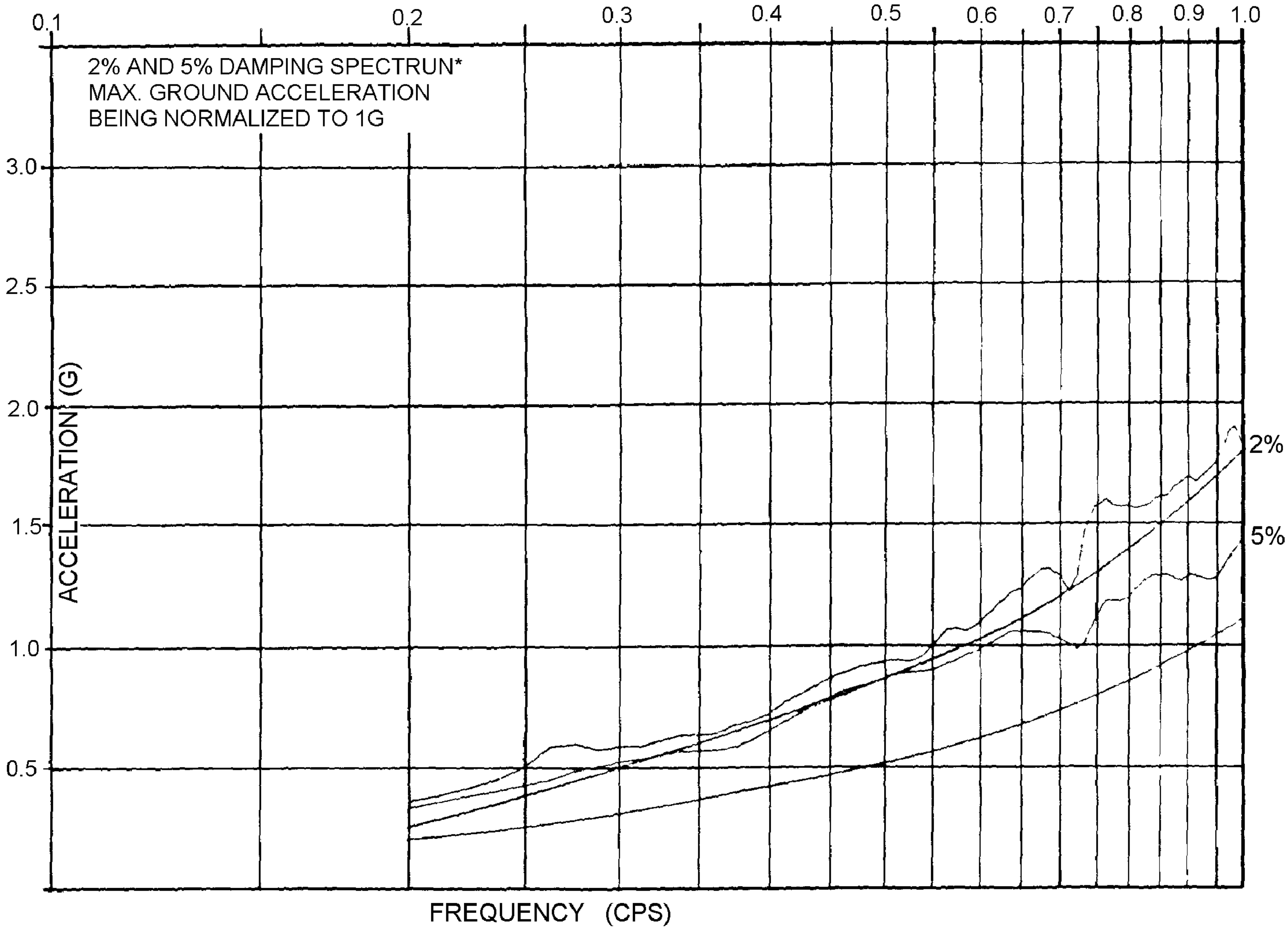
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF TIME HISTORY
RESPONSE SPECTRA AND
DESIGN RESPONSE SPECTRA
3% AND 7% DAMPING (0.2-30 CPS)

FIGURE 3.7B-9, Rev. 55

Auto-Cad Figure Fsar 3_7B_9.dwg



* SSE HORIZONTAL COMPONENT FOR ALL ROCK FOUNDED SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING.

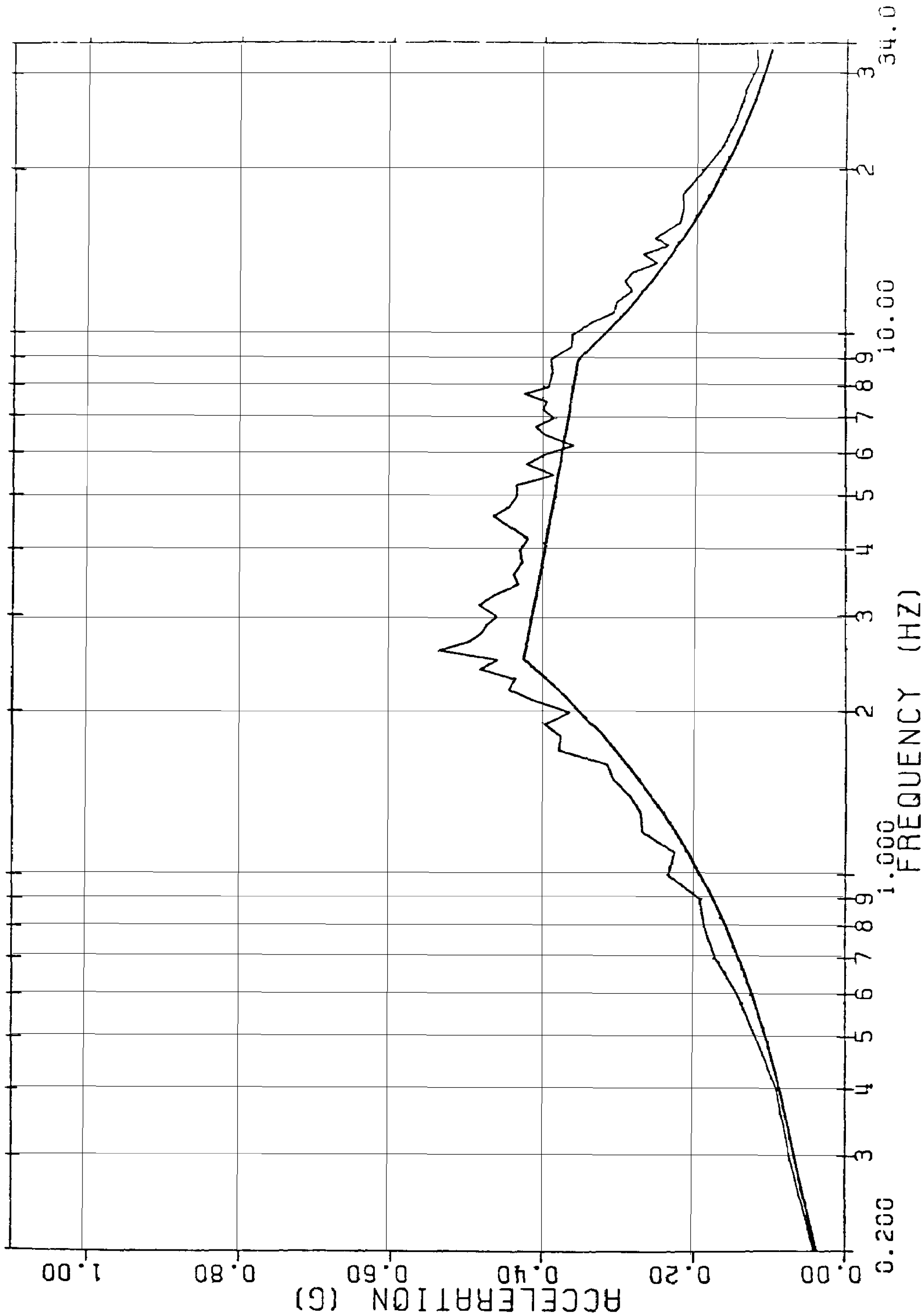
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF TIME HISTORY
RESPONSE SPECTA AND
DESIGN RESPONSE SPECTRA-
2% AND 5% DAMPING (0.2-1.0 CPS)

FIGURE 3.7B-10, Rev. 55

Auto-Cad Figure Fsar 3_7B_10.dwg



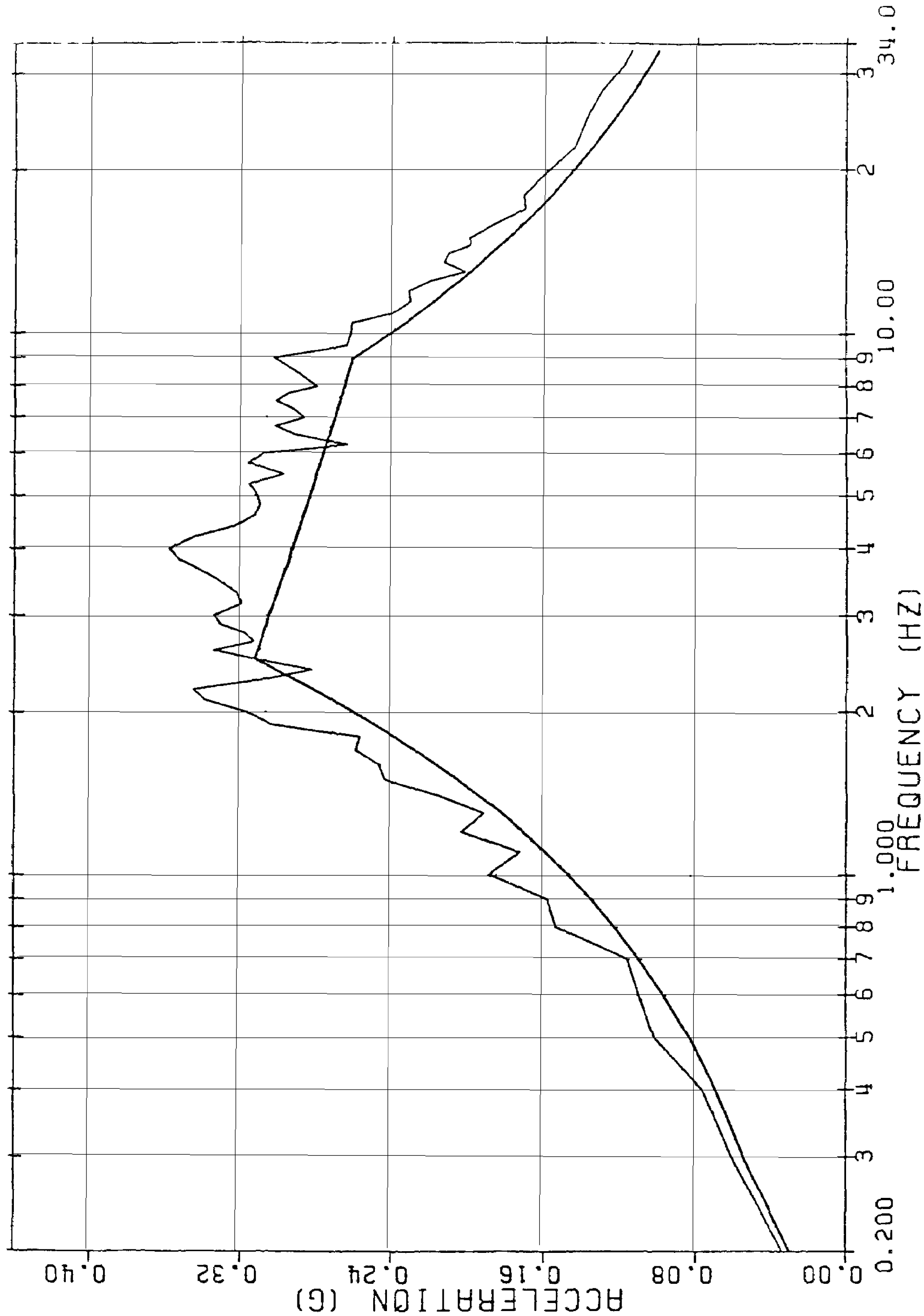
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
COMPARISON OF HORIZONTAL TIME
HISTORY RESPONSE SPECTRUM AND
HORIZONTAL DESIGN RESPONSE
SPECTRUM 2% DAMPING

FIGURE 3.7B-11, Rev. 55

Auto-Cad Figure Fsar 3_7B_11.dwg



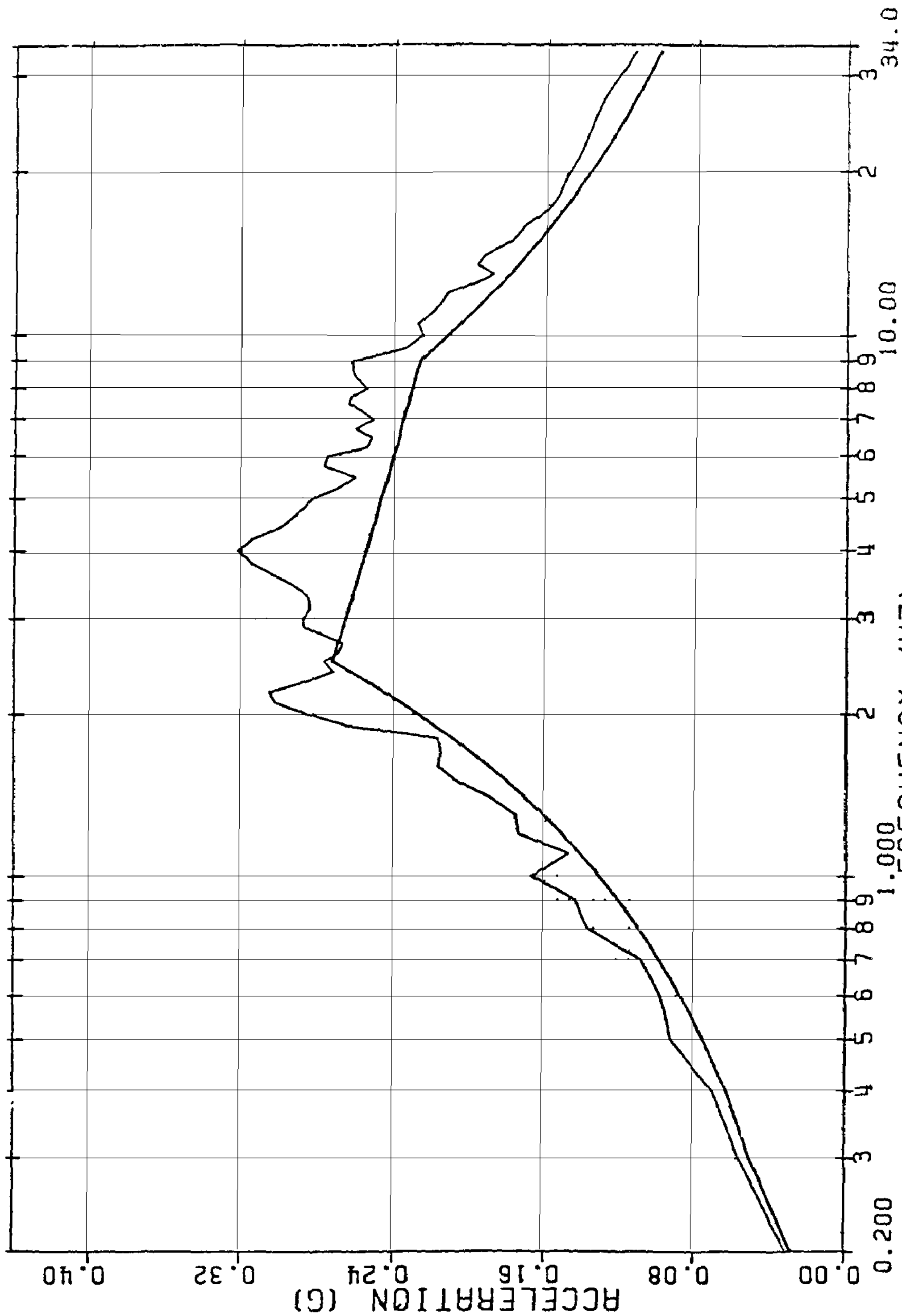
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
COMPARISON OF HORIZONTAL TIME
HISTORY RESPONSE SPECTRUM AND
HORIZONTAL DESIGN RESPONSE
SPECTRUM 5% DAMPING

FIGURE 3.7B-12, Rev. 55

Auto-Cad Figure Fsar 3_7B_12.dwg



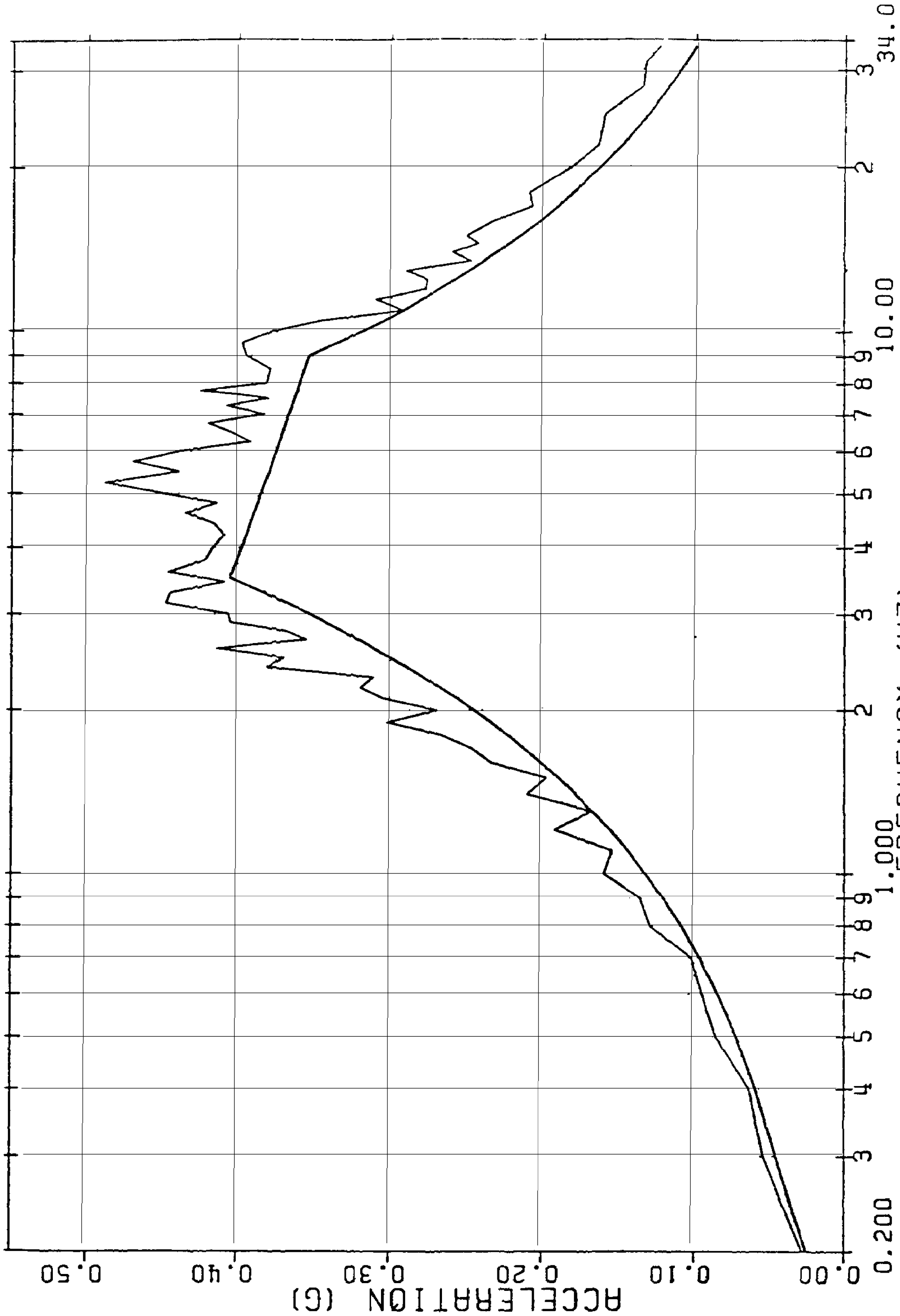
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
COMPARISON OF HORIZONTAL TIME
HISTORY RESPONSE SPECTRUM AND
HORIZONTAL DESIGN RESPONSE
SPECTRUM 7% DAMPING

FIGURE 3.7B-13, Rev. 55

Auto-Cad Figure Fsar 3_7B_13.dwg



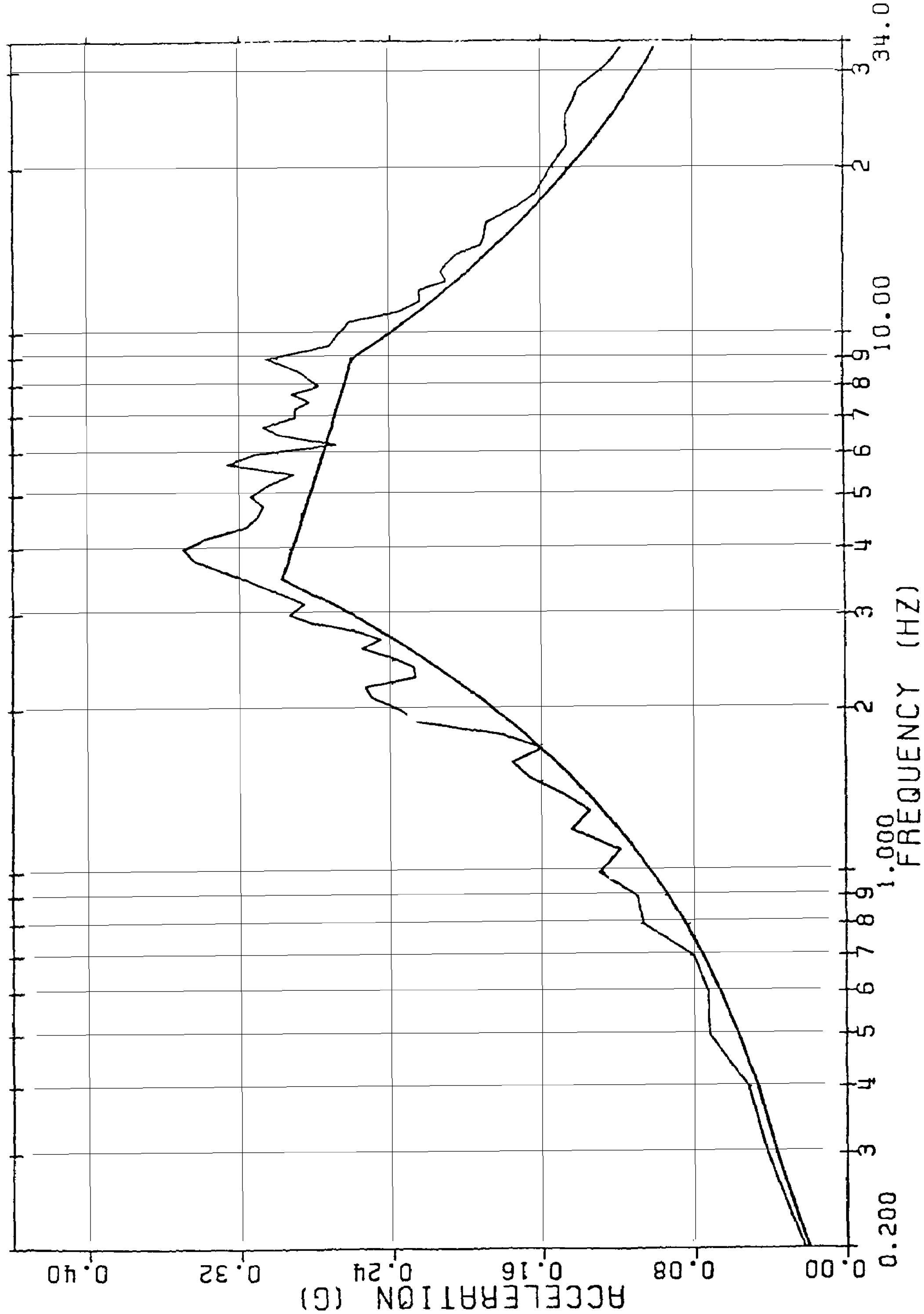
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR 'E' BUILDING
COMPARISON OF VERTICAL TIME
HISTORY RESPONSE SPECTRUM AND
VERTICAL DESIGN RESPONSE
SPECTRUM 2% DAMPING

FIGURE 3.7B-14, Rev. 55

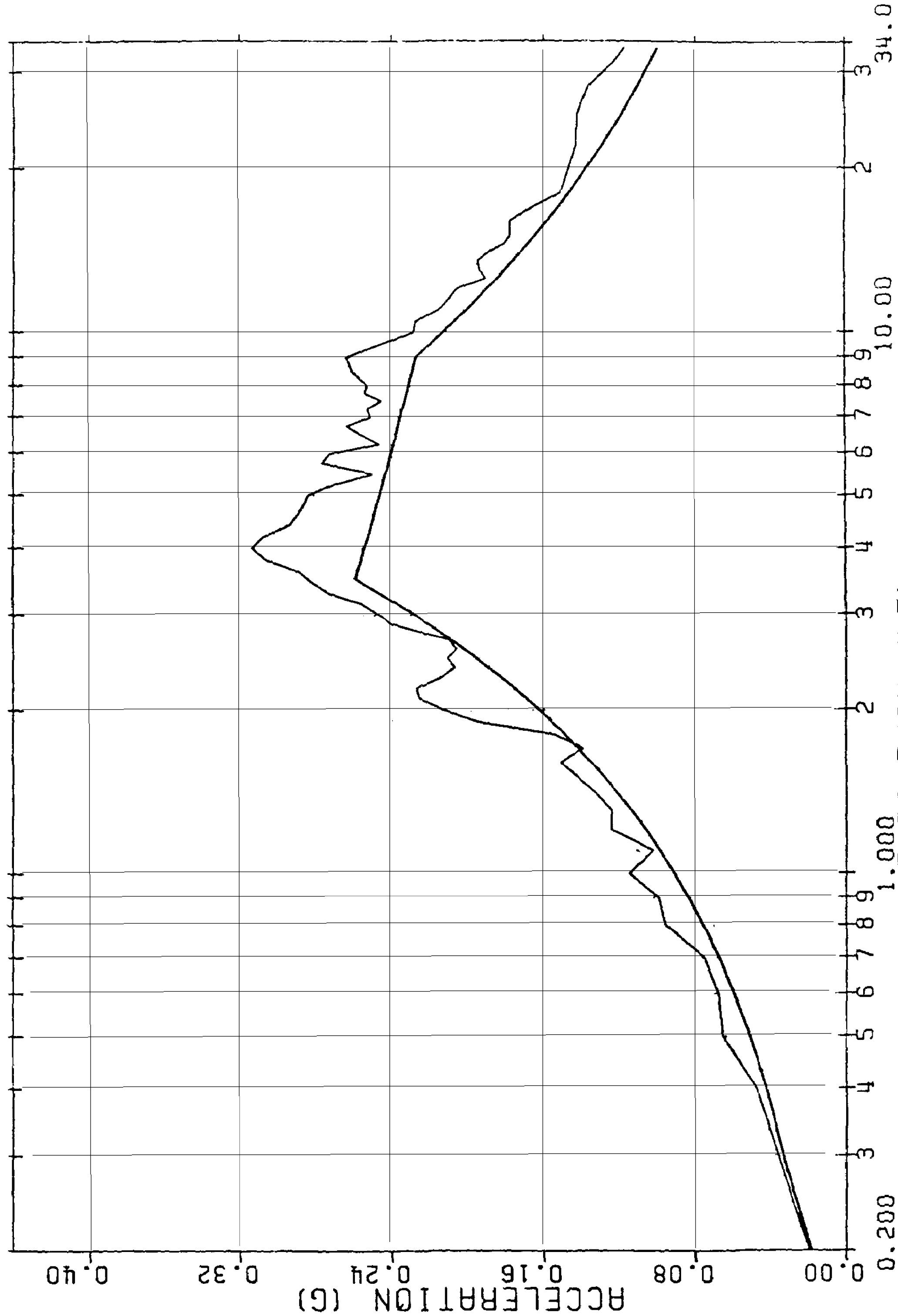
Auto-Cad Figure Fsar 3_7B_14.dwg



FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
DIESEL GENERATOR 'E' BUILDING COMPARISON OF VERTICAL TIME HISTORY RESPONSE SPECTRUM AND VERTICAL DESIGN RESPONSE SPECTRUM 5% DAMPING FIGURE 3.7B-15, Rev. 55

Auto-Cad Figure Fsar 3_7B_15.dwg



FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
DIESEL GENERATOR 'E' BUILDING COMPARISON OF VERTICAL TIME HISTORY RESPONSE SPECTRUM AND VERTICAL DESIGN RESPONSE SPECTRUM 7% DAMPING
FIGURE 3.7B-16, Rev. 55

Auto-Cad Figure Fsar 3_7B_16.dwg

Security-Related Information
Figure Withheld Under 10 CFR 2.390

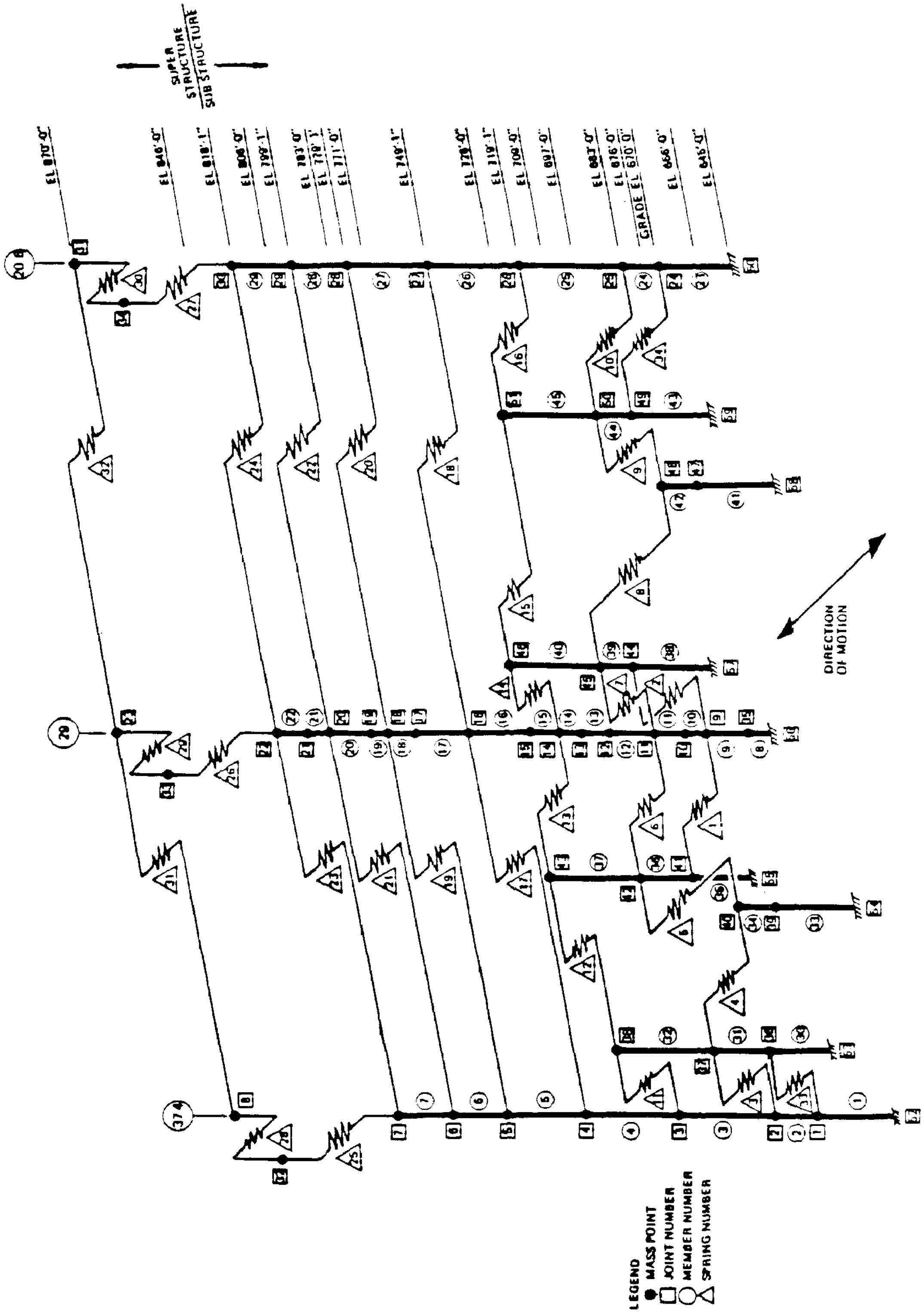
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

HORIZONTAL SEISMIC MODEL
OF CONTAINMENT WITH
FLEXIBLE BASE

FIGURE 3.7B-17

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
VETICAL SEISMIC MODEL OF CONTAINMENT WITH FLEXIBLE BASE FIGURE 3.7B-18



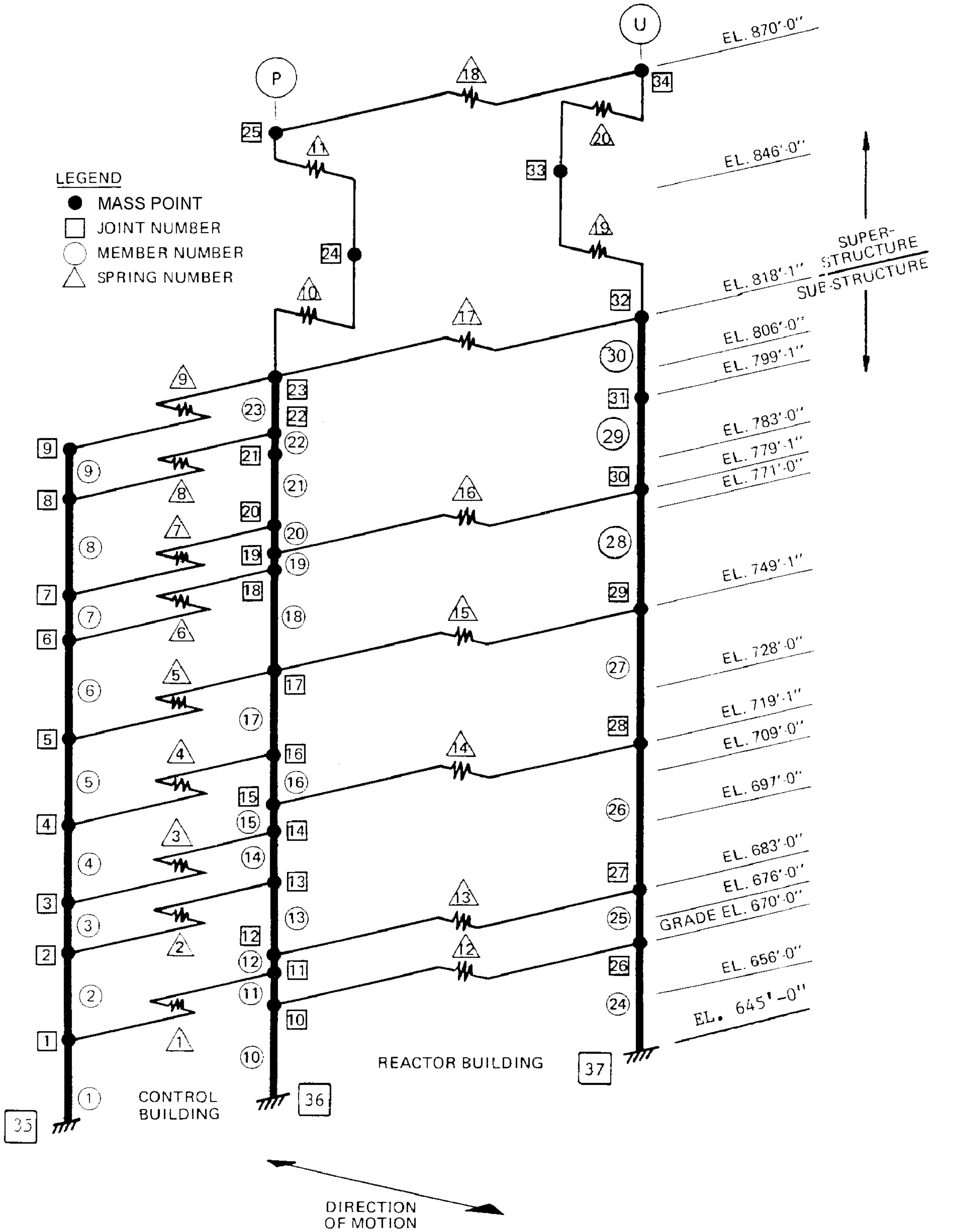
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

E-W SEISMIC MODEL OF
REACTOR AND CONTROL BUILDING

FIGURE 3.7B-19, Rev. 55

Auto-Cad Figure Fsar 3_7B_19.dwg



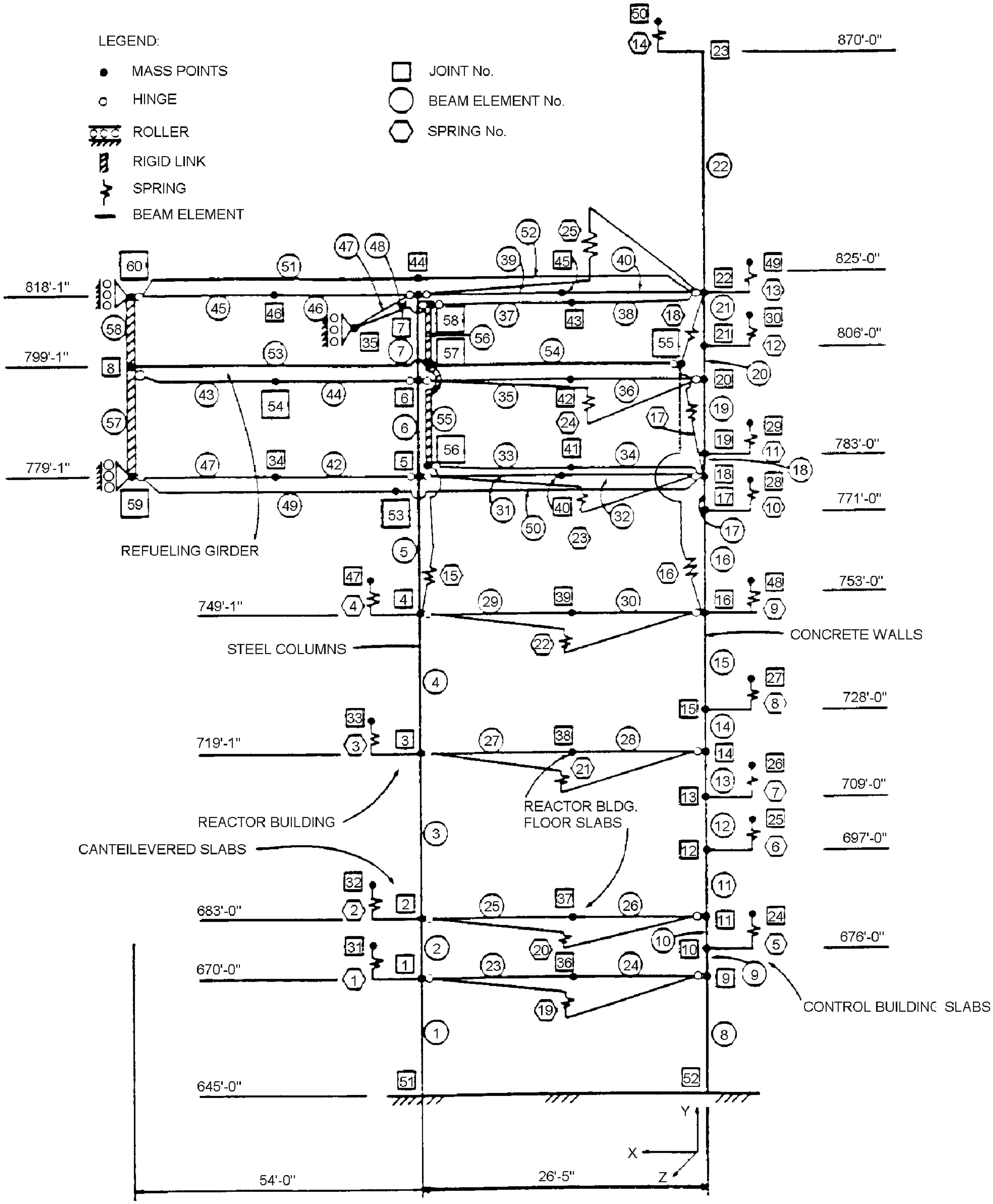
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

N-S SEISMIC MODEL OF
REACTOR AND CONTROL BUILDING

FIGURE 3.7B-20, Rev. 55

Auto-Cad Figure Fsar 3_7B_20.dwg



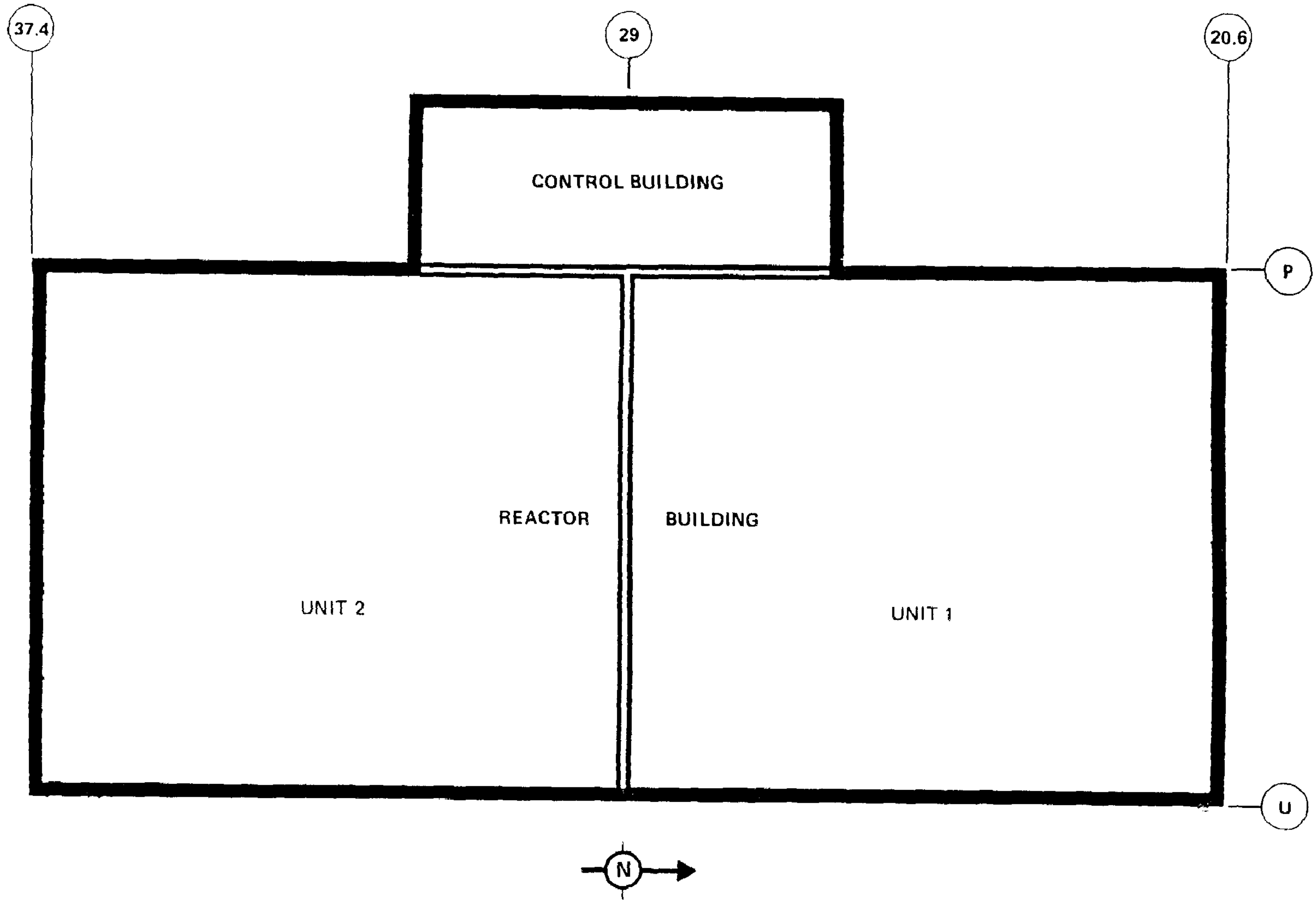
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

VERTICAL SEISMIC MODEL OF
REACTOR AND CONTROL BUILDING

FIGURE 3.7B-21, Rev. 55

Auto-Cad Figure Fsar 3_7B_21.dwg



FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

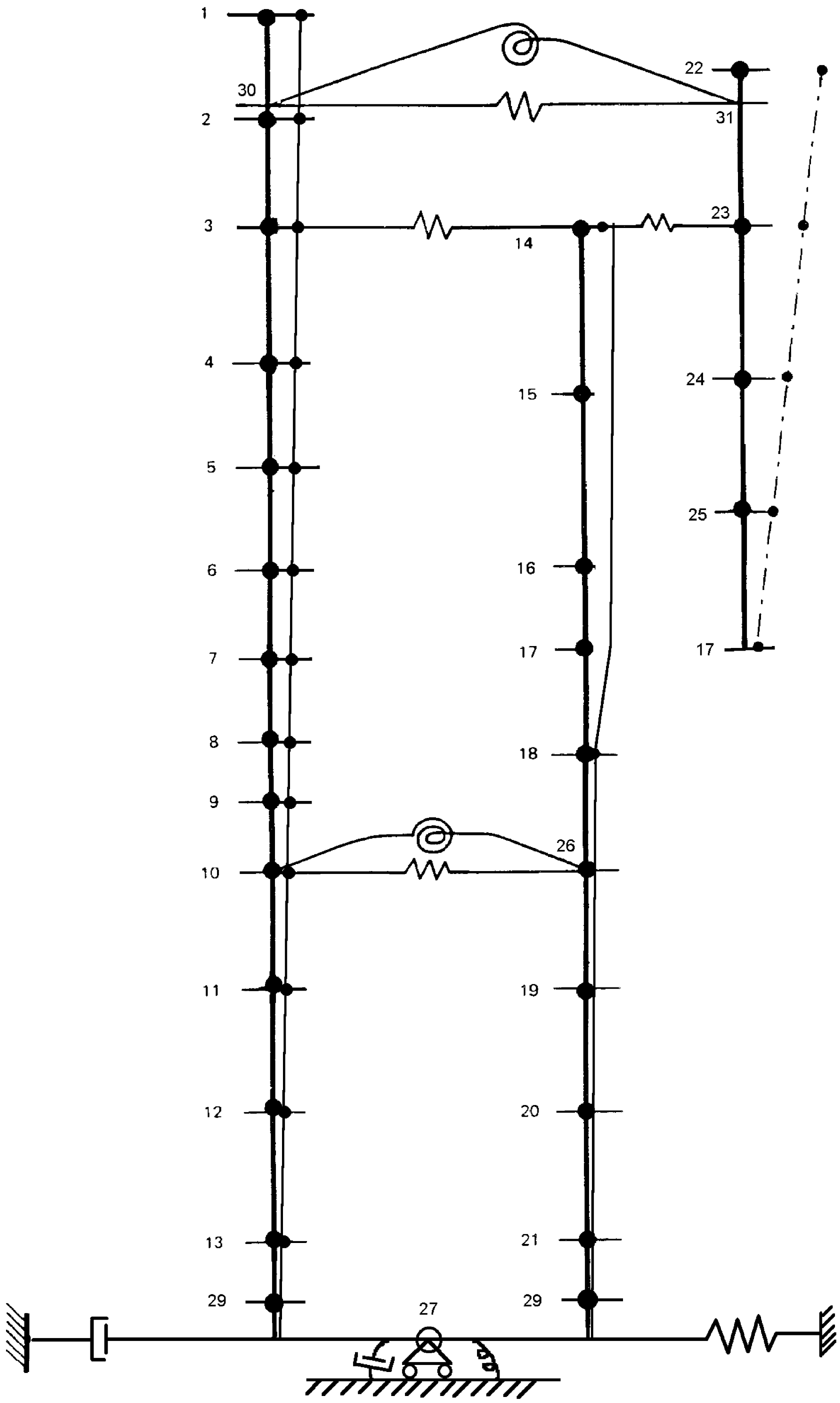
PLAN VIEW OF
REACTOR AND CONTROL BUILDING

FIGURE 3.7B-22, Rev. 55

Auto-Cad Figure Fsar 3_7B_22.dwg

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CORRELATION OF VERTICAL SEISMIC MODEL MASSPOINTS OF THE PHYSICAL STRUCTURE FIGURE 3.7B-23



FREQUENCY = 4.99 CPS

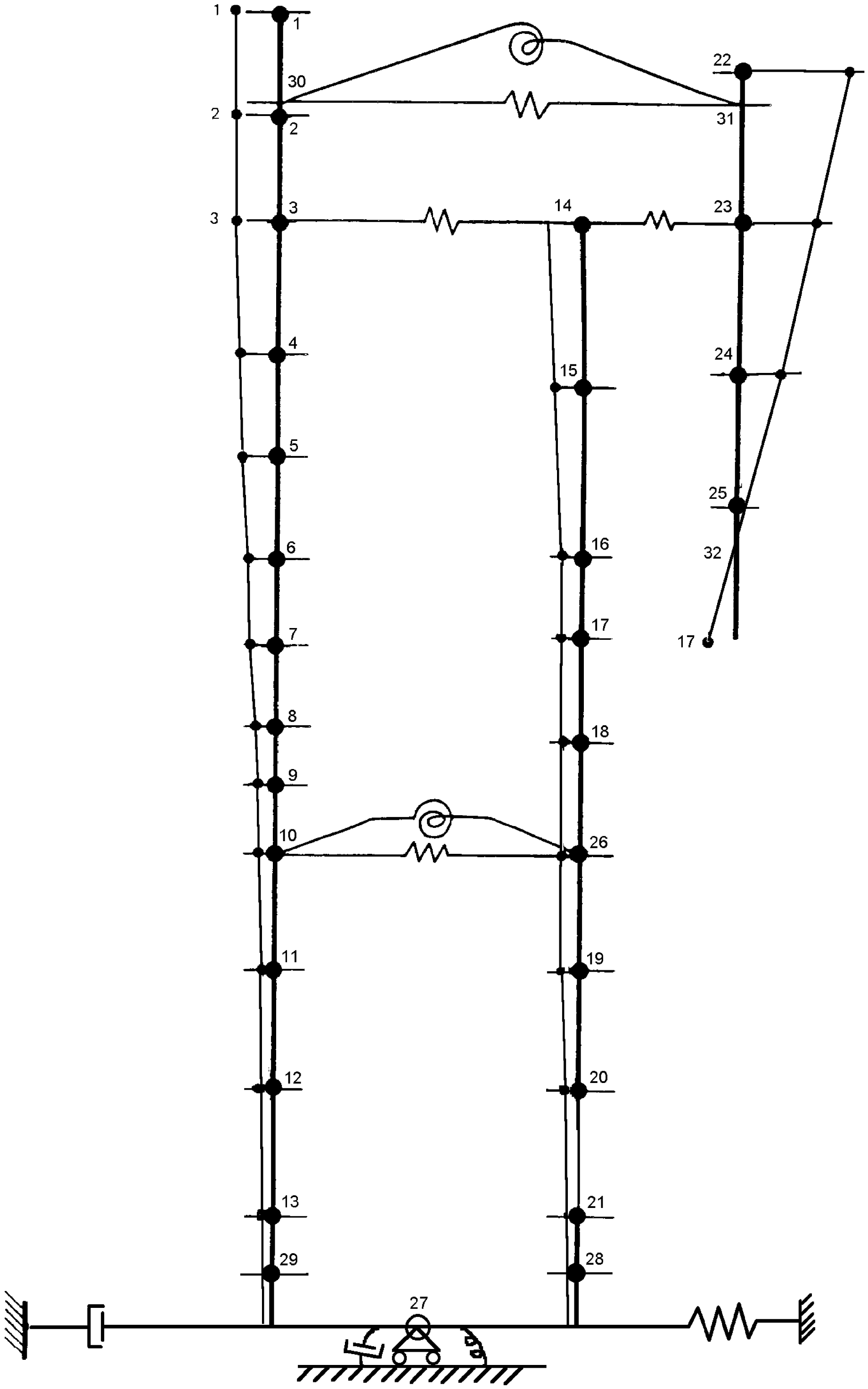
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL MODE SHAPES
MODE 1

FIGURE 3.7B-24, Rev. 55

Auto-Cad Figure Fsar 3_7B_24.dwg



FREQUENCY = 8.77 CPS

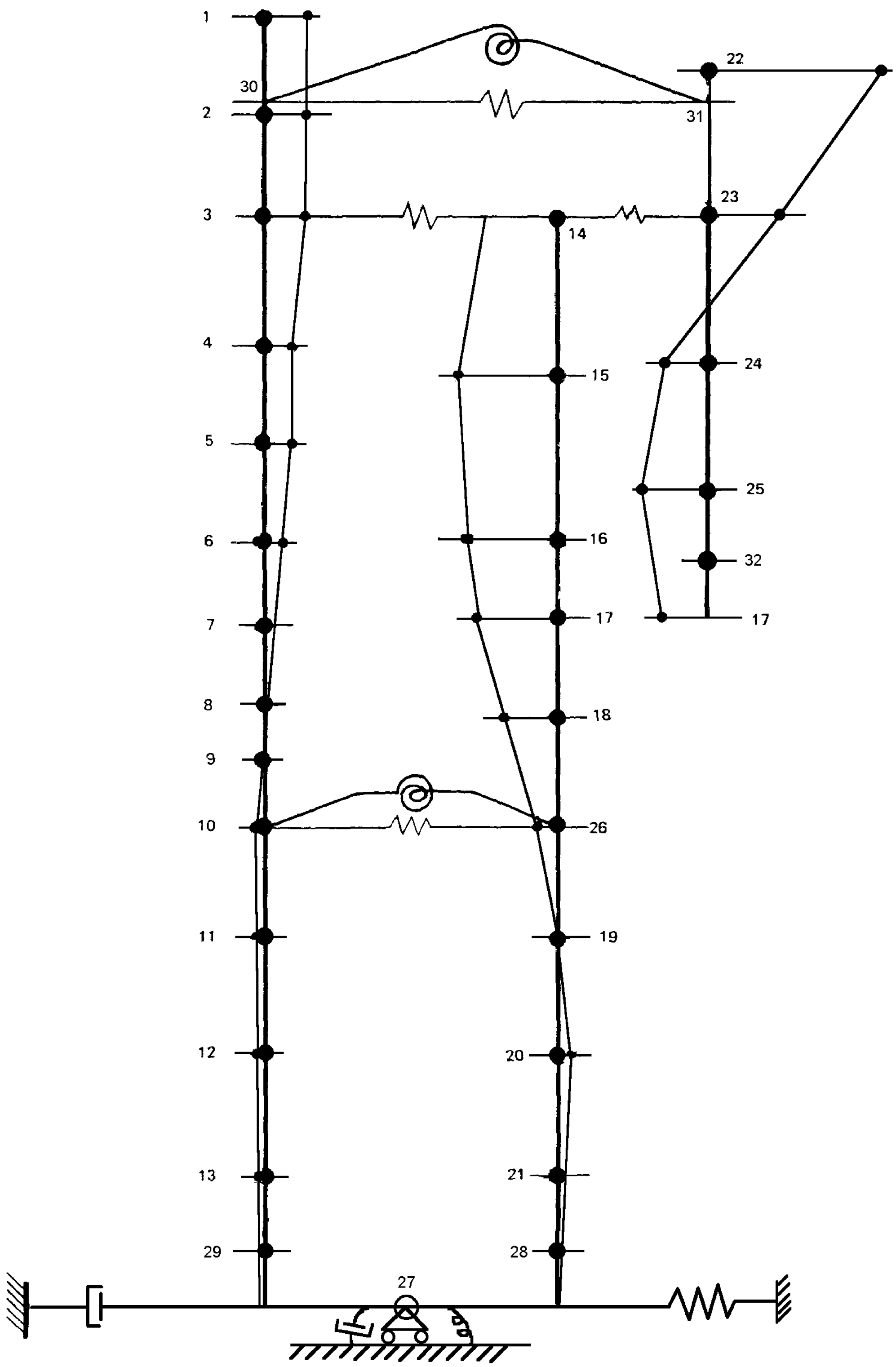
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL MODE SHAPES
MODE 2

FIGURE 3.7B-25, Rev. 55

Auto-Cad Figure Fsar 3_7B_25.dwg



FREQUENCY = 16.12 CPS

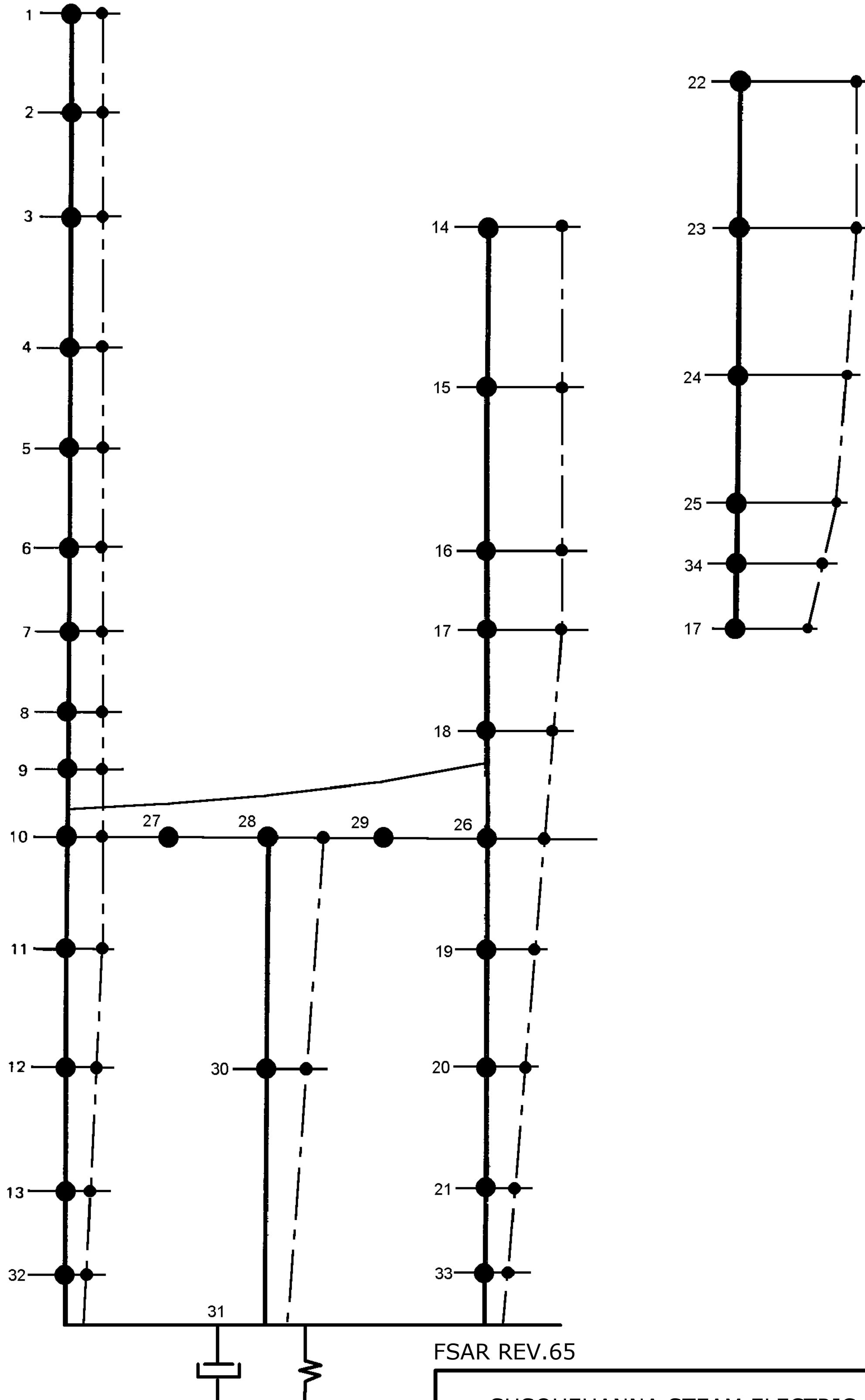
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL MODE SHAPES
MODE 4

FIGURE 3.7B-26, Rev. 55

Auto-Cad Figure Fsar 3_7B_26.dwg



FREQUENCY = 16.19 CPS

NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.

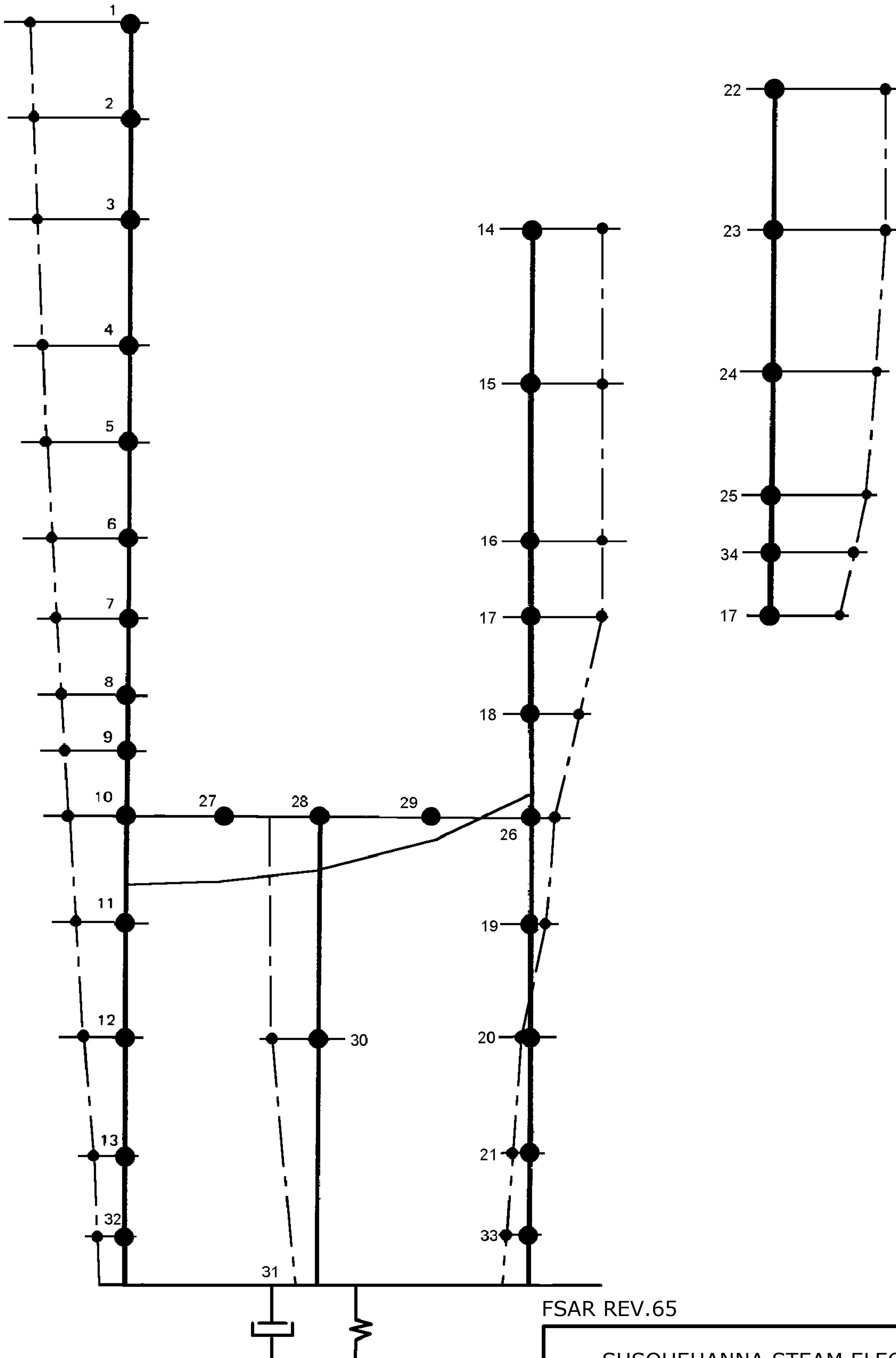
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
VERTICAL MODE SHAPES
MODE 1

FIGURE 3.7B-27, Rev. 55

Auto-Cad Figure Fsar 3_7B_27.dwg



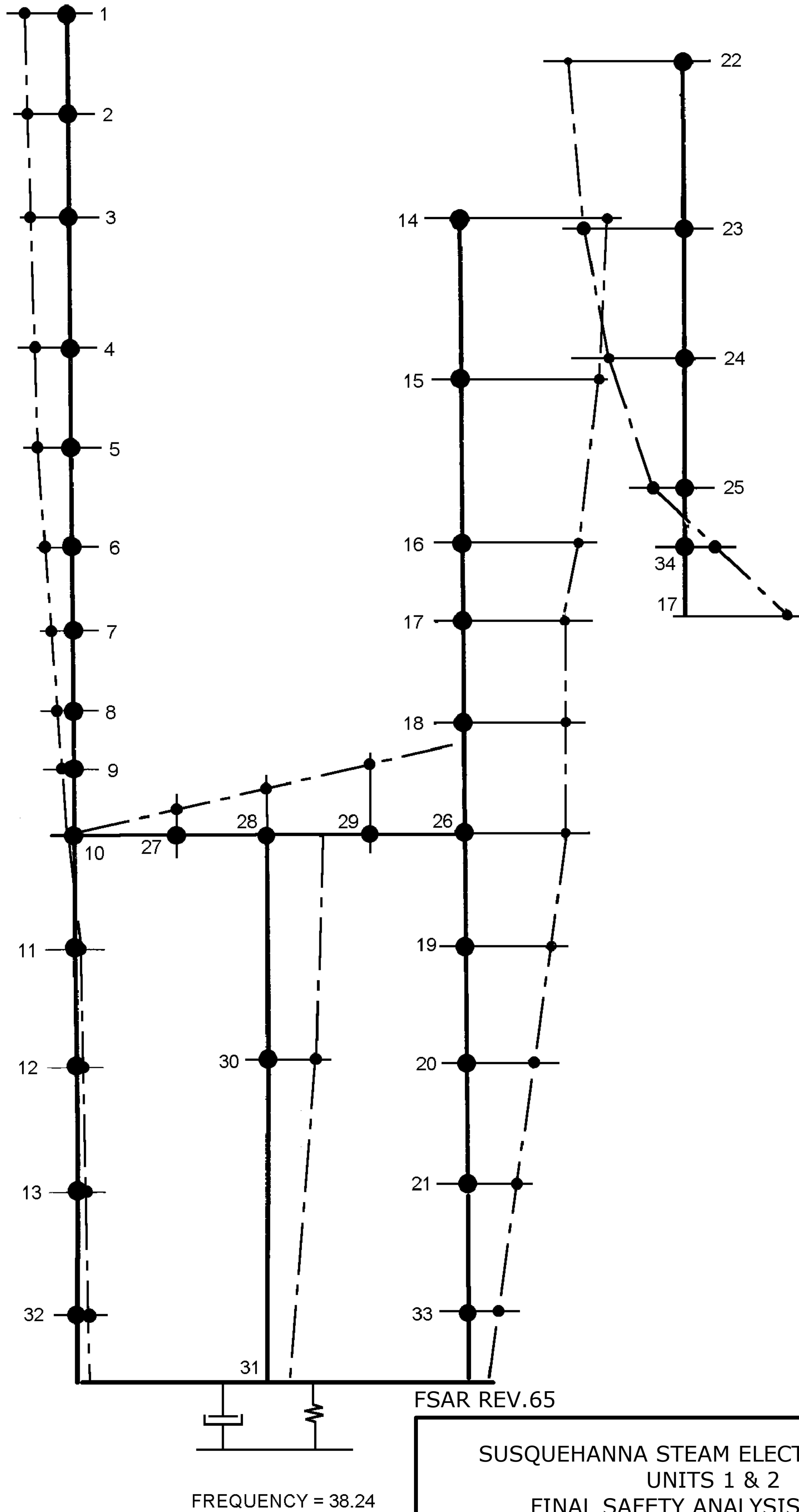
FREQUENCY = 20.95 CPS

NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.

FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CONTAINMENT VERTICAL MODE SHAPES MODE 2
FIGURE 3.7B-28, Rev. 55

Auto-Cad Figure Fsar 3_7B_28.dwg



FSAR REV.65

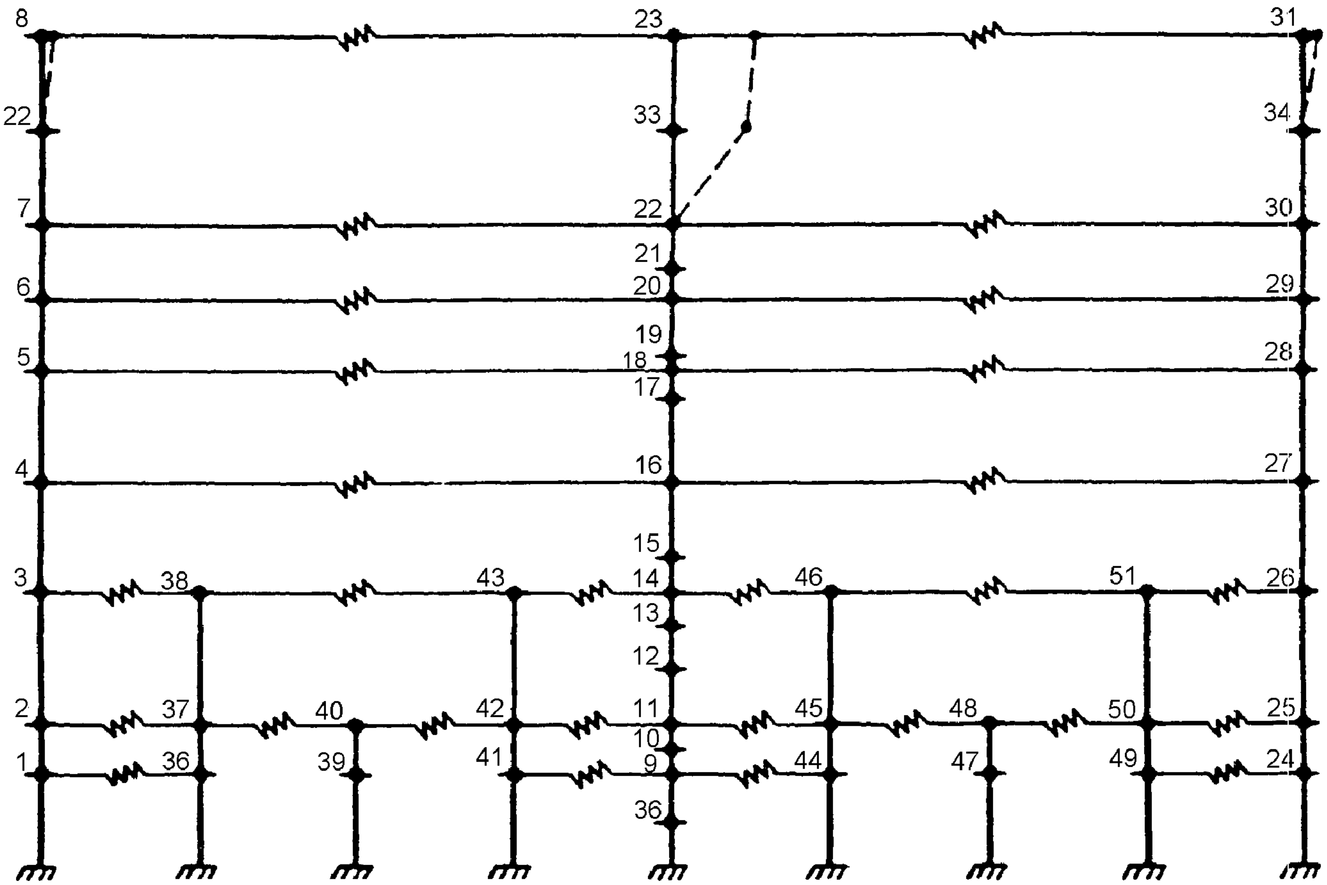
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
VERTICAL MODE SHAPES
MODE 3

FIGURE 3.7B-29, Rev. 55

Auto-Cad Figure Fsar 3_7B_29.dwg

NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

FREQUENCY = 2.23 CPS

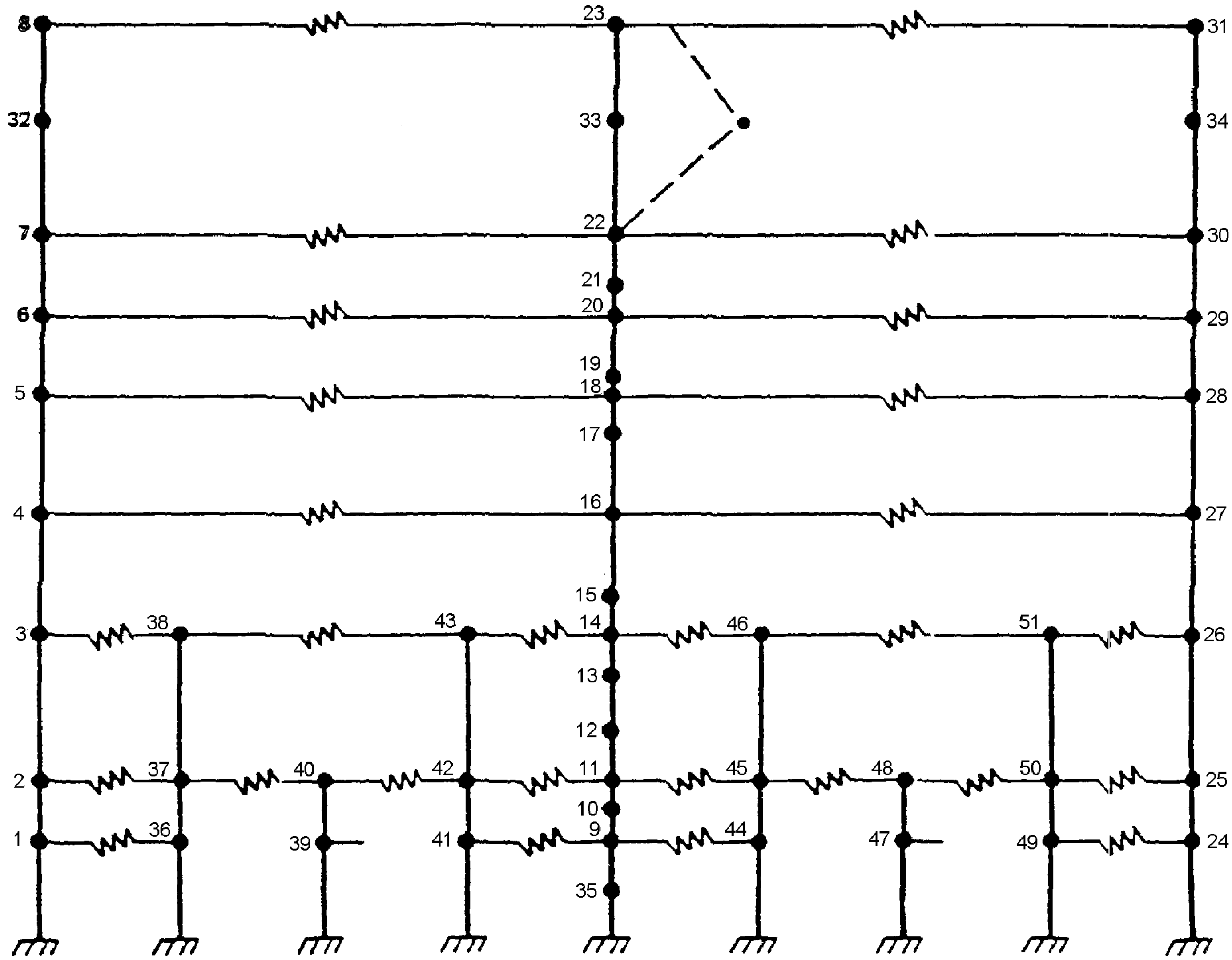
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W MODE SHAPES - MODE 1
(CRANES AT POINTS 32 AND 33)

FIGURE 3.7B-30, Rev. 55

Auto-Cad Figure Fsar 3_7B_30.dwg



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

FREQUENCY = 2.51 CPS

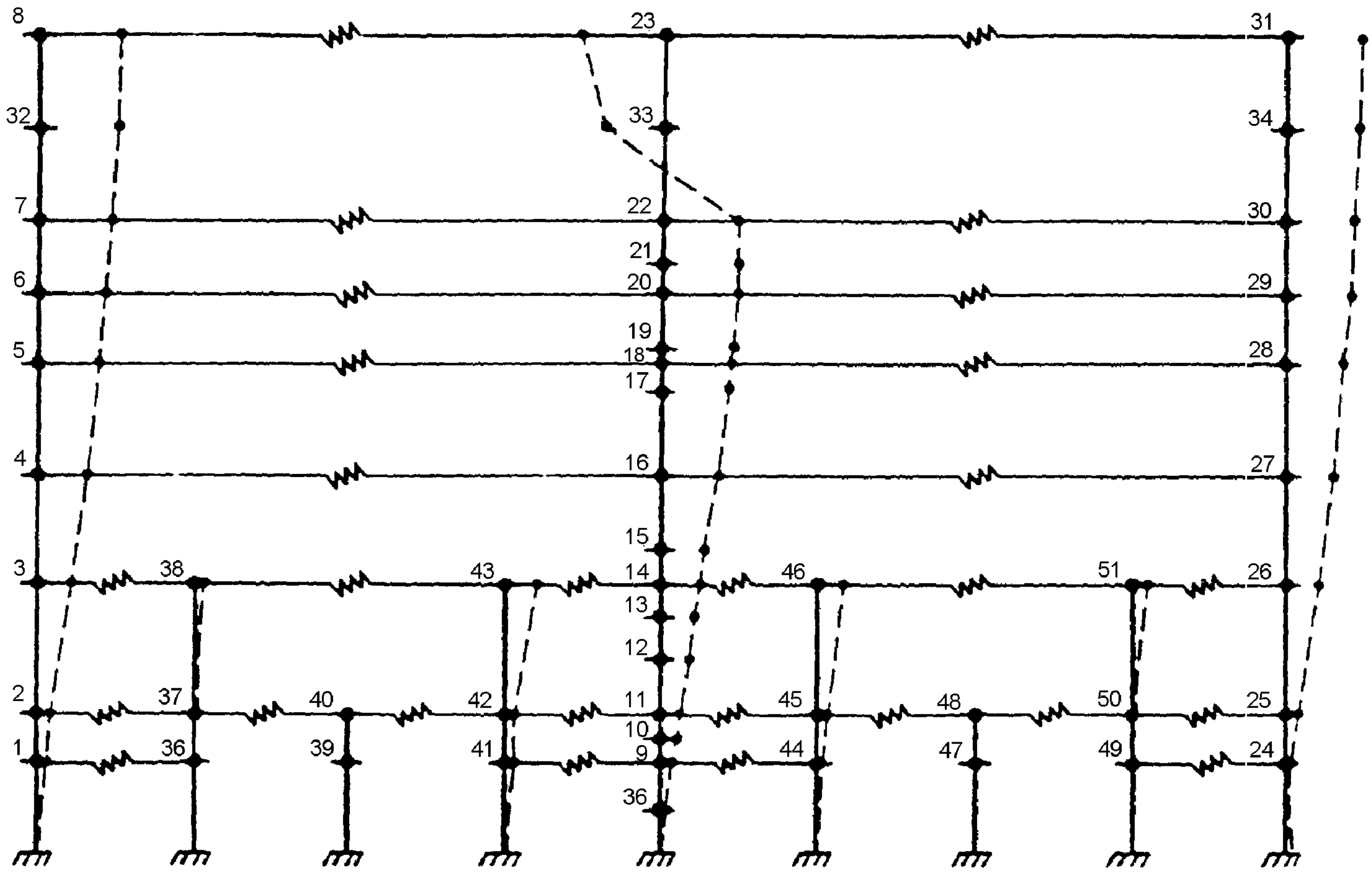
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W MODE SHAPES
MODE 2

FIGURE 3.7B-31, Rev. 55

Auto-Cad Figure Fsar 3_7B_31.dwg



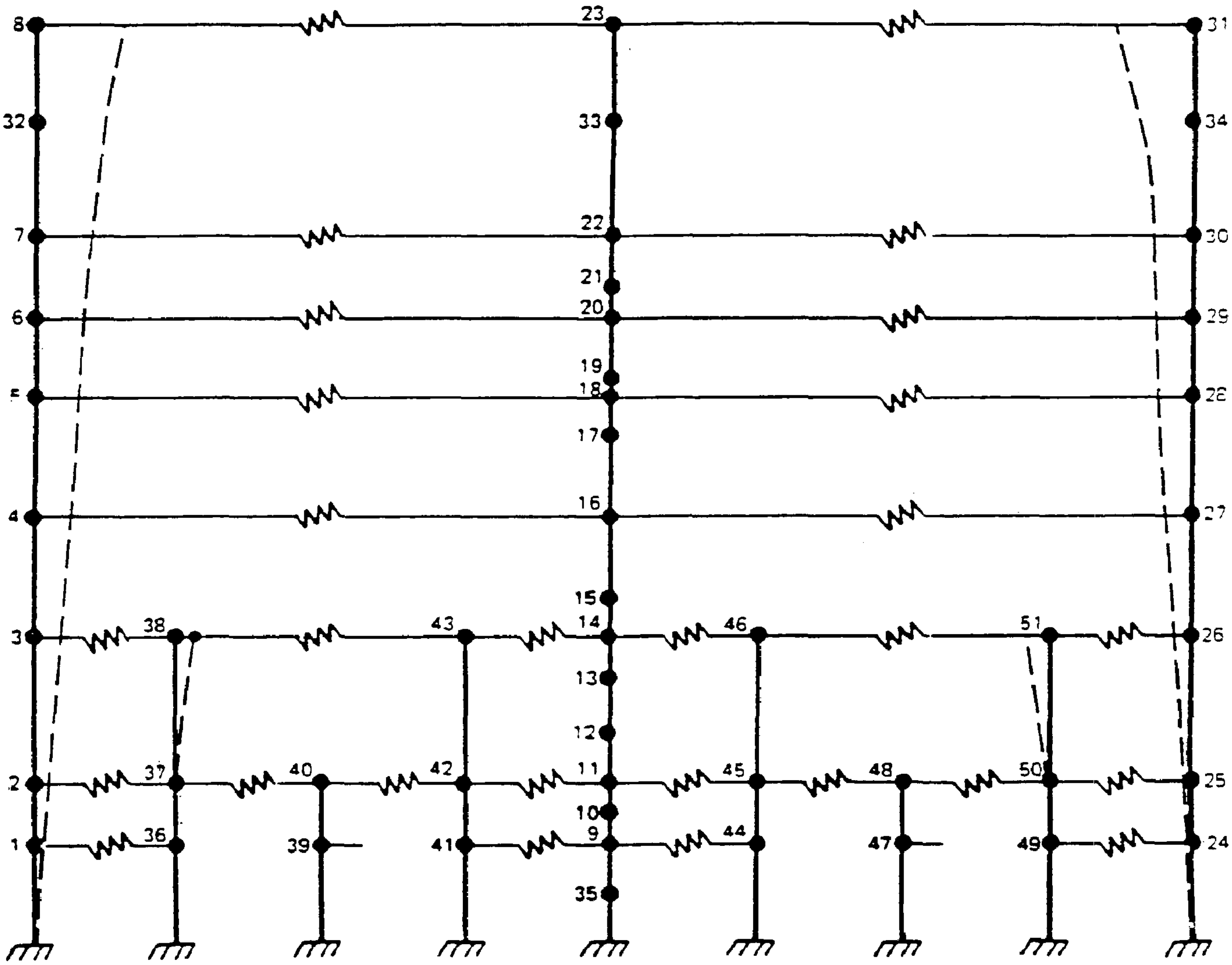
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W MODE SHAPES - MODE 3
(CRANES AT POINTS 32 AND 33)

FIGURE 3.7B-32, Rev. 55

Auto-Cad Figure Fsar 3_7B_32.dwg



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

FREQUENCY = 4.31 CPS

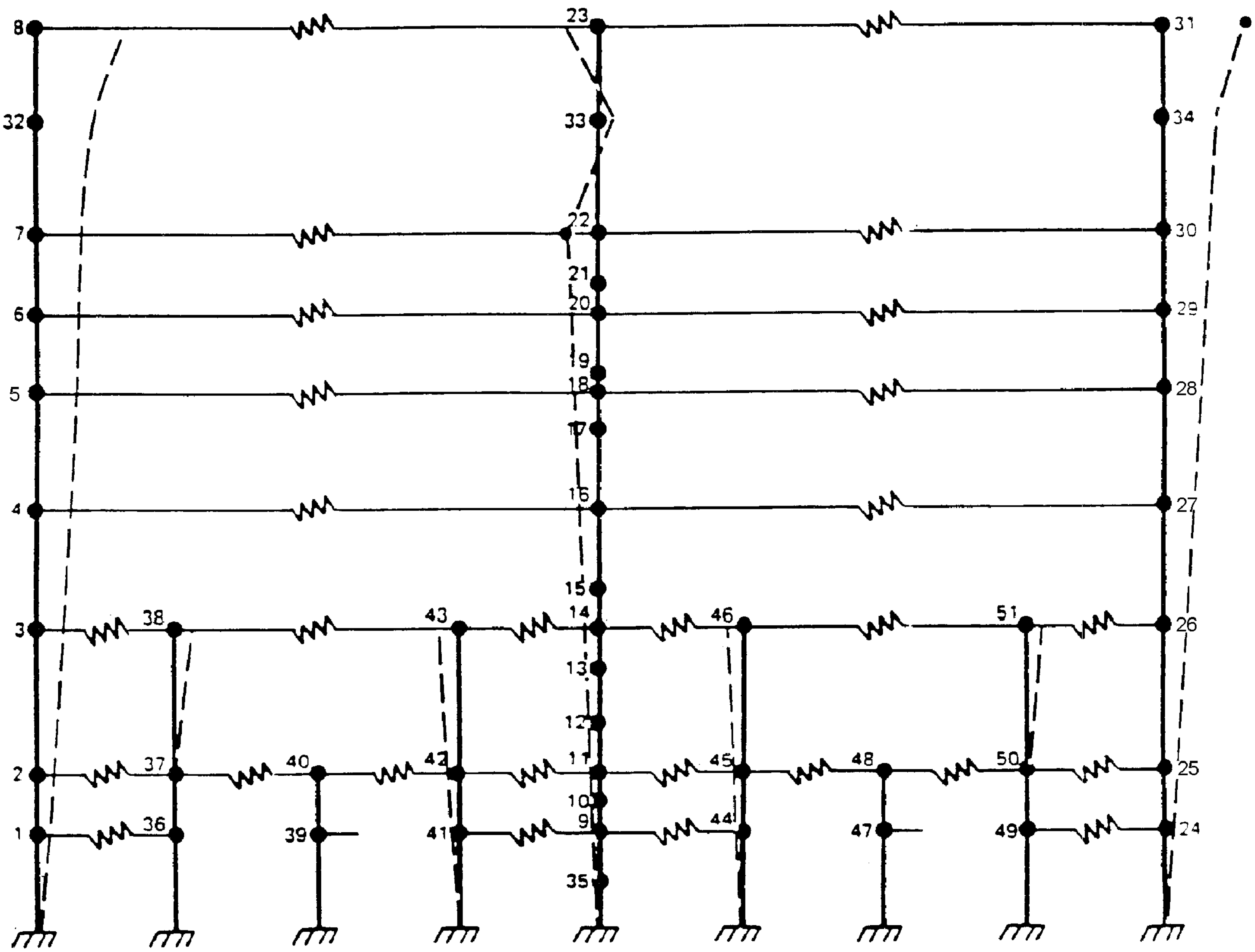
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W MODE SHAPES
MODE 4

FIGURE 3.7B-33, Rev. 55

Auto-Cad Figure Fsar 3_7B_33.dwg



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

FREQUENCY = 4.77 CPS

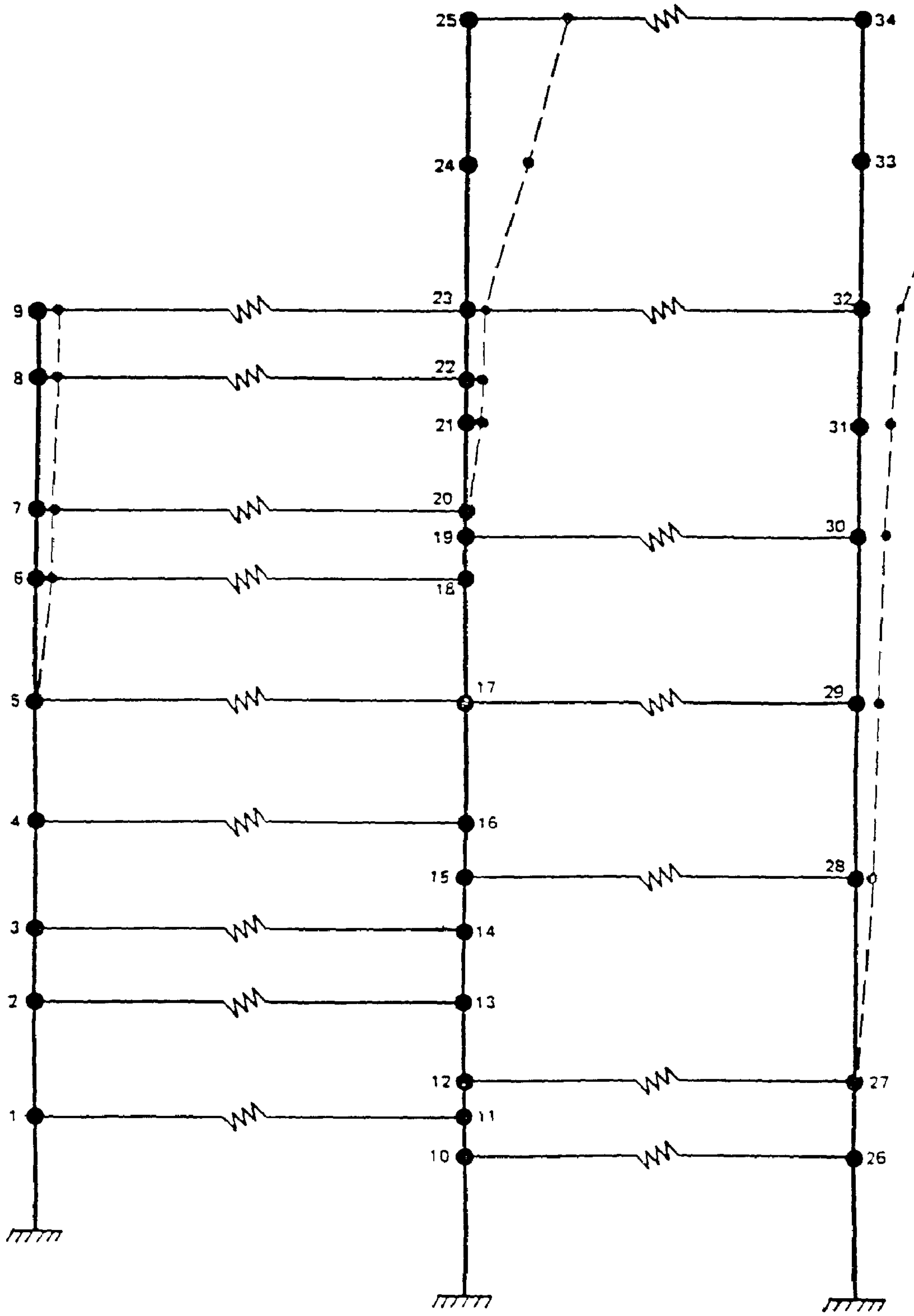
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W MODE SHAPES
MODE 5

FIGURE 3.7B-34, Rev. 55

Auto-Cad Figure Fsar 3_7B_34.dwg



FSAR REV.65

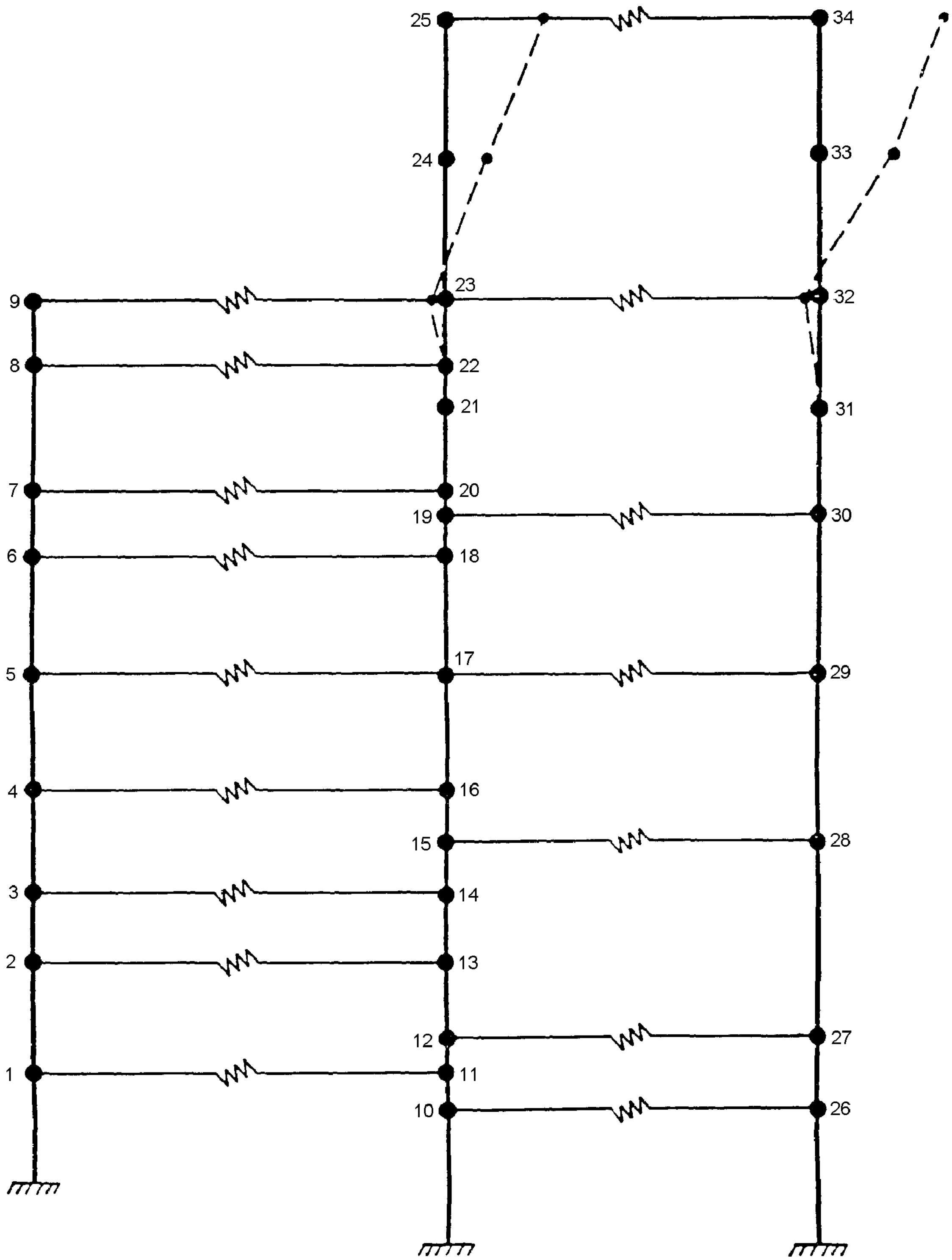
FREQUENCY = 3.92 CPS

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S MODE SHAPES
MODE 1

FIGURE 3.7B-35, Rev. 55

Auto-Cad Figure Fsar 3_7B_35.dwg



FREQUENCY = 4.53 CPS

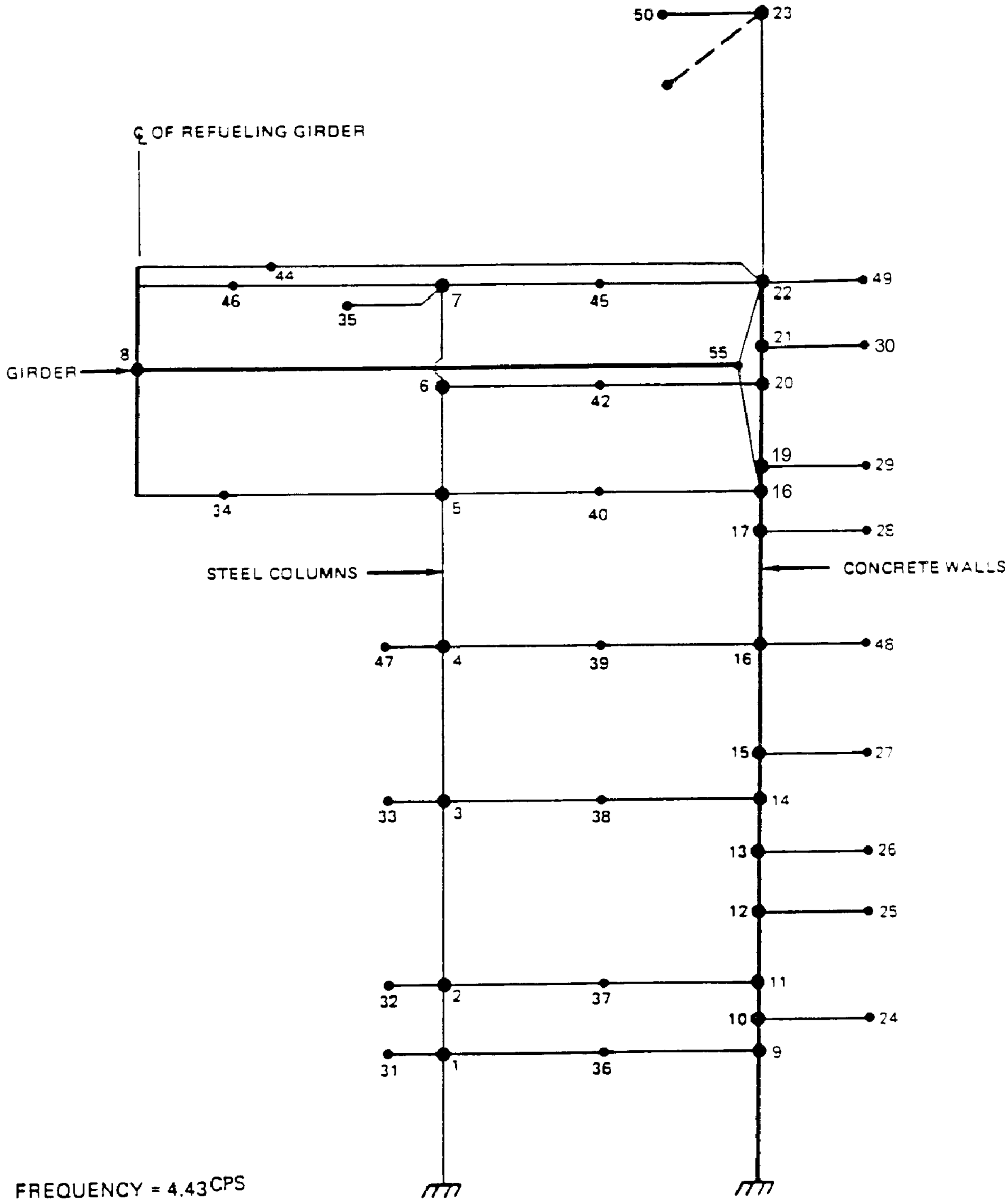
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S MODE SHAPES
MODE 3

FIGURE 3.7B-36, Rev. 55

Auto-Cad Figure Fsar 3_7B_36.dwg



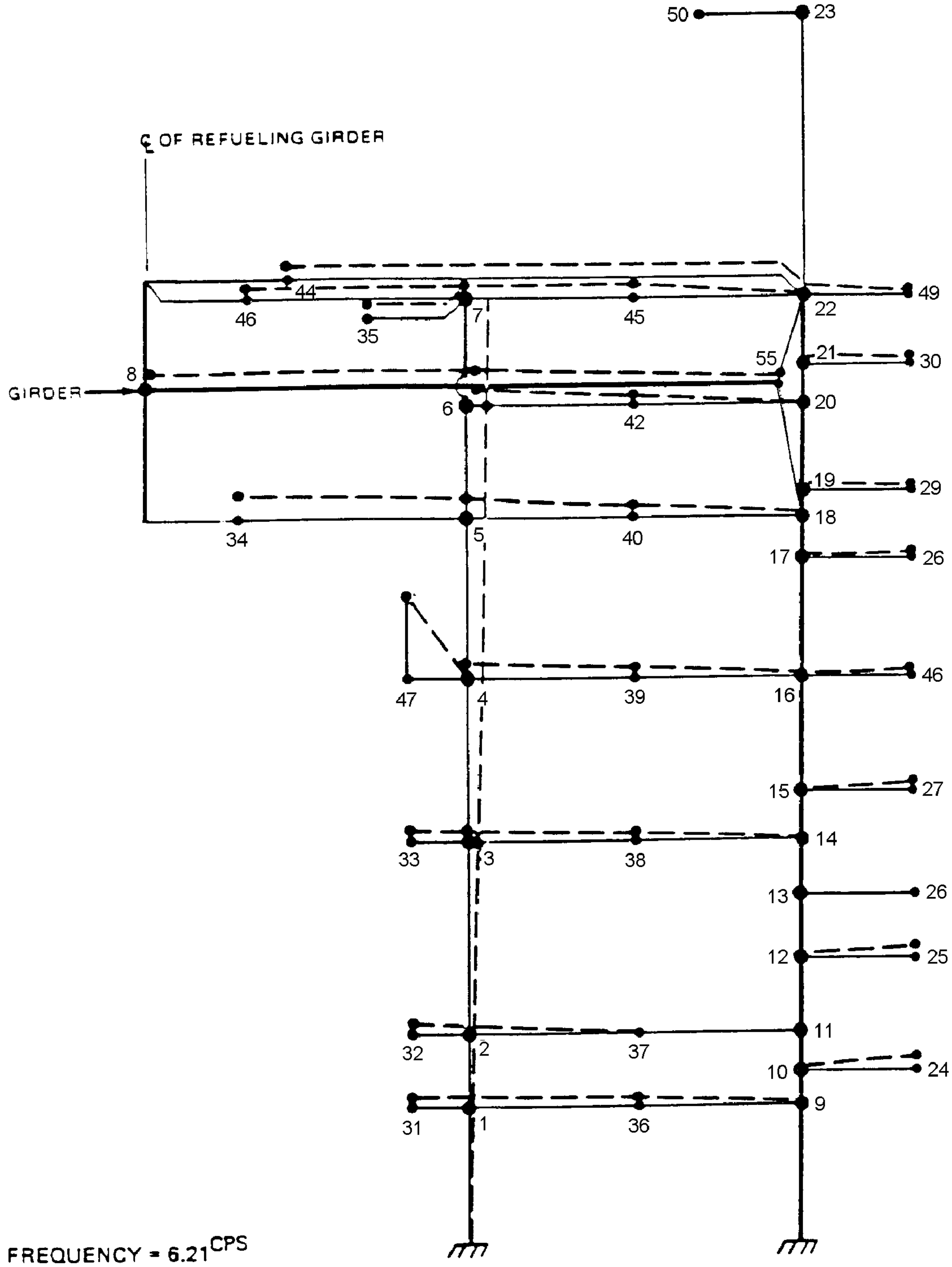
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL MODE SHAPES
MODE 1

FIGURE 3.7B-37, Rev. 55

Auto-Cad Figure Fsar 3_7B_37.dwg

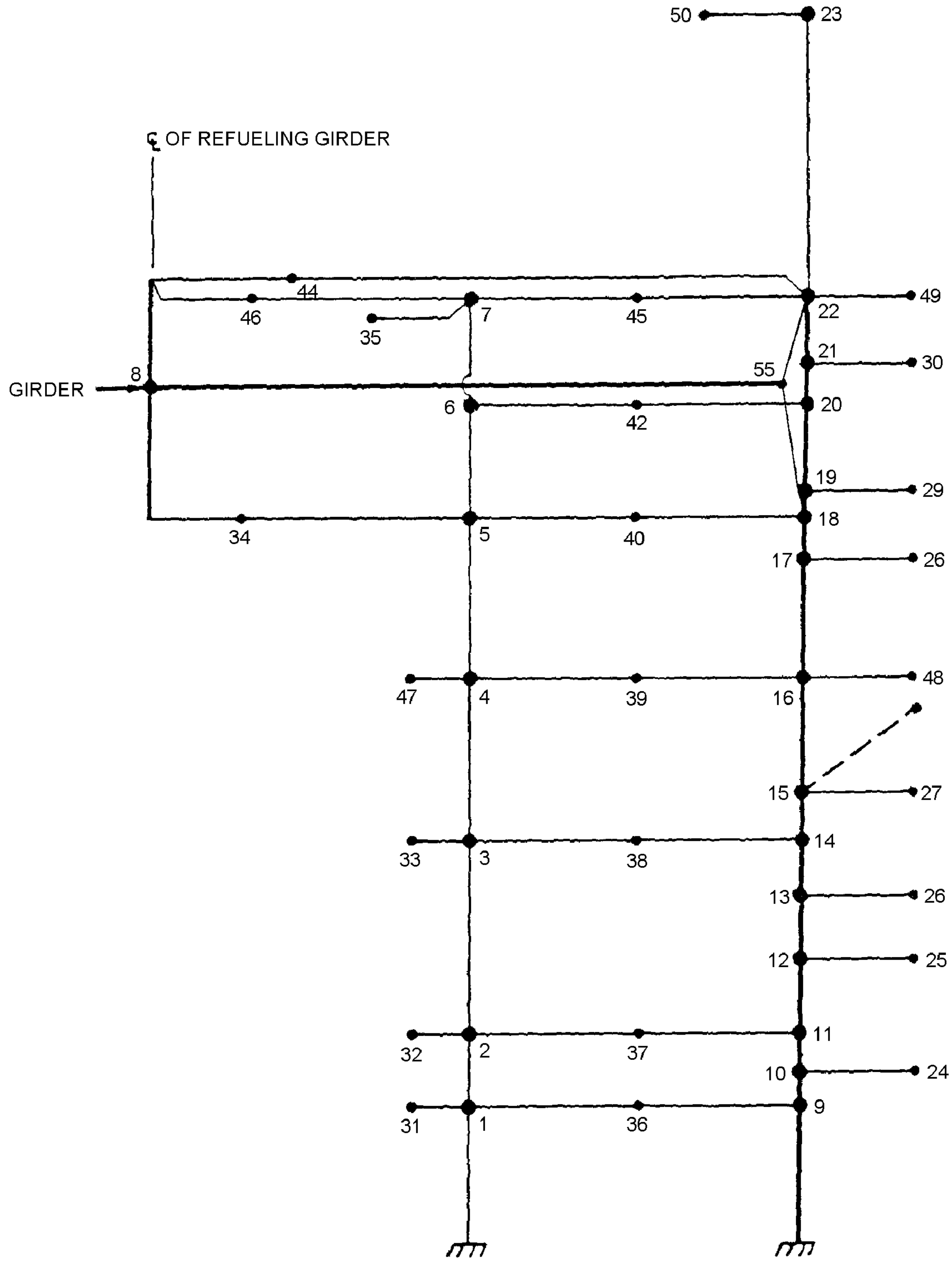


FSAR REV.65

NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
REACTOR AND CONTROL BUILDING VERTICAL MODE SHAPES MODE 2 FIGURE 3.7B-38, Rev. 55

Auto-Cad Figure Fsar 3_7B_38.dwg



FREQUENCY = 6.80 CPS

NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.

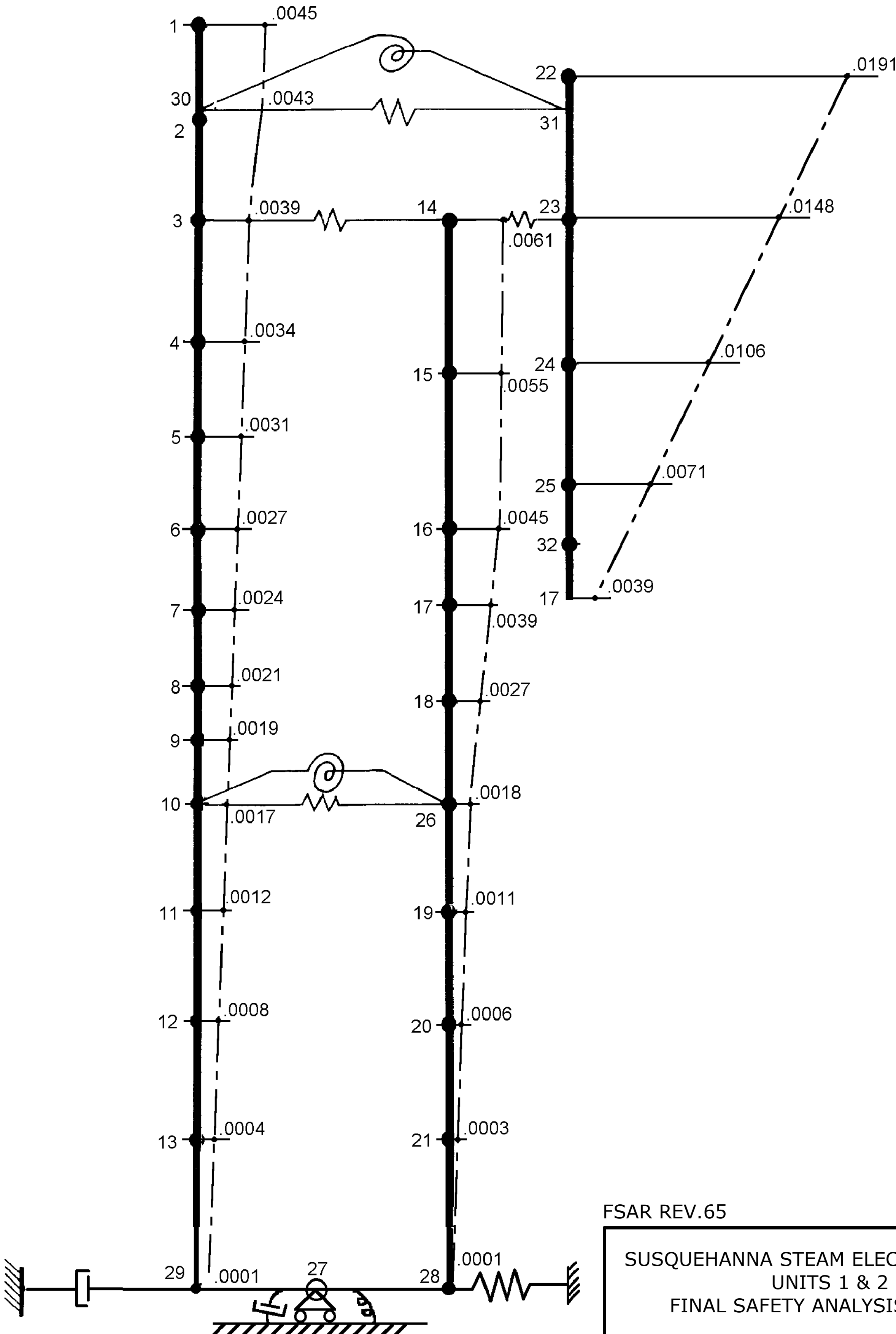
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL MODE SHAPES
MODE 3

FIGURE 3.7B-39, Rev. 55

Auto-Cad Figure Fsar 3_7B_39.dwg



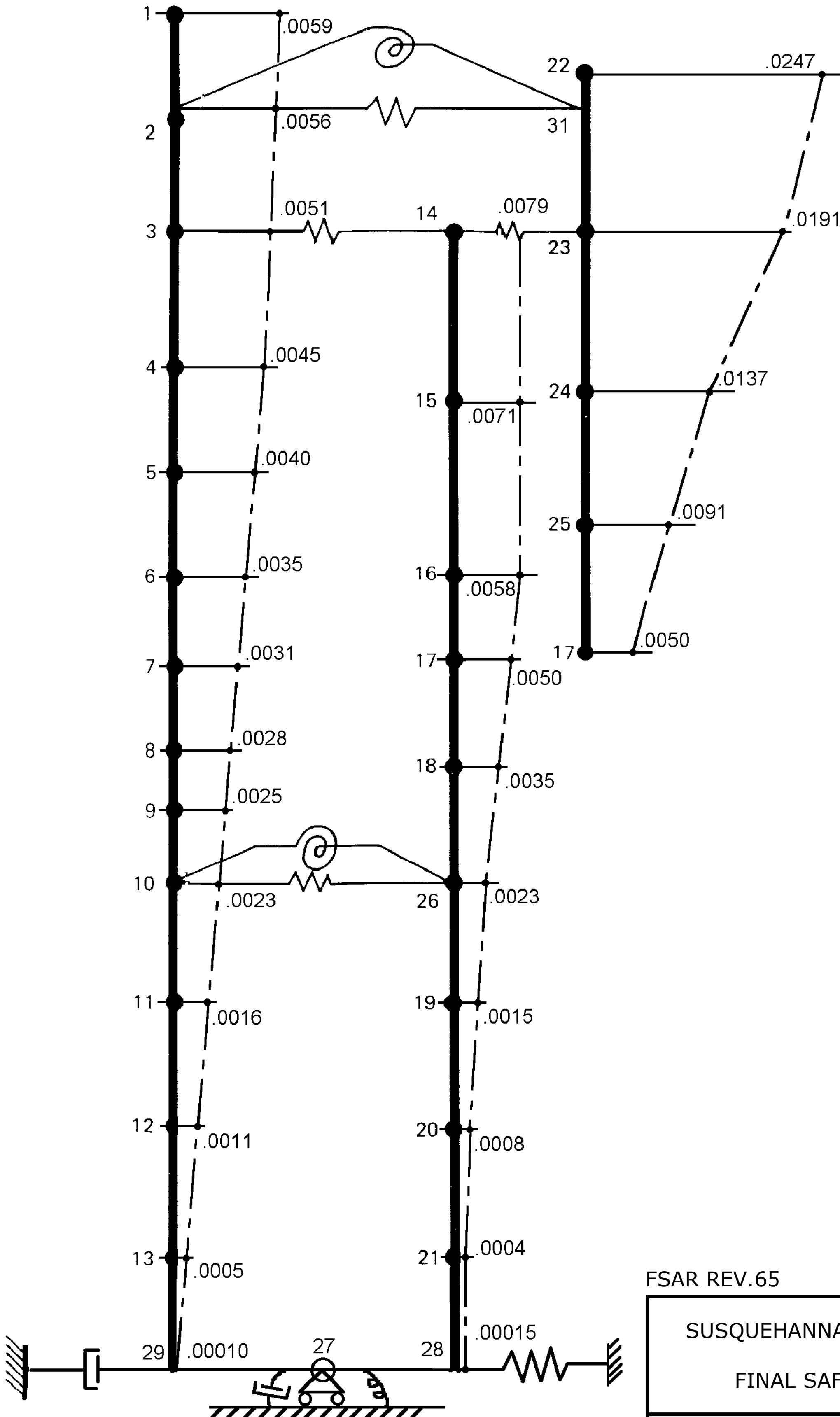
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL REPLACEMENTS
OBE

FIGURE 3.7B-40, Rev. 55

Auto-Cad Figure Fsar 3_7B_40.dwg



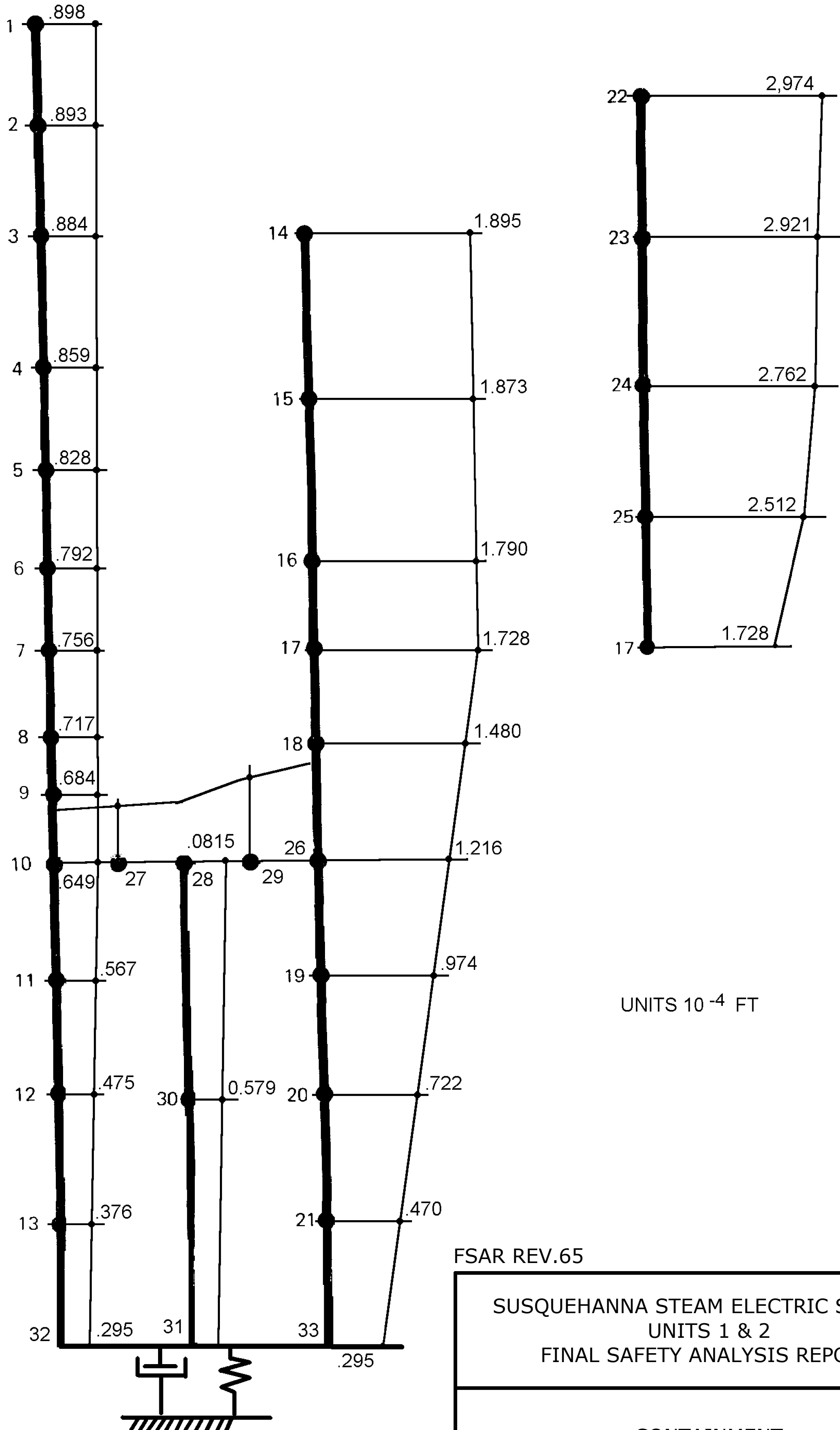
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL DISPALCEMENTS
SSE

FIGURE 3.7B-41, Rev. 55

Auto-Cad Figure Fsar 3_7B_41.dwg



NOTE:
FOR CLARITY OF ILLUSTRATION, THE DISPLACEMENT VALUES ASSOCIATED WITH THE NODES ORIENTATED ALONG THE VERTICAL MEMBERS ARE DISPLAYED GRAPHICALLY IN THE HORIZONTAL DIRECTION. THE DISPLACEMENTS ARE IN THE VERTICAL DIRECTION.

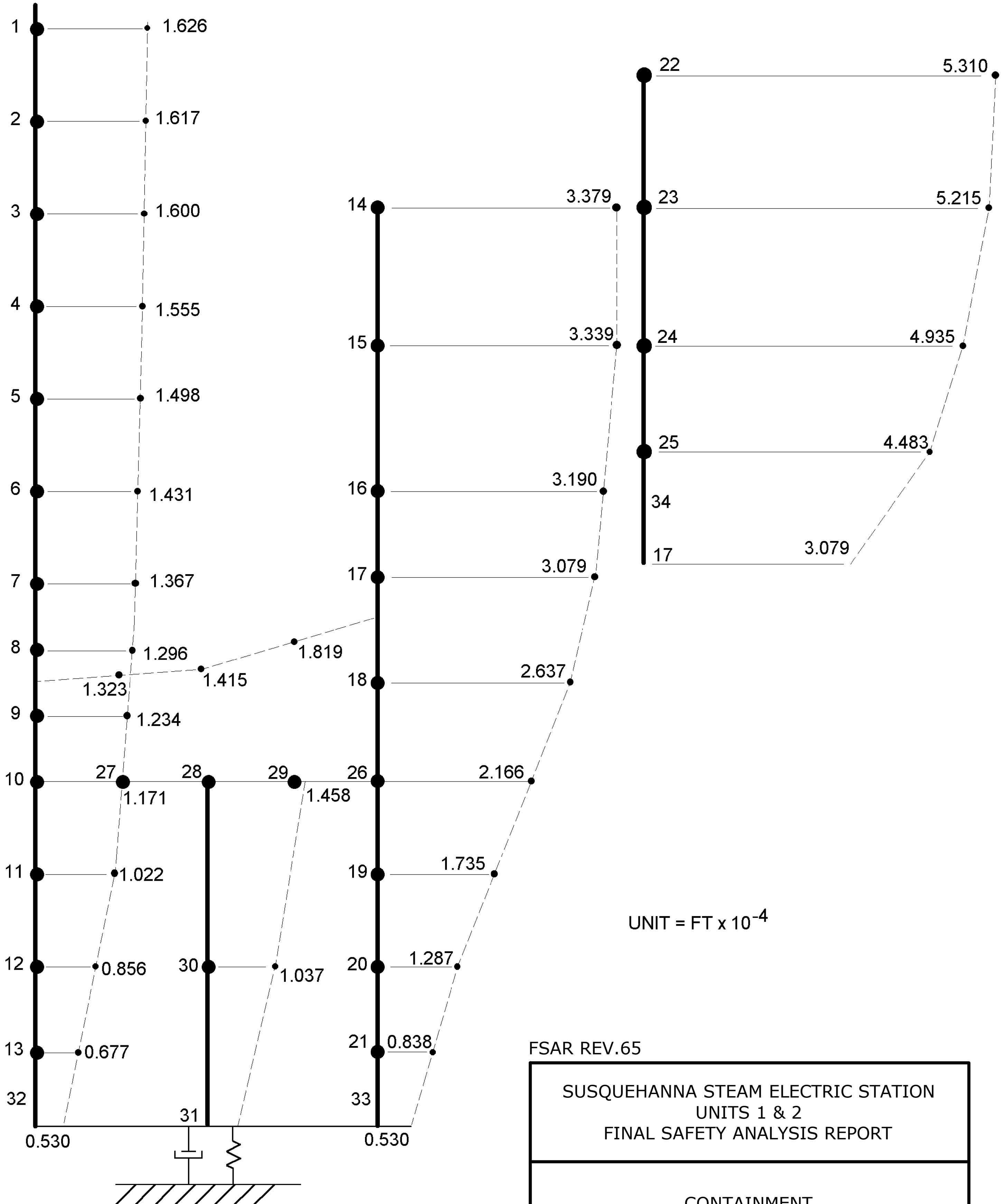
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
VERTICAL DISPALCEMENTS
OBE

FIGURE 3.7B-42, Rev. 55

Auto-Cad Figure Fsar 3_7B_42.dwg



NOTE: For clarity of illustration, the displacement values associated with the nodes orientated along the vertical members are displayed graphically in the horizontal direction. The displacements are in the vertical direction.

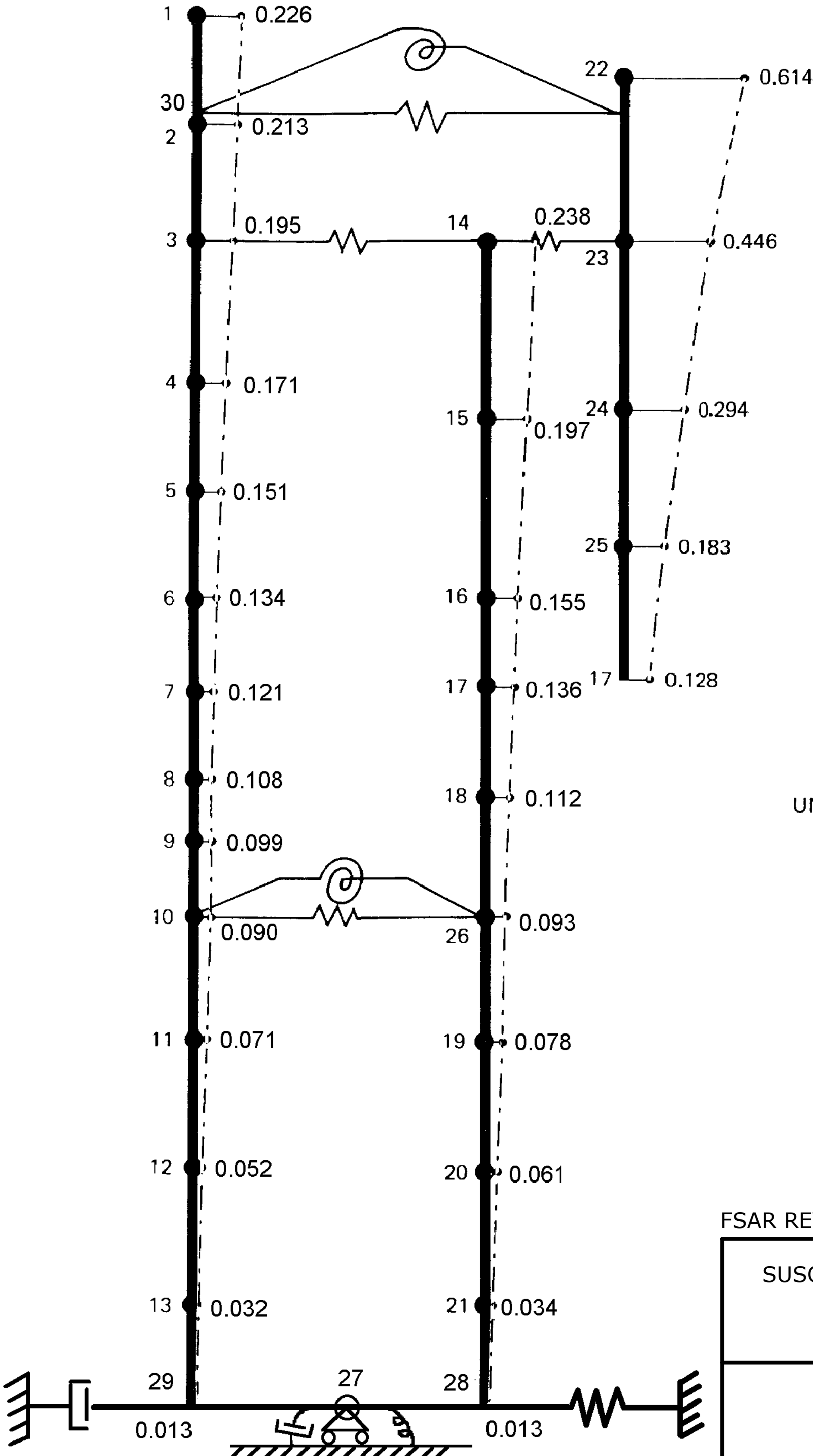
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
VERTICAL DISPALCEMENTS
SSE

FIGURE 3.7B-43, Rev. 55

Auto-Cad Figure Fsar 3_7B_43.dwg



UNITS: G's

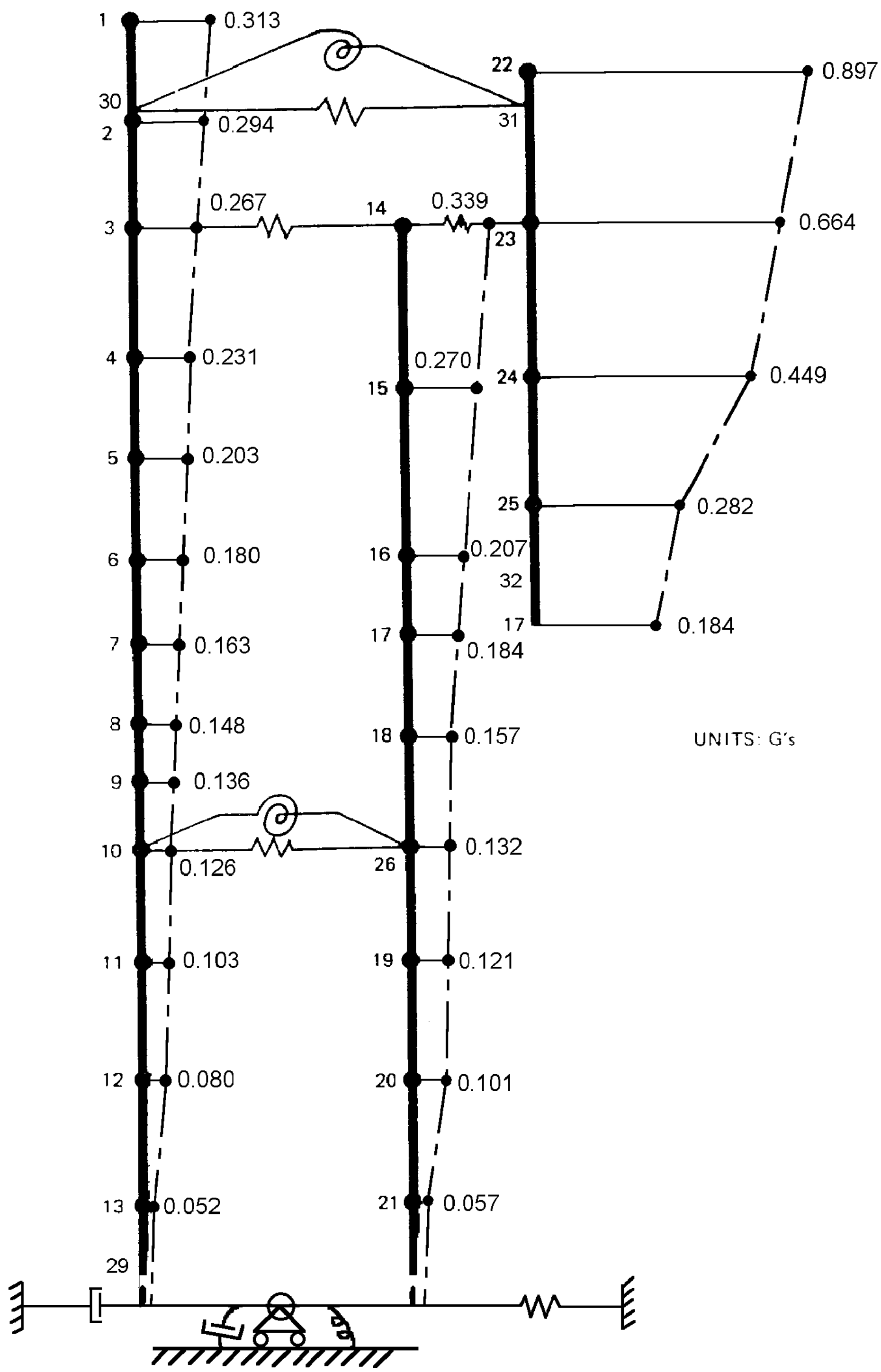
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL ACCELERATIONS
OBE

FIGURE 3.7B-44, Rev. 55

Auto-Cad Figure Fsar 3_7B_44.dwg



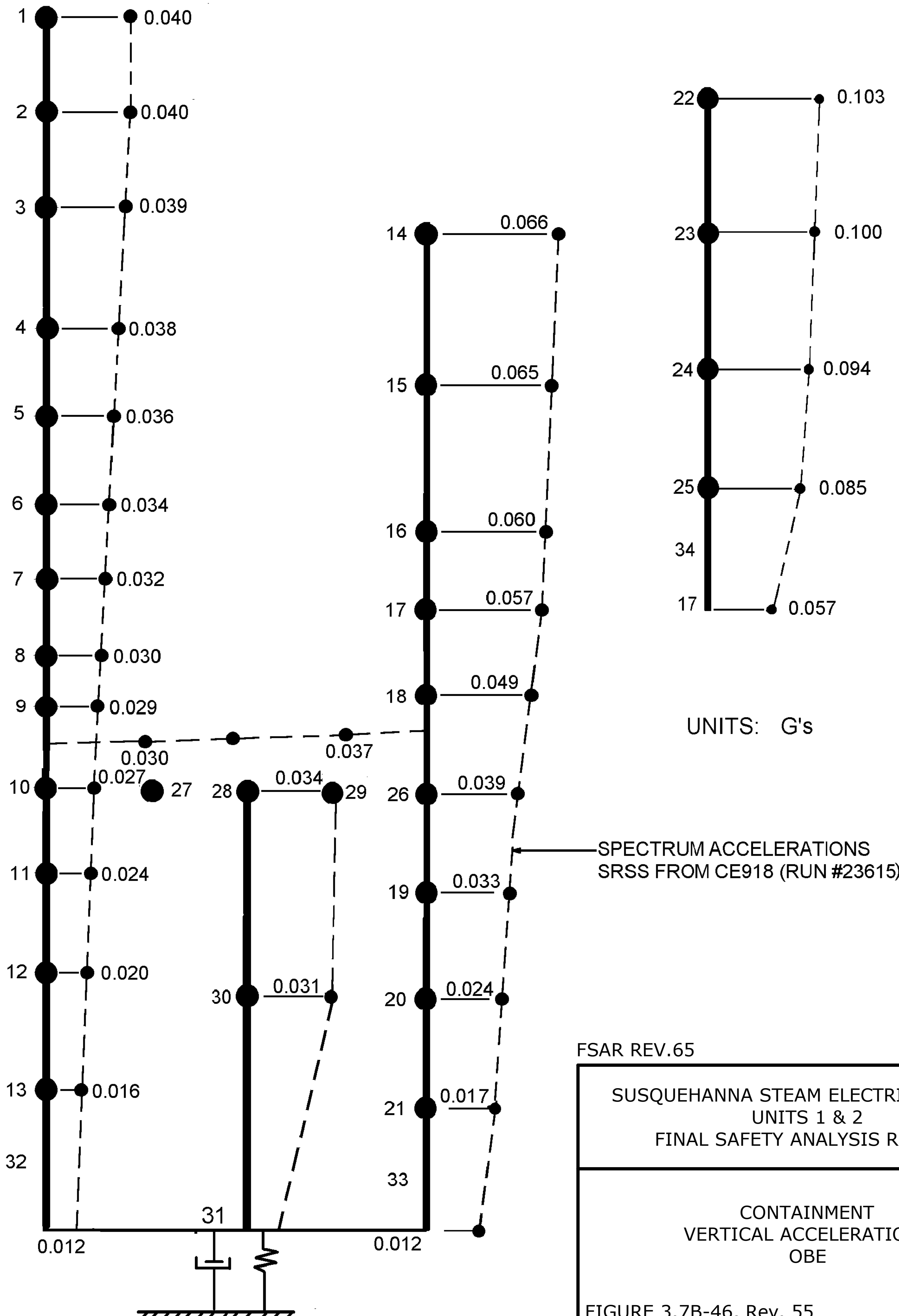
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
HORIZONTAL ACCELERATIONS
SSE

FIGURE 3.7B-45, Rev. 55

Auto-Cad Figure Fsar 3_7B_45.dwg



FSAR REV.65

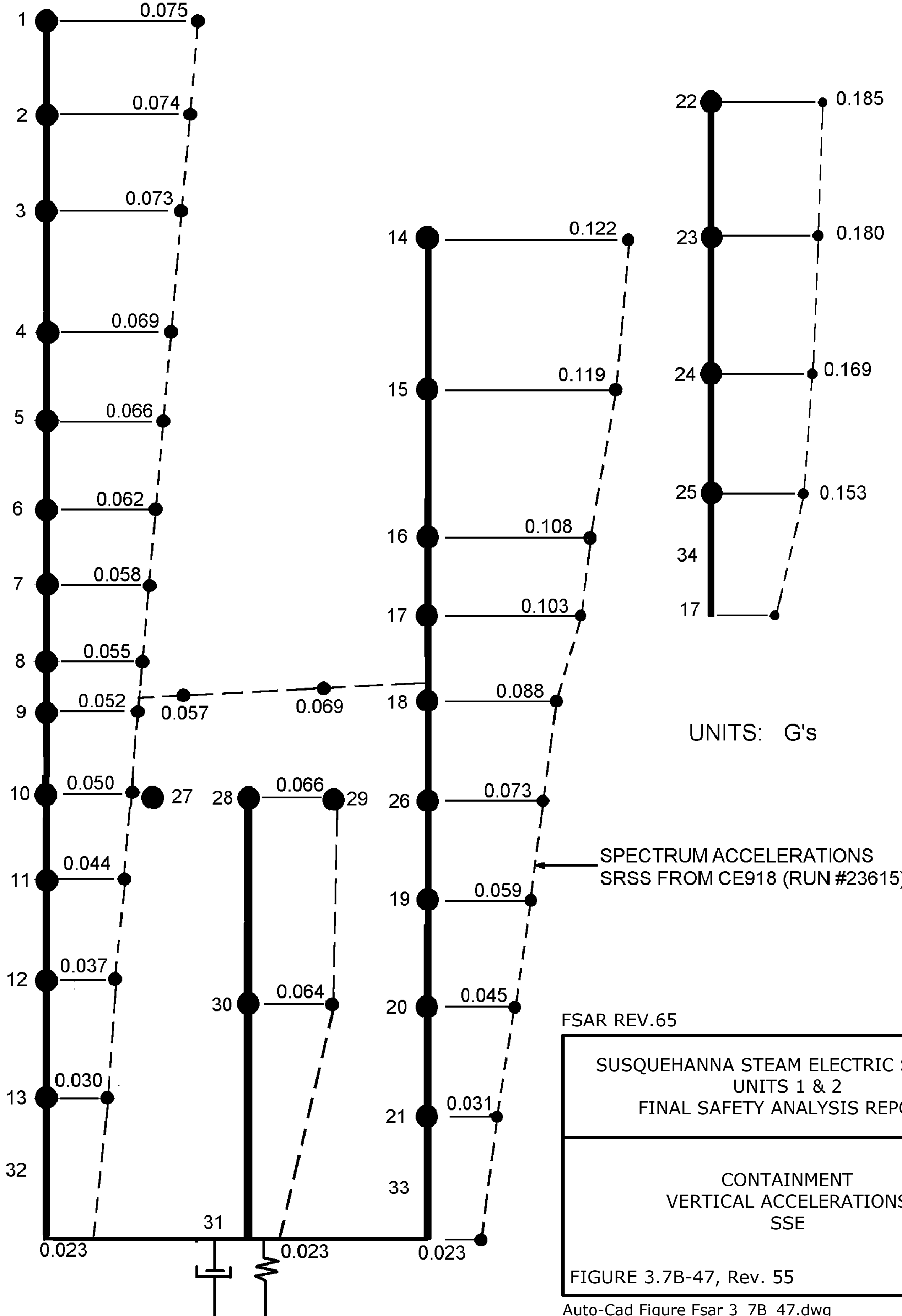
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CONTAINMENT
VERTICAL ACCELERATIONS
OBE

FIGURE 3.7B-46, Rev. 55

Auto-Cad Figure Fsar 3_7B_46.dwg

Note;
For clarity of illustration, the acceleration values associated with the nodes oriented along the vertical members are displayed graphically in the horizontal direction. The accelerations are in the vertical direction.

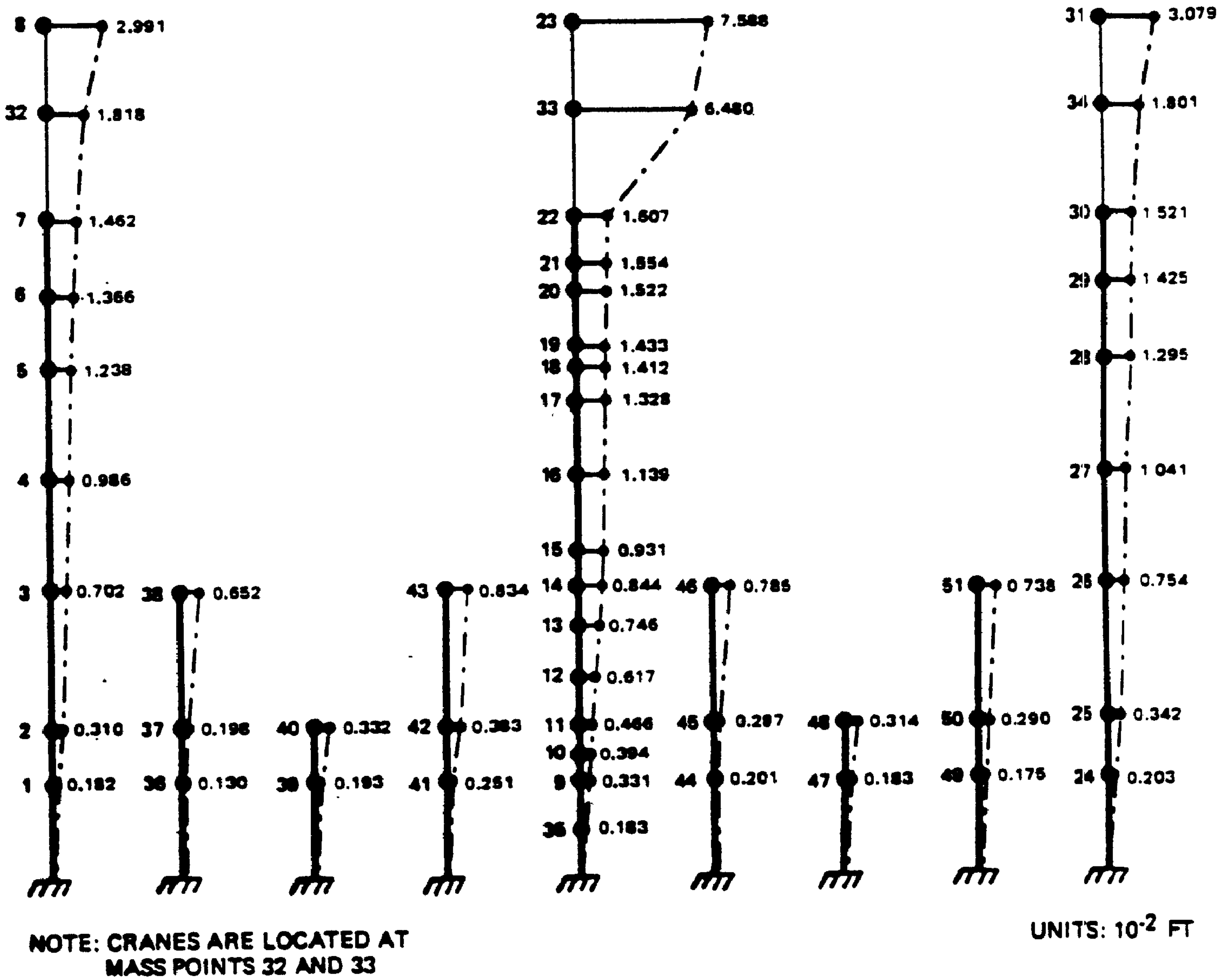


FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CONTAINMENT VERTICAL ACCELERATIONS SSE FIGURE 3.7B-47, Rev. 55

Auto-Cad Figure Fsar 3_7B_47.dwg

Note;
For clarity of illustration, the acceleration values associated with the nodes oriented along the vertical members are displayed graphically in the horizontal direction. The accelerations are in the vertical direction.



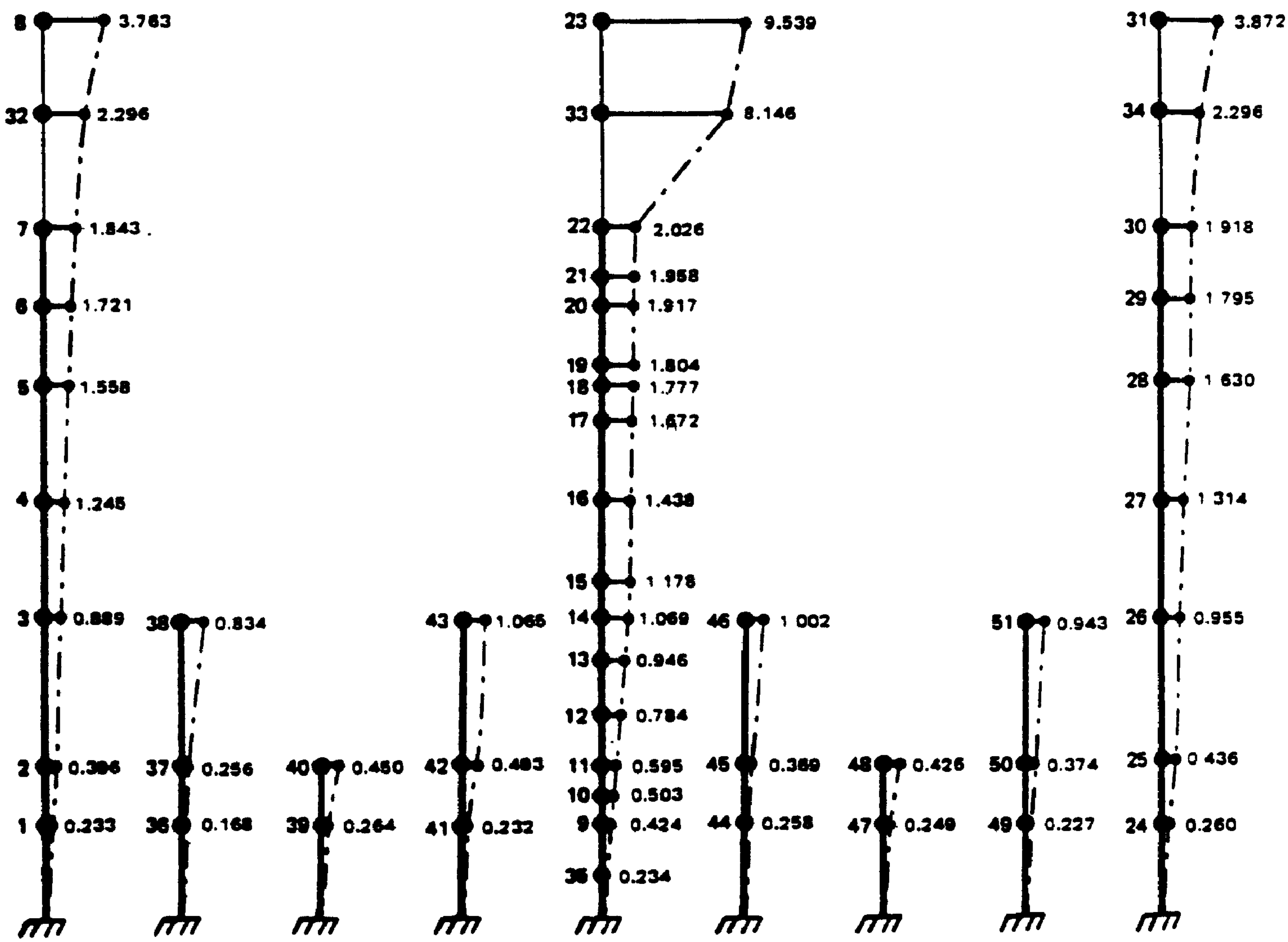
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W DISPLACEMENTS
OBE

FIGURE 3.7B-48, Rev. 55

Auto-Cad Figure Fsar 3_7B_48.dwg



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

UNITS: 10^{-2} FT

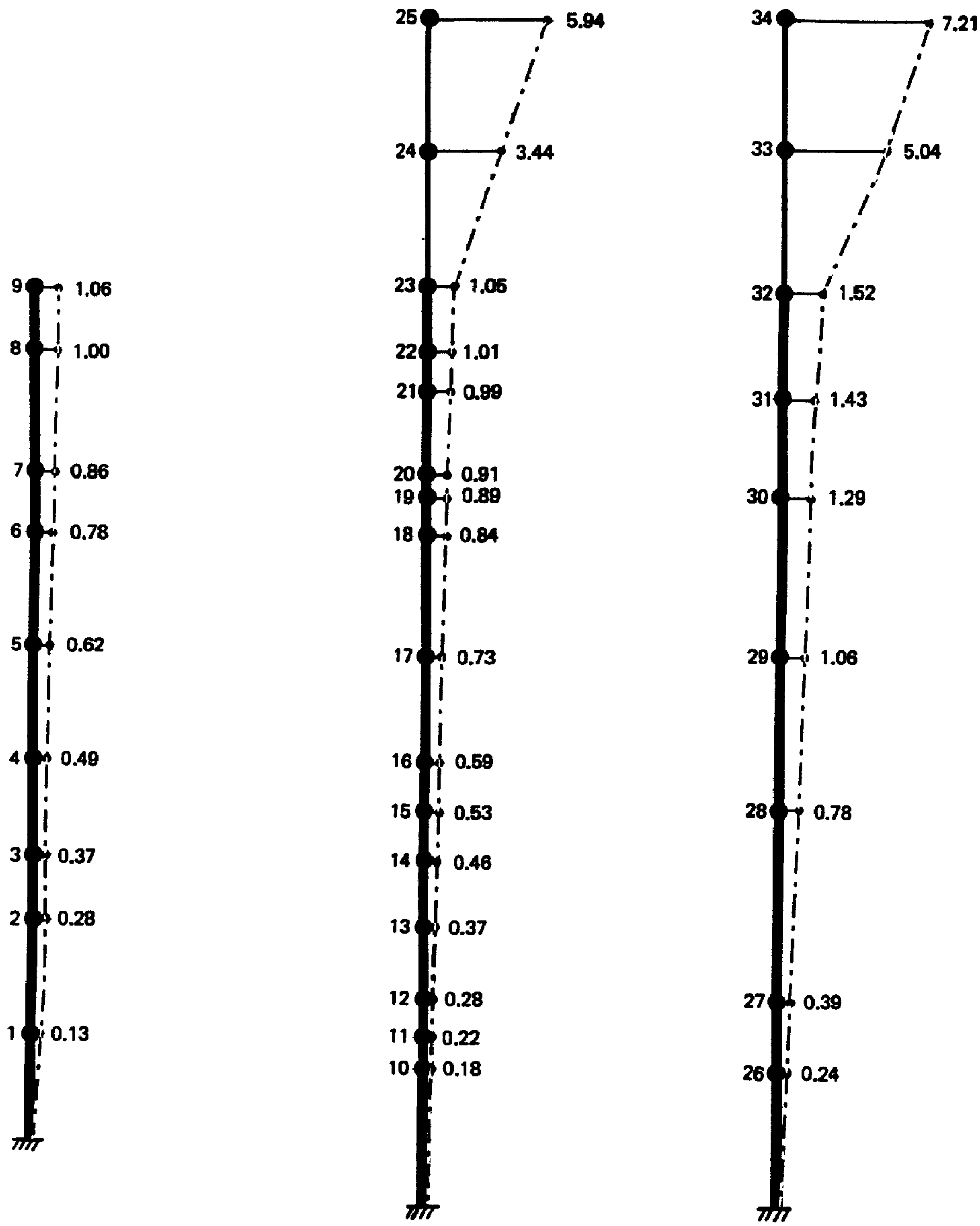
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W DISPLACEMENTS
SSE

FIGURE 3.7B-49, Rev. 55

Auto-Cad Figure Fsar 3_7B_49.dwg



UNITS: 10^{-2} FT

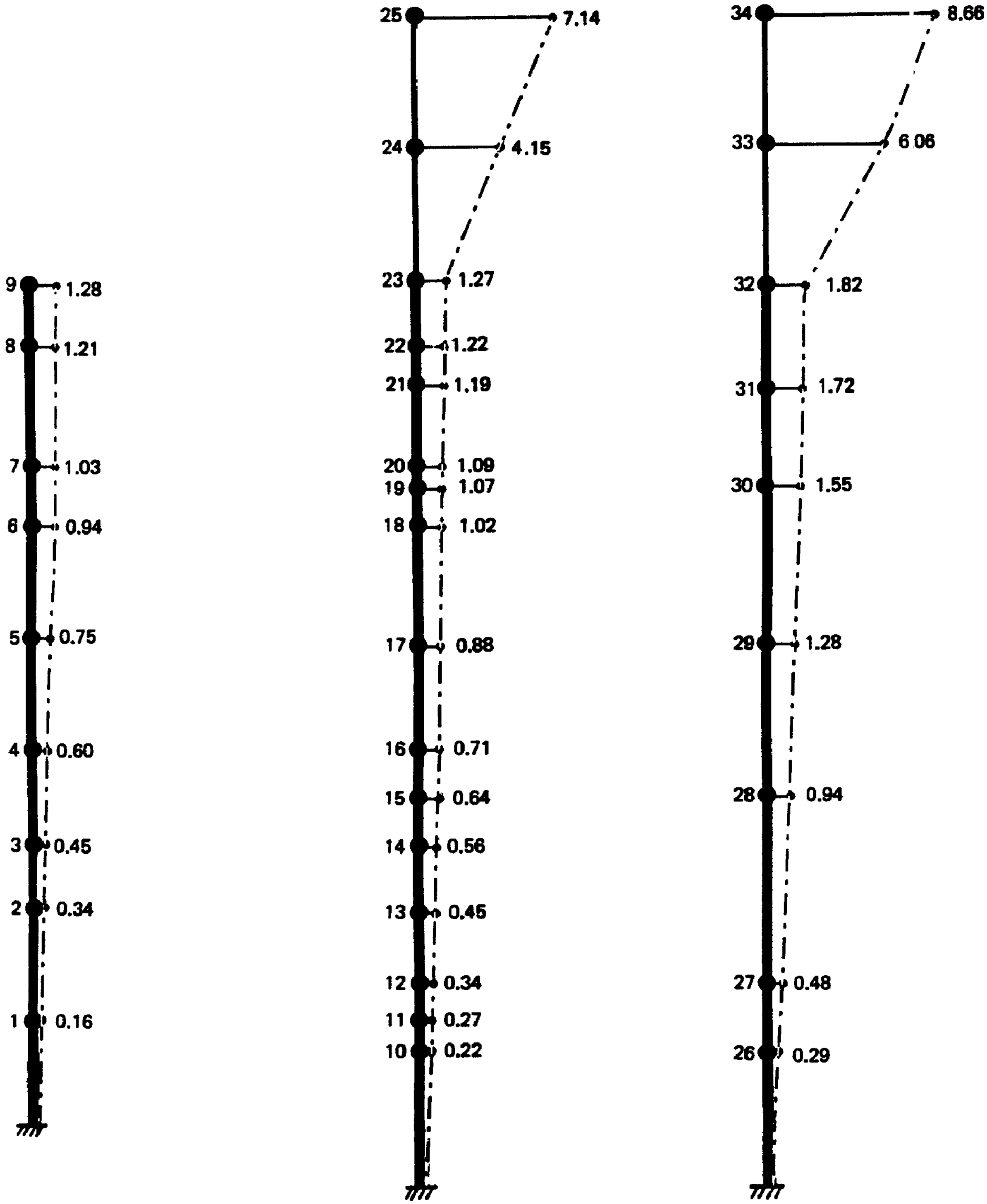
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S DISPLACEMENTS
OBE

FIGURE 3.7B-50, Rev. 55

Auto-Cad Figure Fsar 3_7B_50.dwg



FSAR REV.65

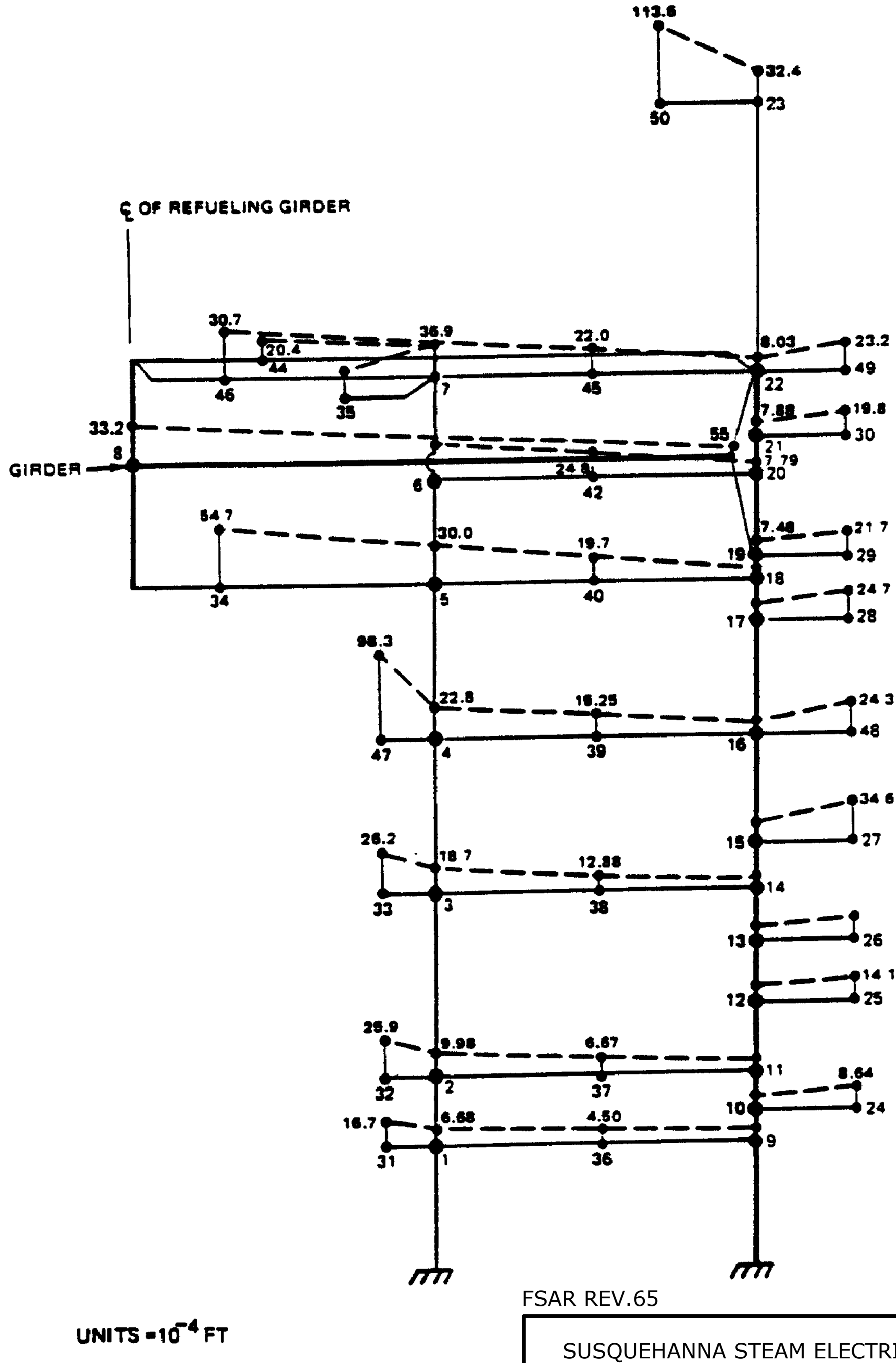
UNITS: 10^{-2} FT

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S DISPLACEMENTS
SSE

FIGURE 3.7B-51, Rev. 55

Auto-Cad Figure Fsar 3_7B_51.dwg



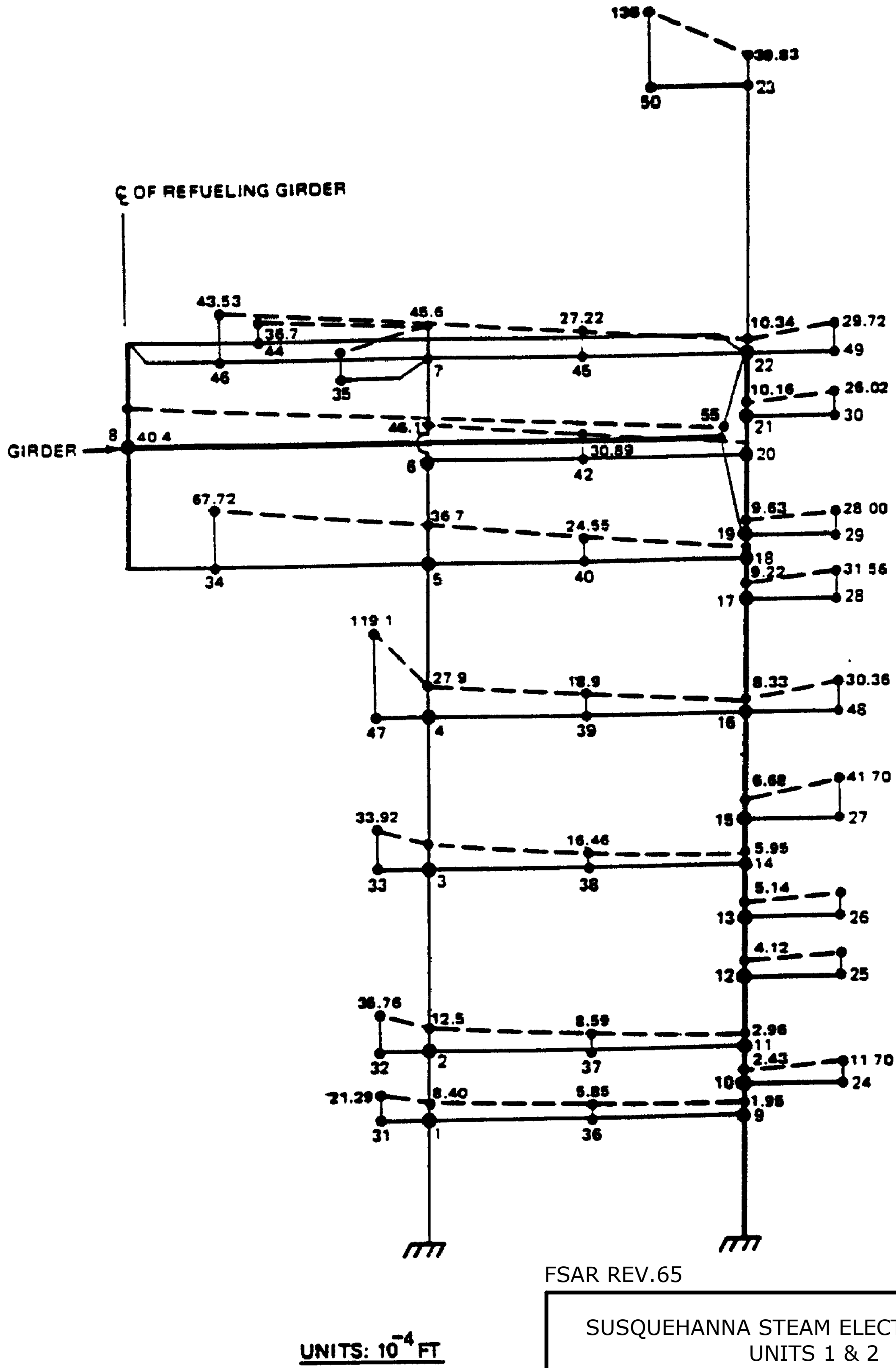
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL DISPLACEMENTS
OBE

FIGURE 3.7B-52, Rev. 55

Auto-Cad Figure Fsar 3_7B_52.dwg



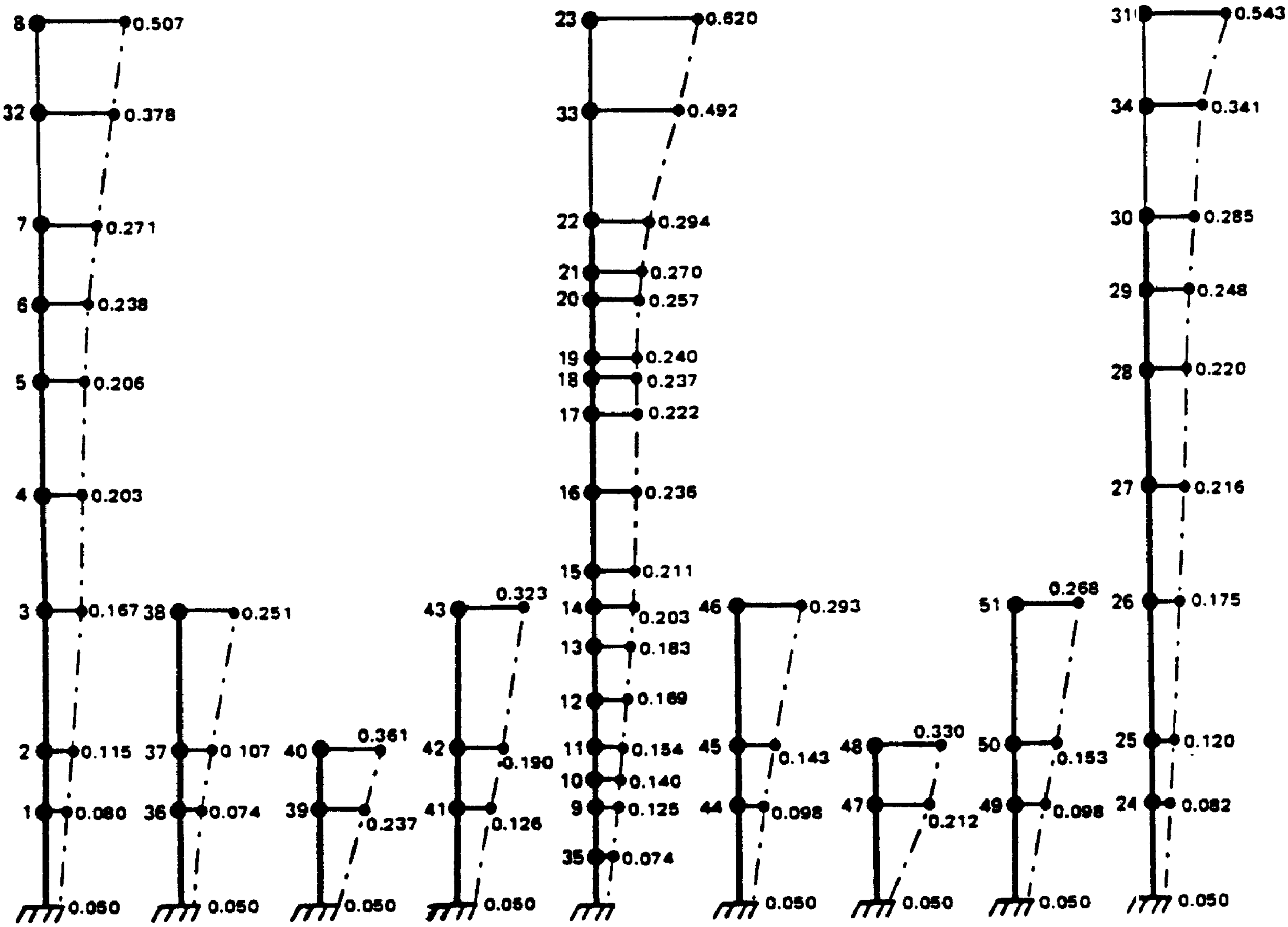
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL DISPLACEMENTS
SSE

FIGURE 3.7B-53, Rev. 55

Auto-Cad Figure Fsar 3_7B_53.dwg



UNITS: G's

NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

ΦBE RESPONSES

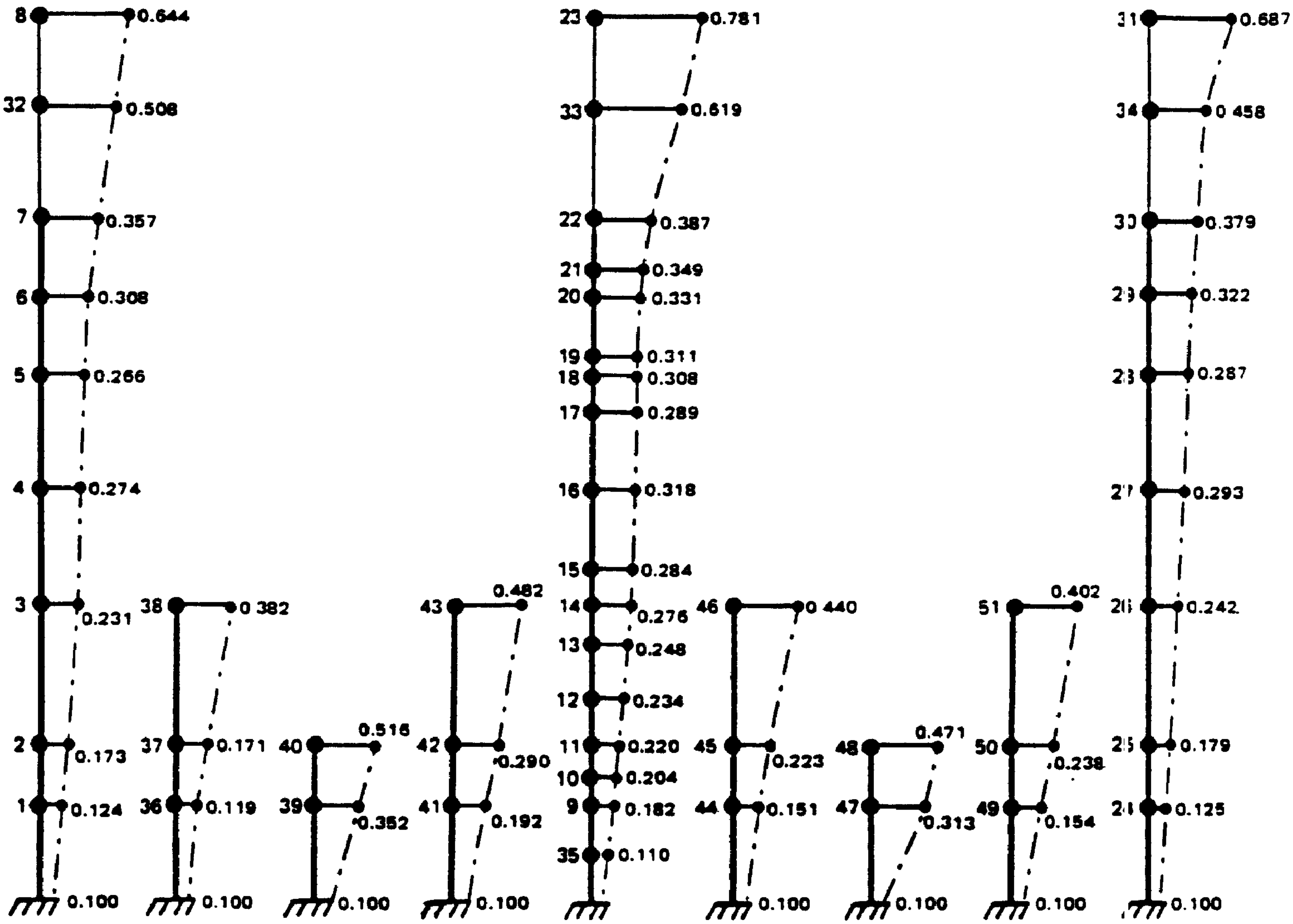
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W ACCELERATIONS
OBE

FIGURE 3.7B-54, Rev. 55

Auto-Cad Figure Fsar 3_7B_54.dwg



NOTE: CRANES ARE LOCATED AT MASS POINTS 32 AND 33

UNITS = G's

SSE RESPONSES

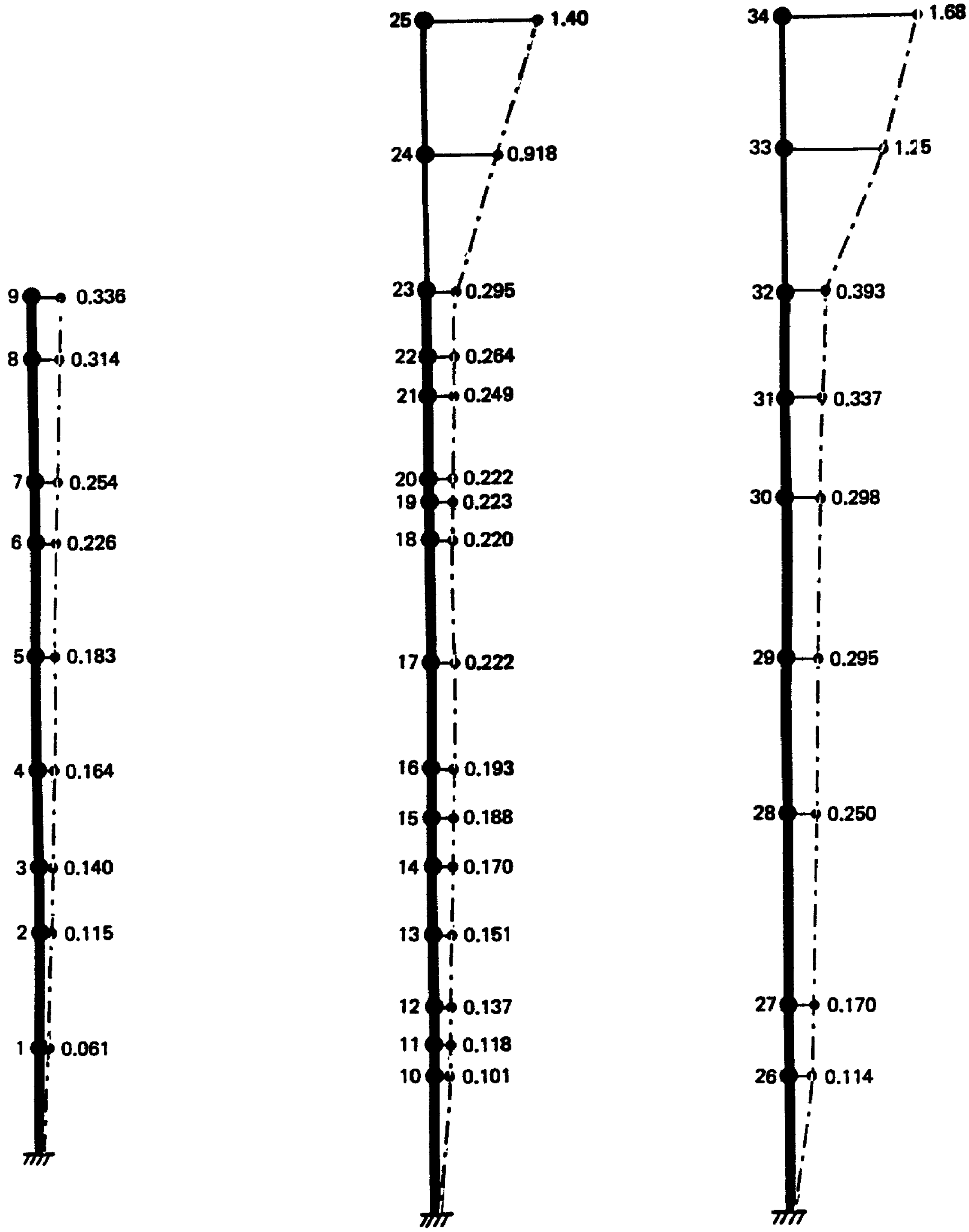
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
E-W ACCELERATIONS
SSE

FIGURE 3.7B-55, Rev. 55

Auto-Cad Figure Fsar 3_7B_55.dwg



UNITS: G's

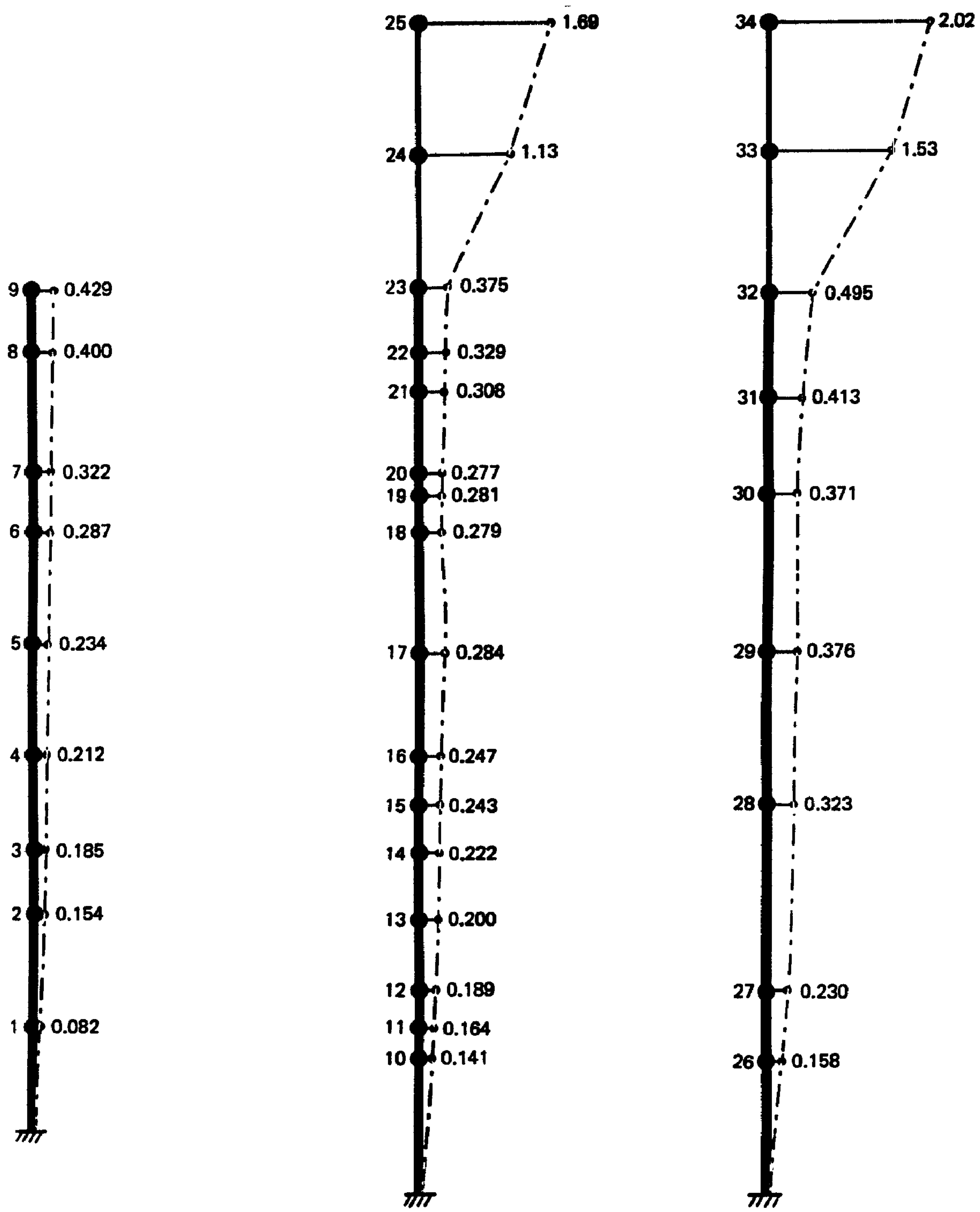
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S ACCELERATIONS
OBE

FIGURE 3.7B-56, Rev. 55

Auto-Cad Figure Fsar 3_7B_56.dwg



UNITS: G's

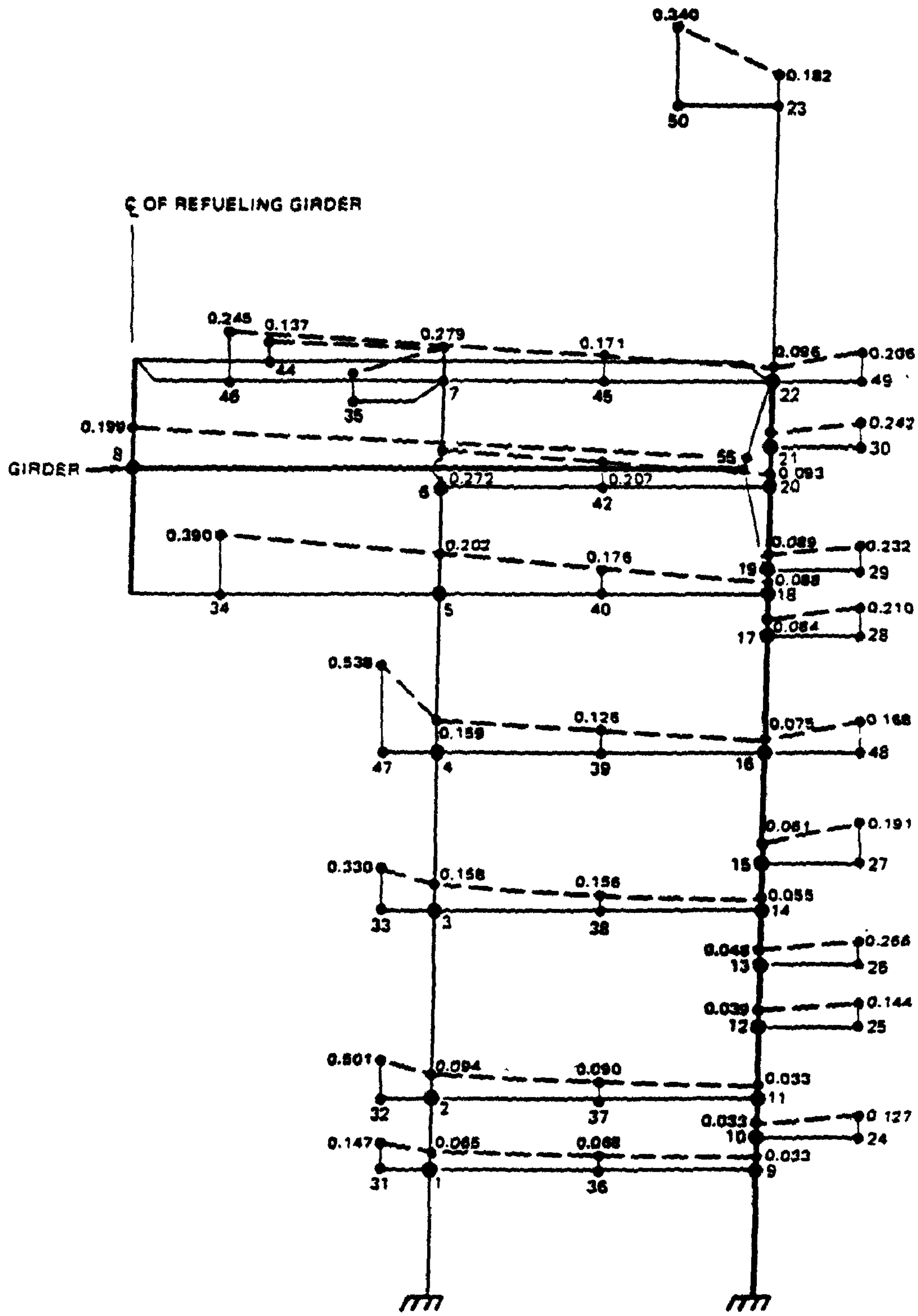
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
N-S ACCELERATIONS
SSE

FIGURE 3.7B-57, Rev. 55

Auto-Cad Figure Fsar 3_7B_57.dwg



UNITS = G's

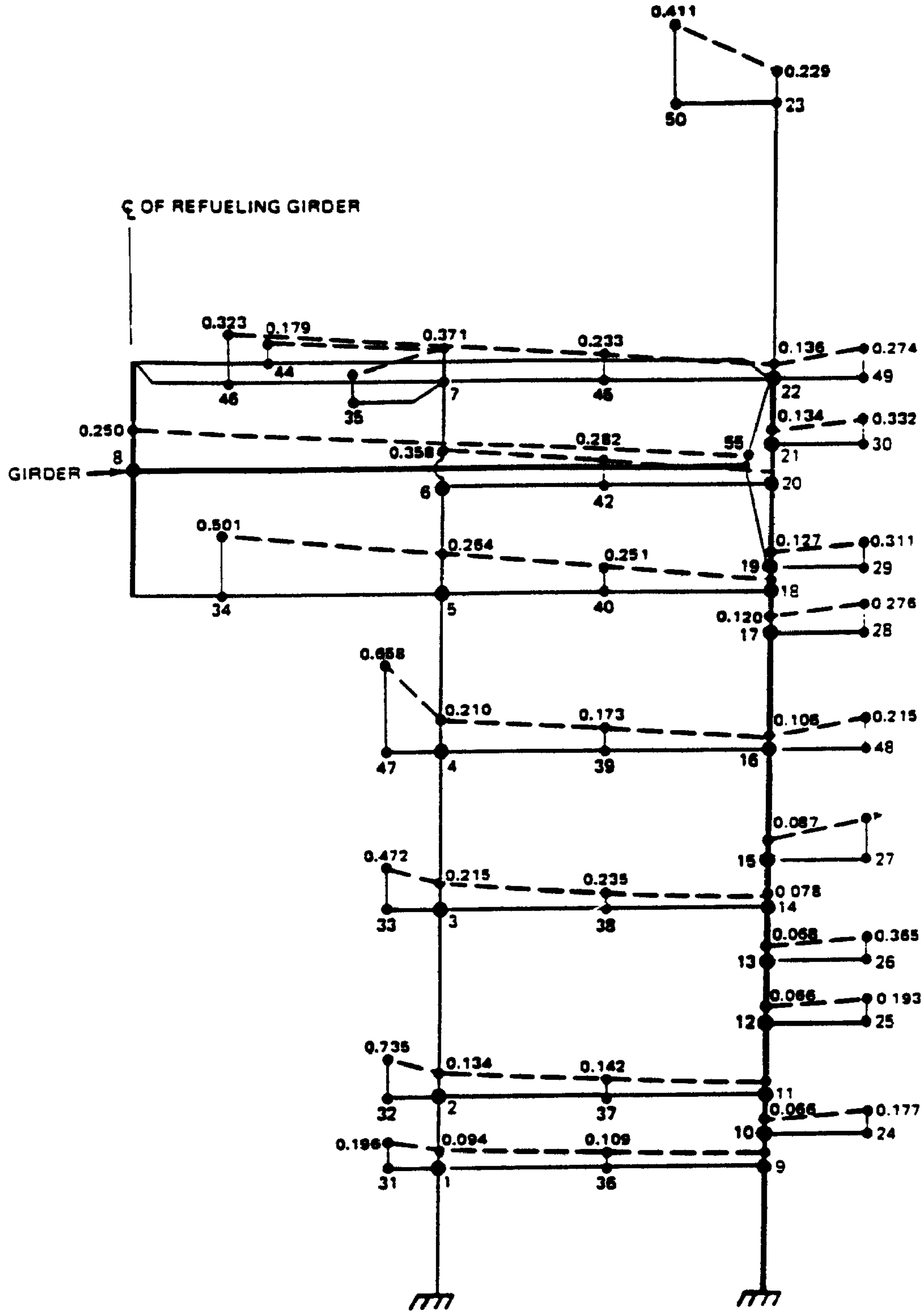
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL ACCELERATION
OBE

FIGURE 3.7B-58, Rev. 55

Auto-Cad Figure Fsar 3_7B_58.dwg



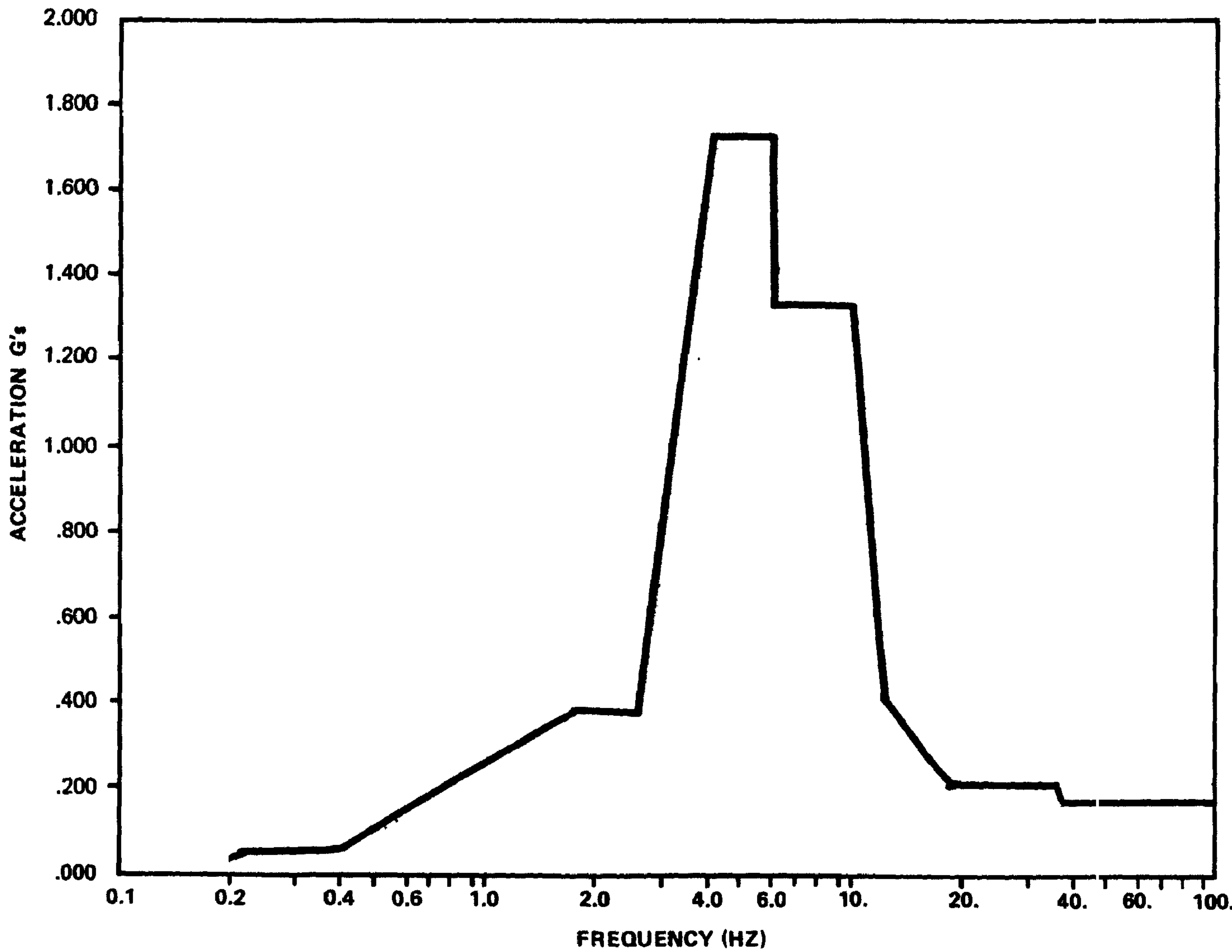
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

REACTOR AND CONTROL BUILDING
VERTICAL ACCELERATIONS
SSE

FIGURE 3.7B-59, Rev. 55

Auto-Cad Figure Fsar 3_7B_59.dwg



LOCATION: RPV PEDESTAL
DIRECTION: HORIZONTAL
EARTHQUAKE: OBE
DAMPING: 0.005

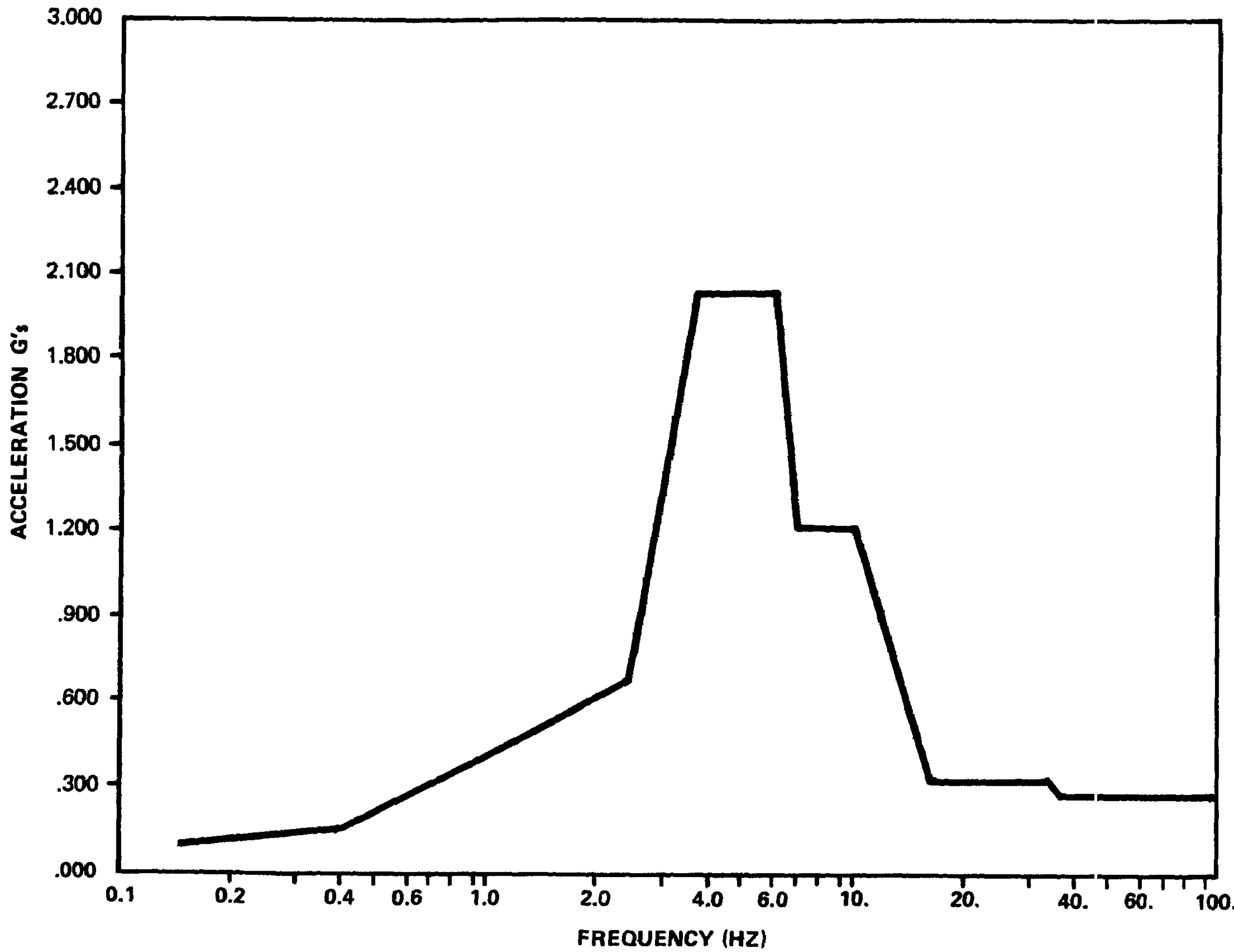
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT RPV PEDESTAL
HORIZONTAL OBE

FIGURE 3.7B-60, Rev. 55

Auto-Cad Figure Fsar 3_7B_60.dwg



LOCATION: RPV PEDESTAL
DIRECTION: HORIZONTAL
EARTHQUAKE: SSE
DAMPING: 0.010

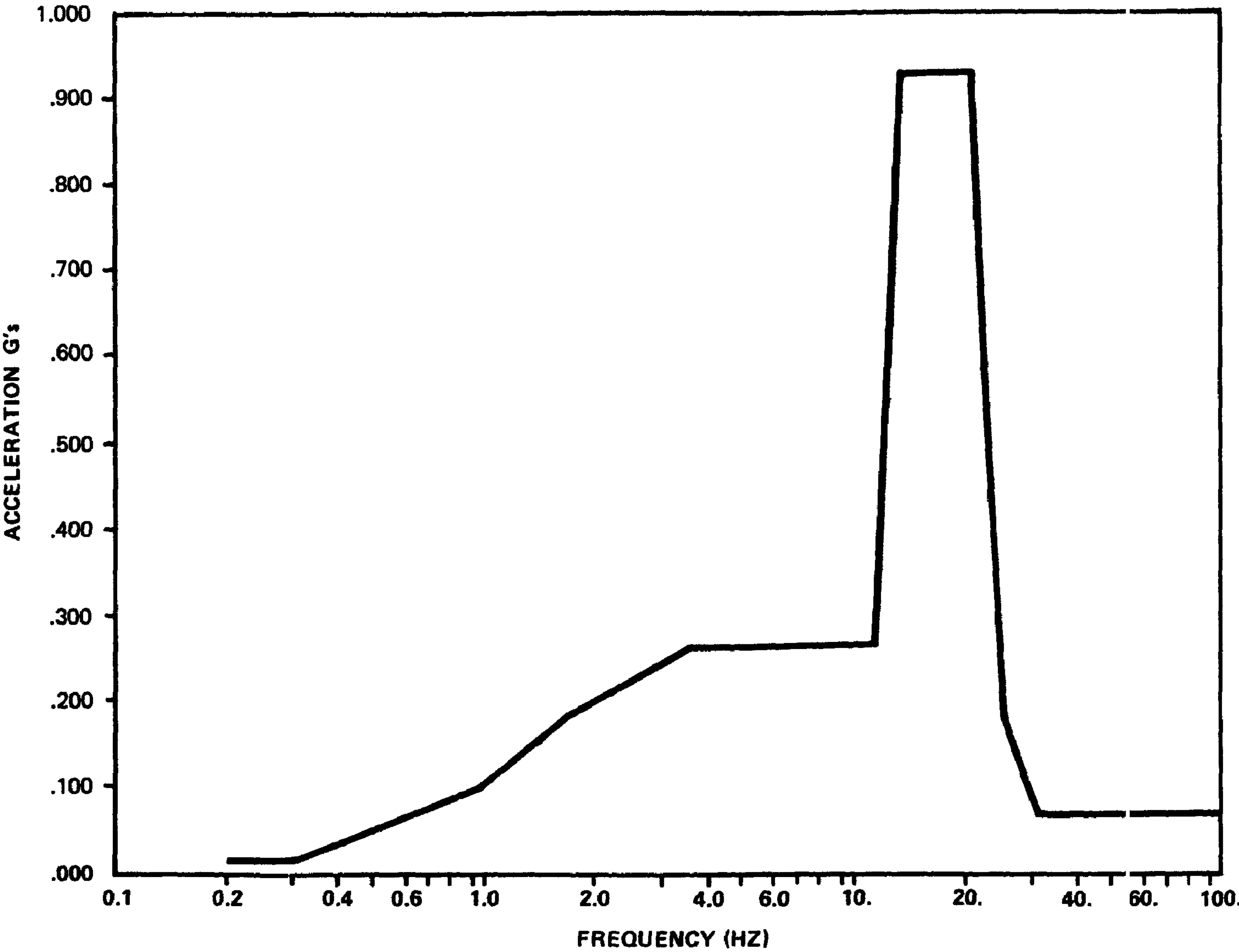
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT RPV PEDESTAL
HORIZONTAL SSE

FIGURE 3.7B-61, Rev. 55

Auto-Cad Figure Fsar 3_7B_61.dwg



LOCATION: RPV PEDESTAL
DIRECTION: VERTICAL
EARTHQUAKE: OBE
DAMPING: 0.005

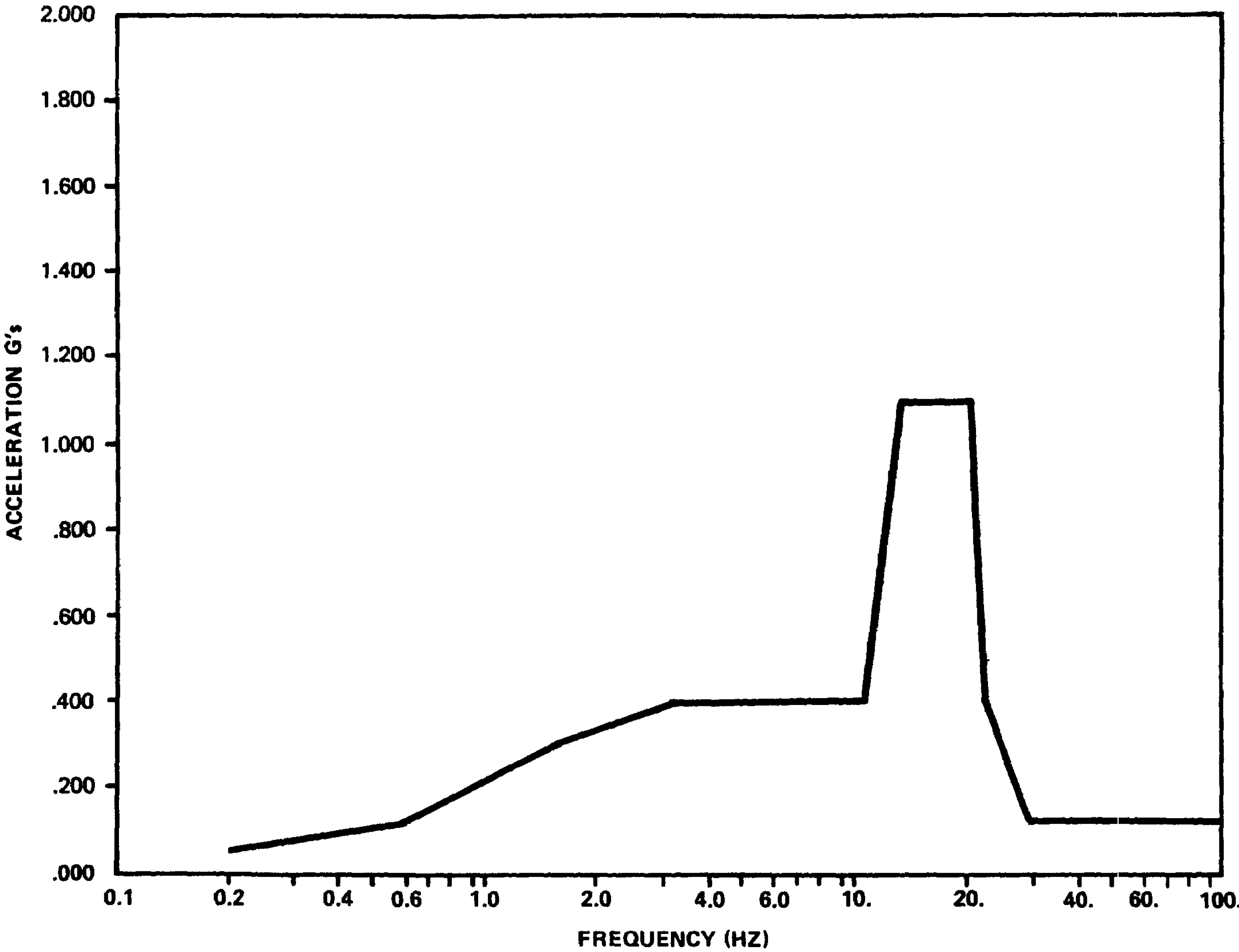
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT RPV PEDESTAL
VERTICAL OBE

FIGURE 3.7B-62, Rev. 55

Auto-Cad Figure Fsar 3_7B_62.dwg



LOCATION: RPV PEDESTAL
DIRECTION: VERTICAL
EARTHQUAKE: SSE
DAMPING: 0.010

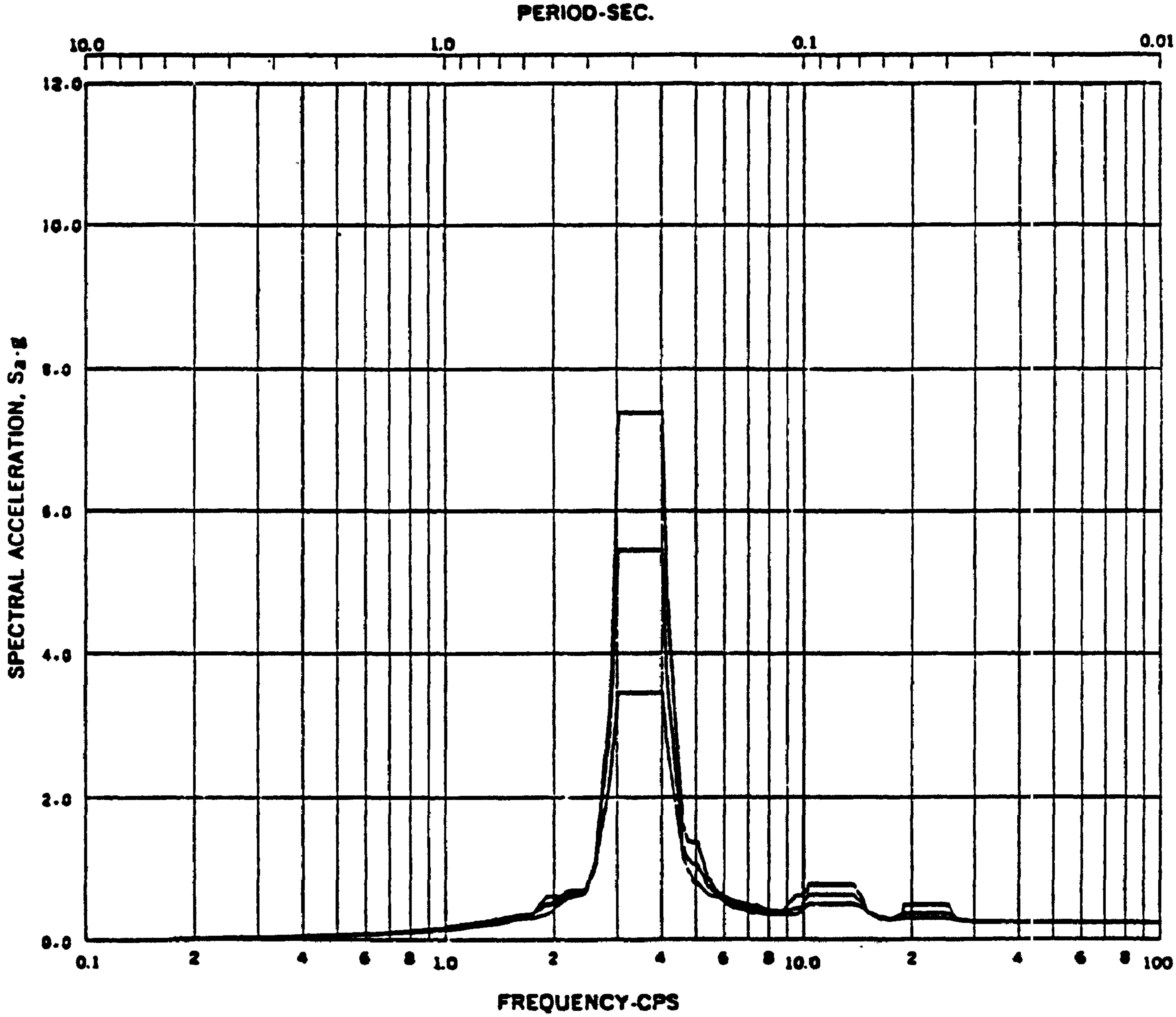
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT RPV PEDESTAL
VERTICAL SSE

FIGURE 3.7B-63, Rev. 55

Auto-Cad Figure Fsar 3_7B_63.dwg



ACCELERATION SPECTRA FOR REACTOR/CONTROL BLDG

LOAD CASE SUSQUEHANNA OBE

NODE 22, DIRECTION EW, ELEV 818'-1

DAMPING 0.005.0.010.0.02

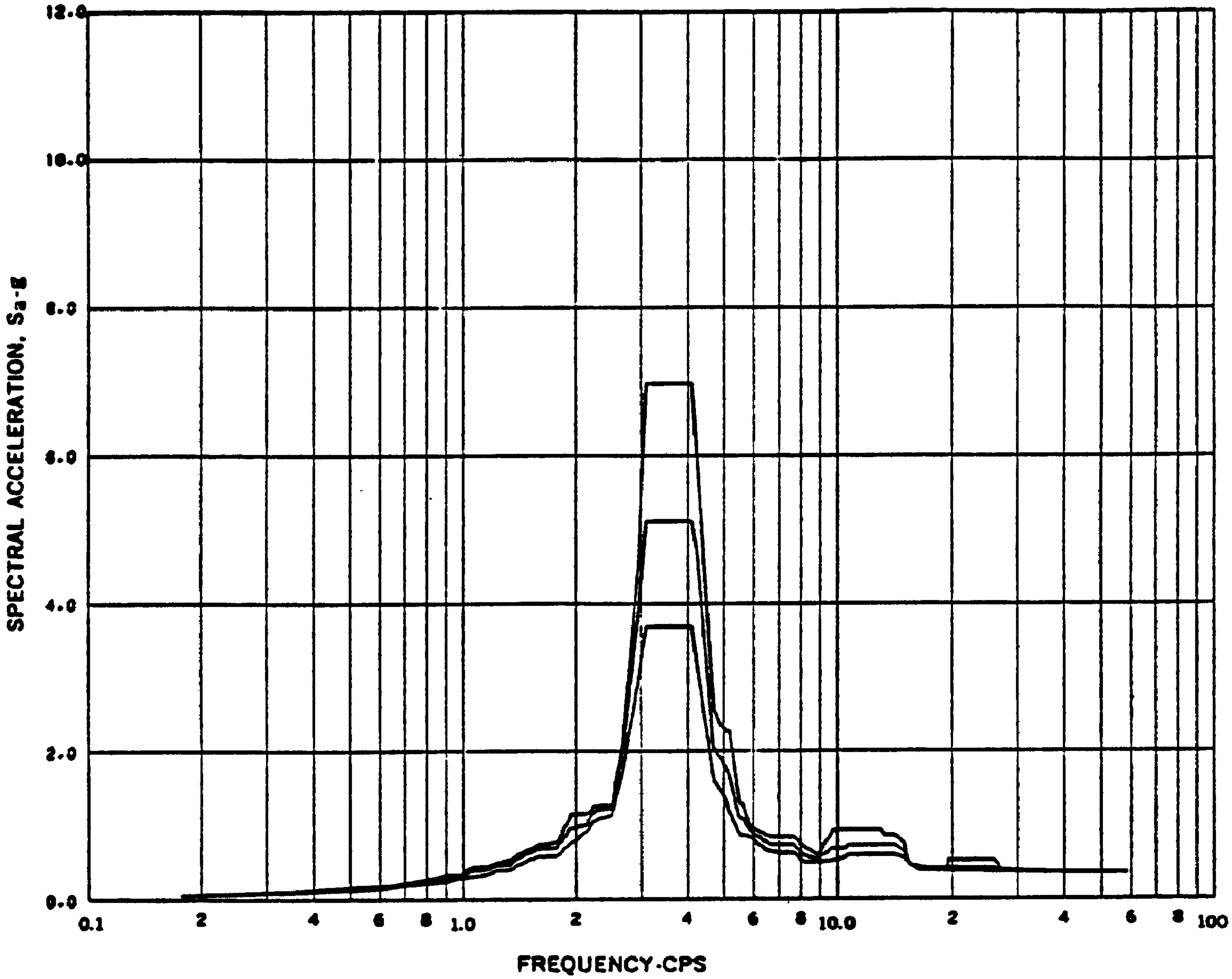
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
E-W OBE

FIGURE 3.7B-64, Rev. 55

Auto-Cad Figure Fsar 3_7B_64.dwg



ACCELERATION SPECTRA FOR REACTOR/CONTROL BLDG

LOAD CASE SUSQUEHANNA SSE

NODE 22, DIRECTION EW, ELEV 818'-1

DAMPING 0.005.0.010.0.02

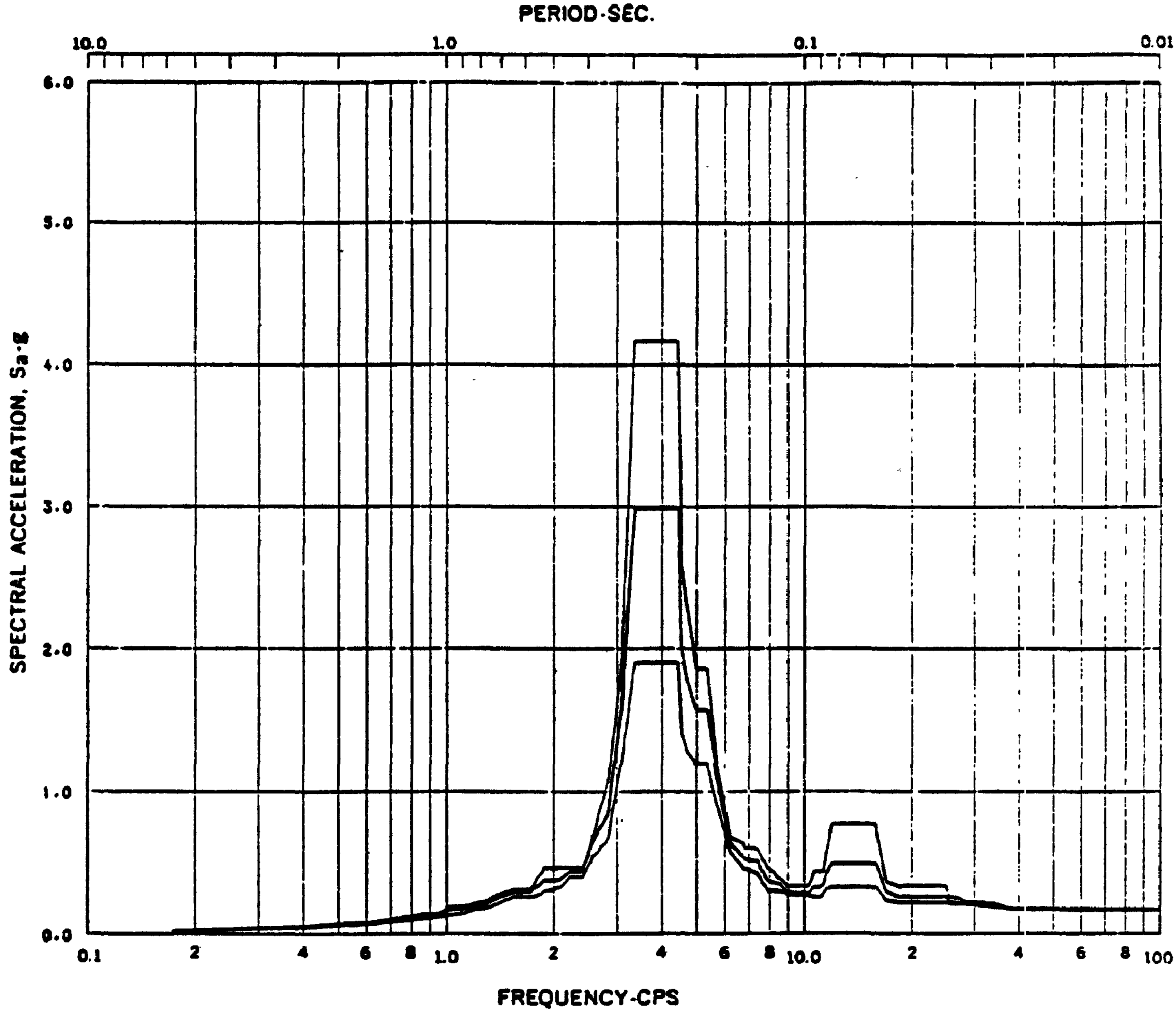
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
E-W SSE

FIGURE 3.7B-65, Rev. 55

Auto-Cad Figure Fsar 3_7B_65.dwg



ACCELERATION SPECTRA FOR REACTOR/CONTROL BLDG

LOAD CASE SUSQUEHANNA NS OBE

NODE 23, DIRECTION NS, ELEV 818'-1

DAMPING 0.005,0.01,0.02

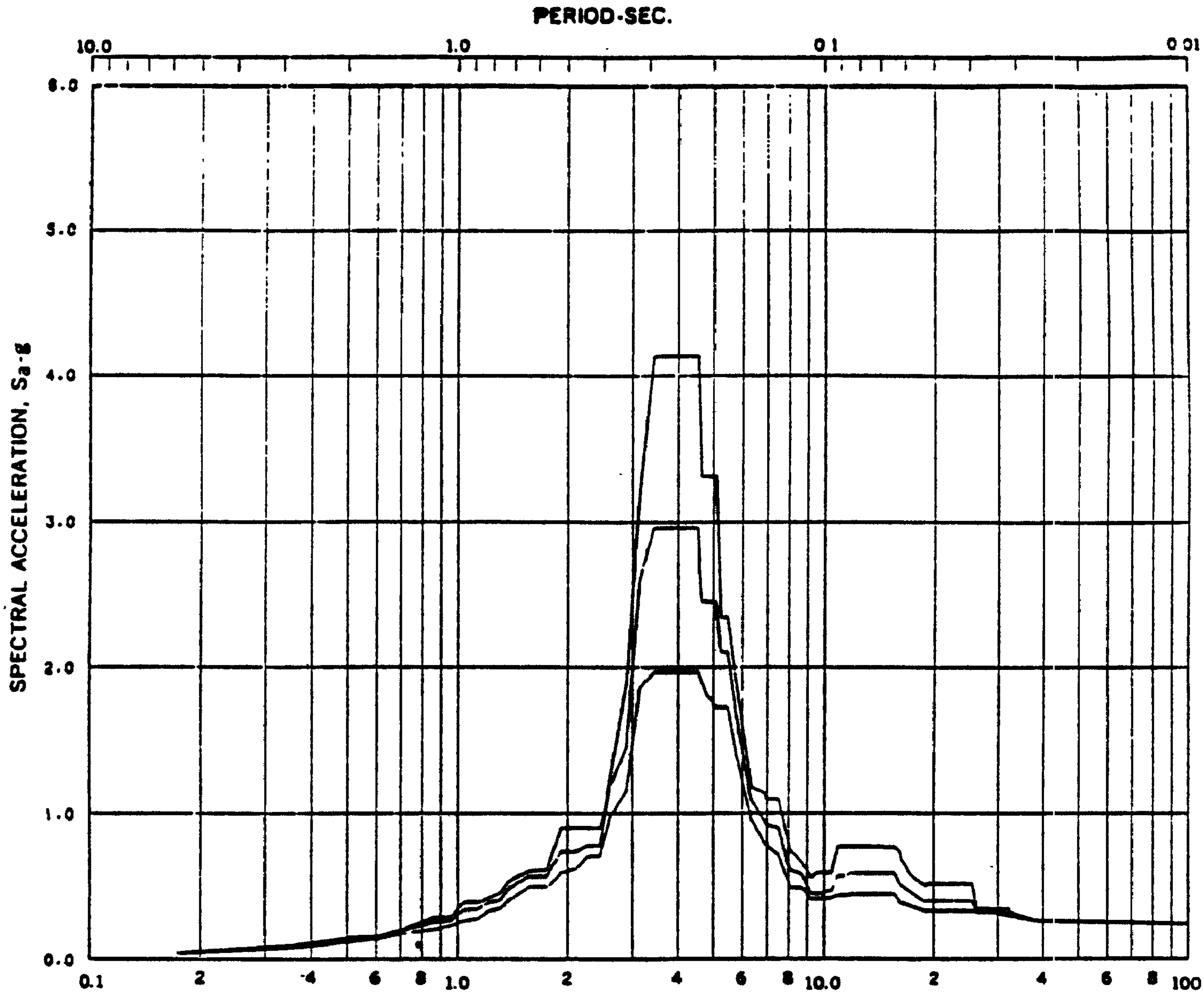
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
N-S OBE

FIGURE 3.7B-66, Rev. 55

Auto-Cad Figure Fsar 3_7B_66.dwg



ACCELERATION SPECTRA FOR REACTOR/CONTROL BLDG

LOAD CASE SUSQUEHANNA SSE

NODE 23, DIRECTION NS, ELEV 818'-1

DAMPING 0.005.0.010.0.02

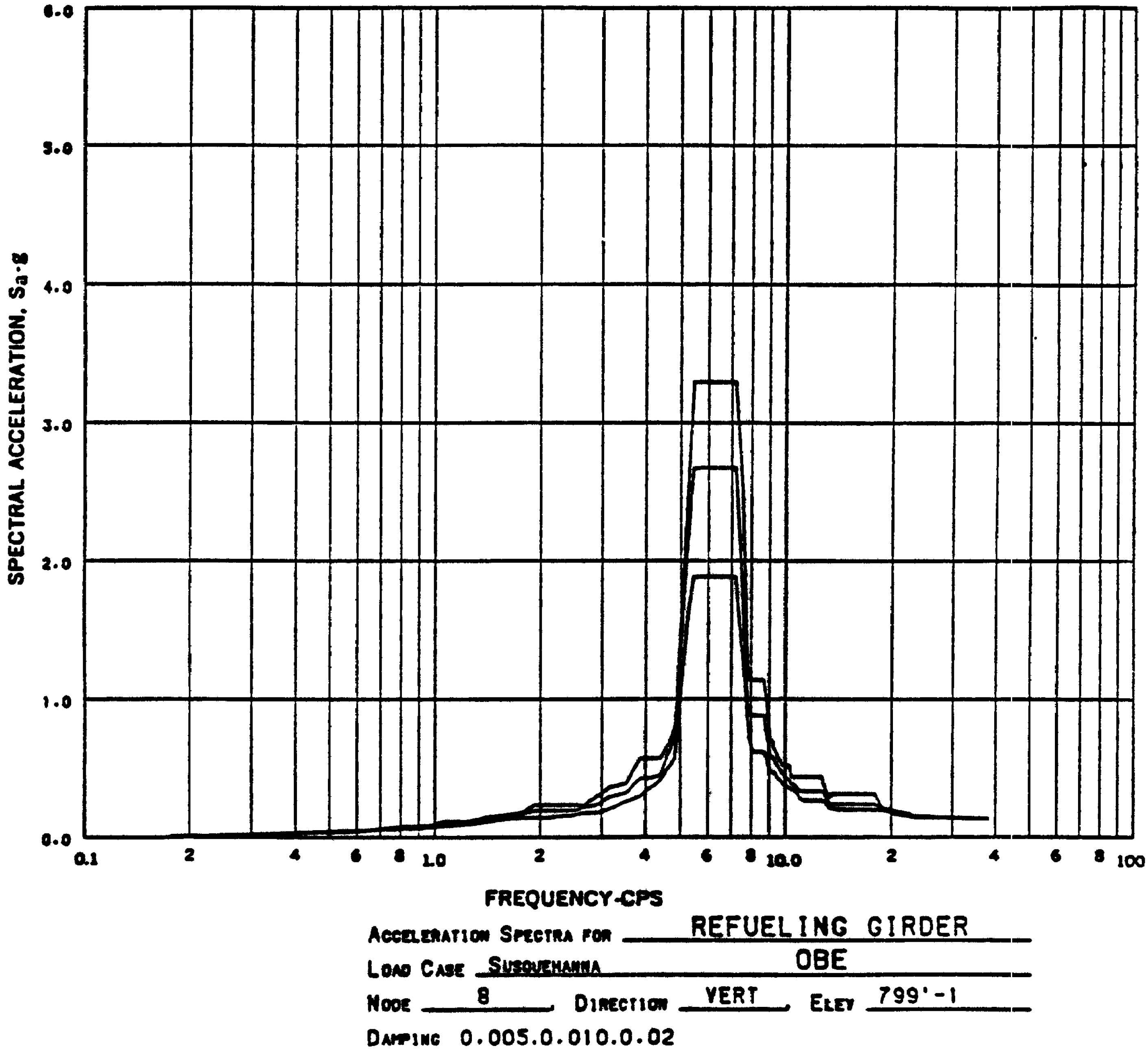
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
N-S SSE

FIGURE 3.7B-67, Rev. 55

Auto-Cad Figure Fsar 3_7B_67.dwg



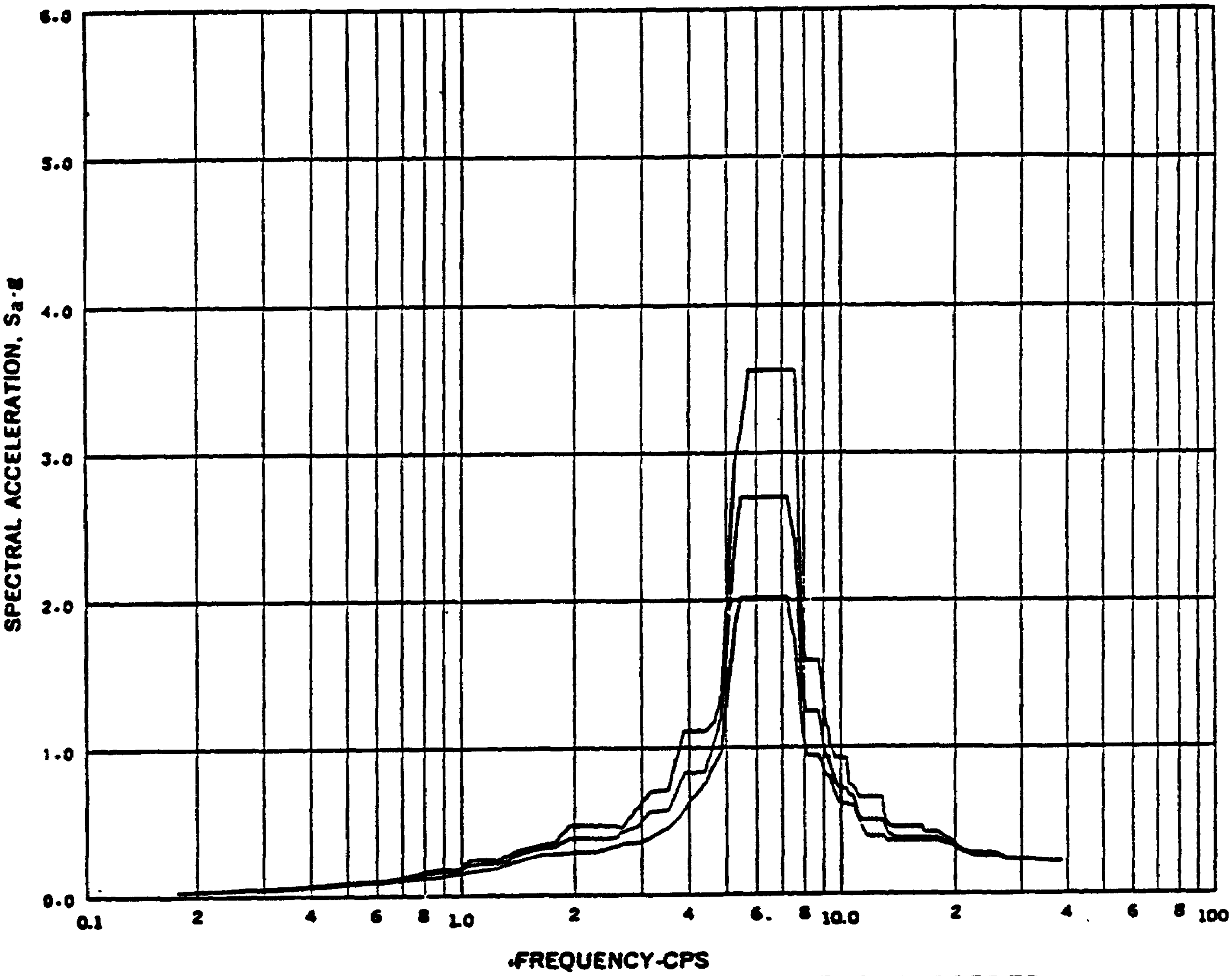
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
VERTICAL OBE

FIGURE 3.7B-68, Rev. 55

Auto-Cad Figure Fsar 3_7B_68.dwg



ACCELERATION SPECTRA FOR REFUELING GIRDER

LOAD CASE SUSQUEHANNA SSE

NODE 8, DIRECTION VERT, ELEV 799'-1

DAMPING 0.005.0.010.0.02

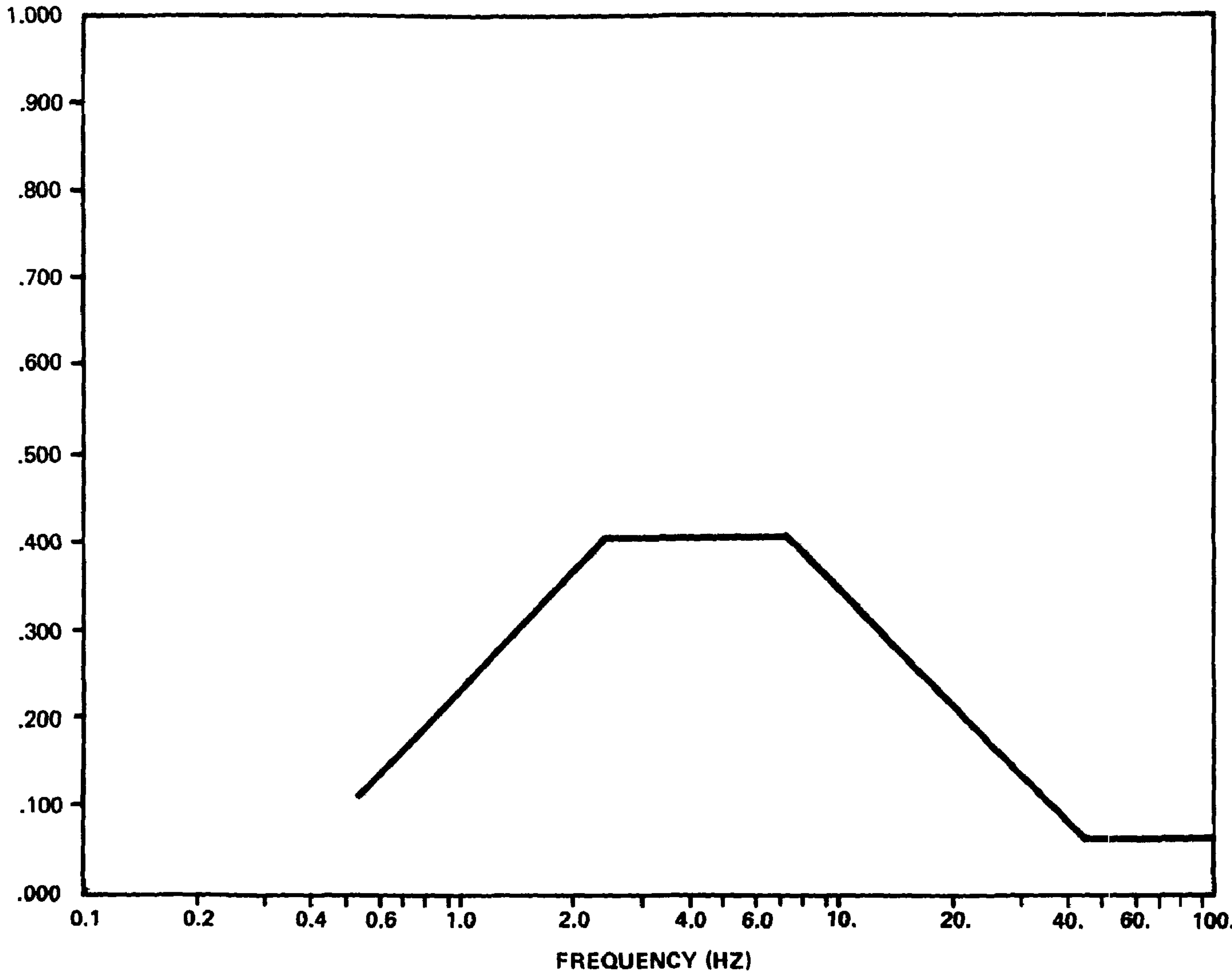
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT REFUELING AREA
VERTICAL SSE

FIGURE 3.7B-69, Rev. 55

Auto-Cad Figure Fsar 3_7B_69.dwg



LOCATION: TOP OF PEDESTAL FOR DIESELS 'A-D'
DIRECTION: E-W
EARTHQUAKE: OBE
DAMPING: 0.005

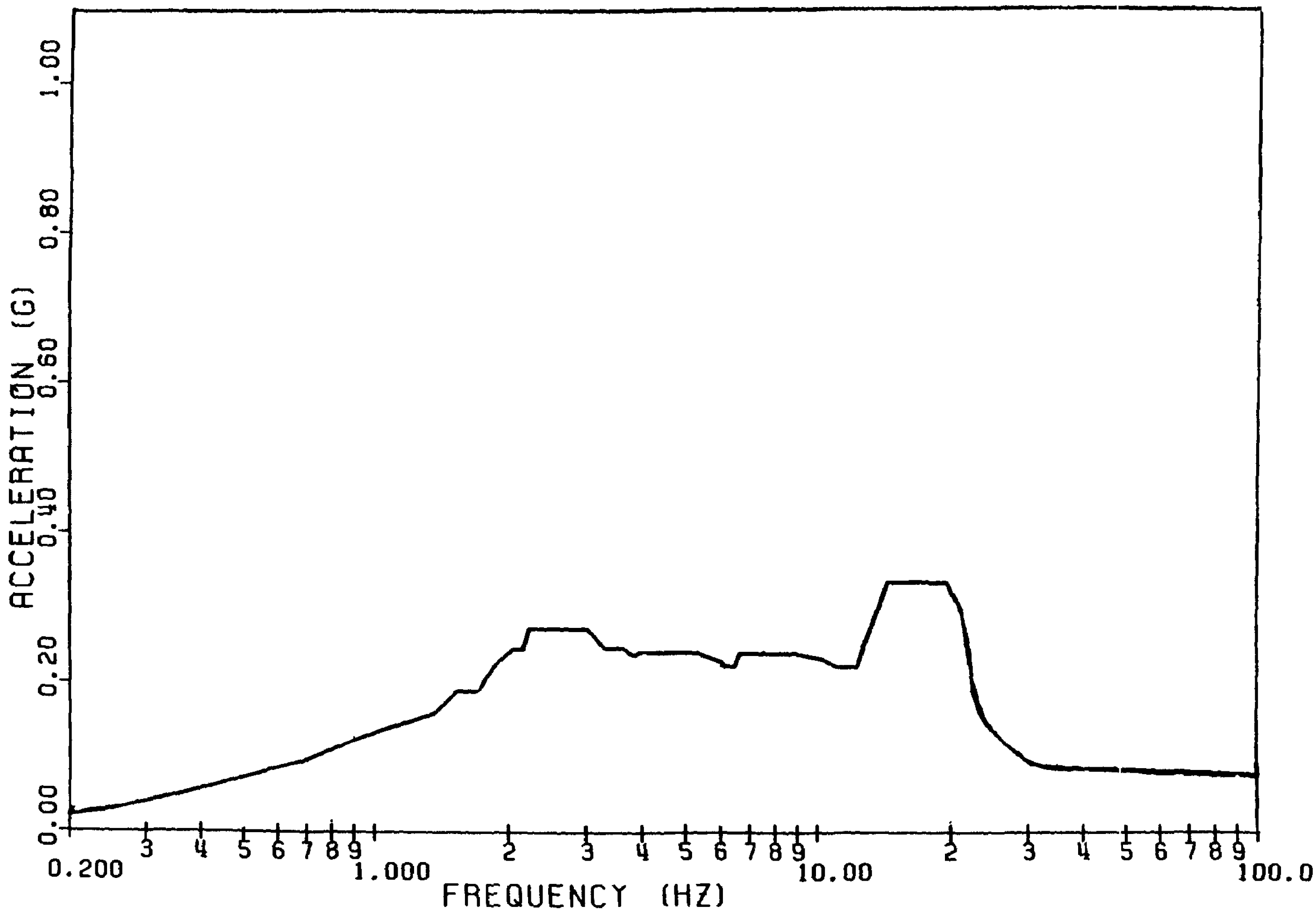
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL
(DIESELS 'A-D') E-W OBE

FIGURE 3.7B-70, Rev. 55

Auto-Cad Figure Fsar 3_7B_70.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: E-W
EARTHQUAKE: OBE
DAMPING: 0.020

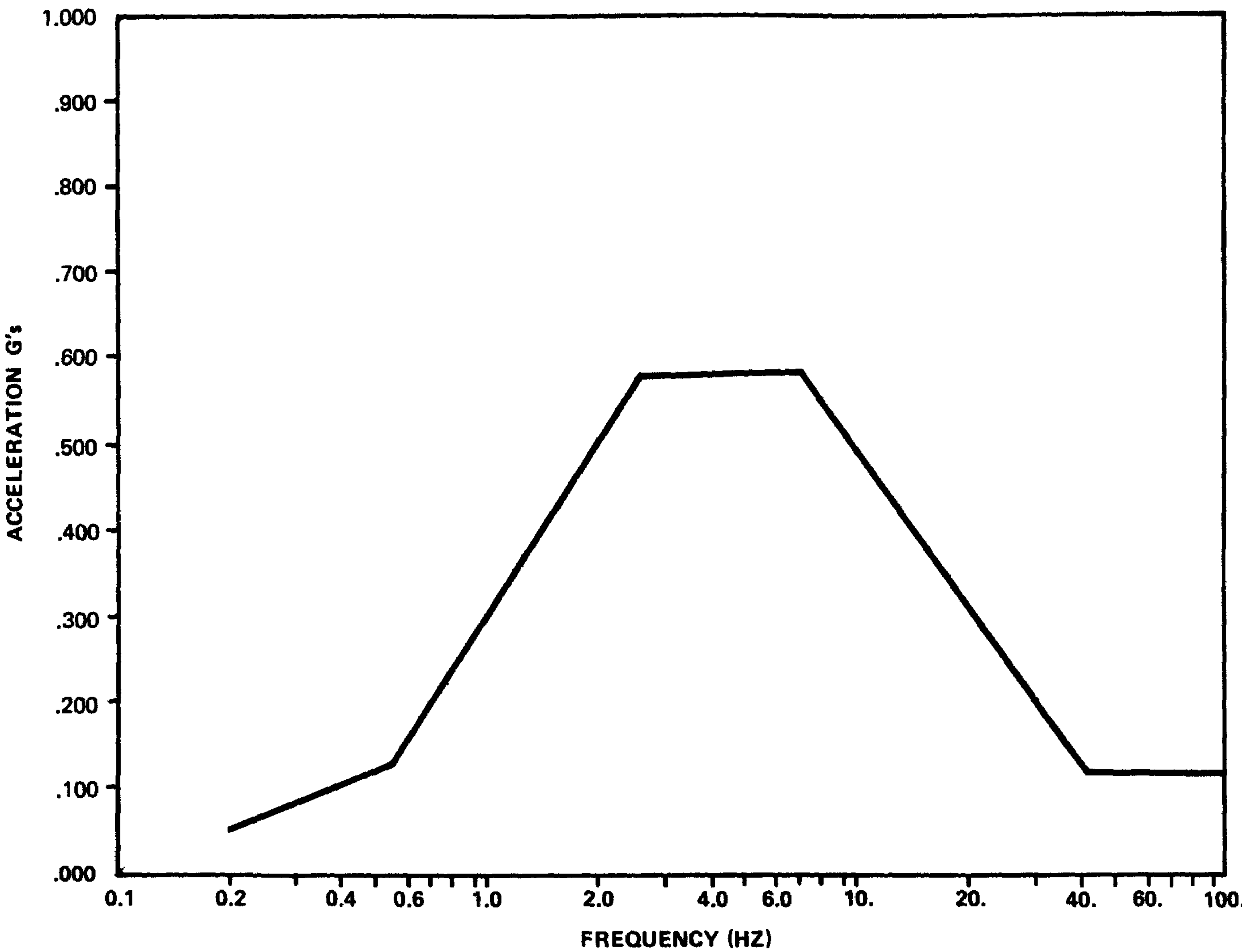
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL
FOR DIESEL 'E'
E-W OBE

FIGURE 3.7B-71, Rev. 55

Auto-Cad Figure Fsar 3_7B_71.dwg



LOCATION: TOP OF PEDESTAL FOR DIESELS 'A-D'
DIRECTION: E-W
EARTHQUAKE: SSE
DAMPING: 0.010

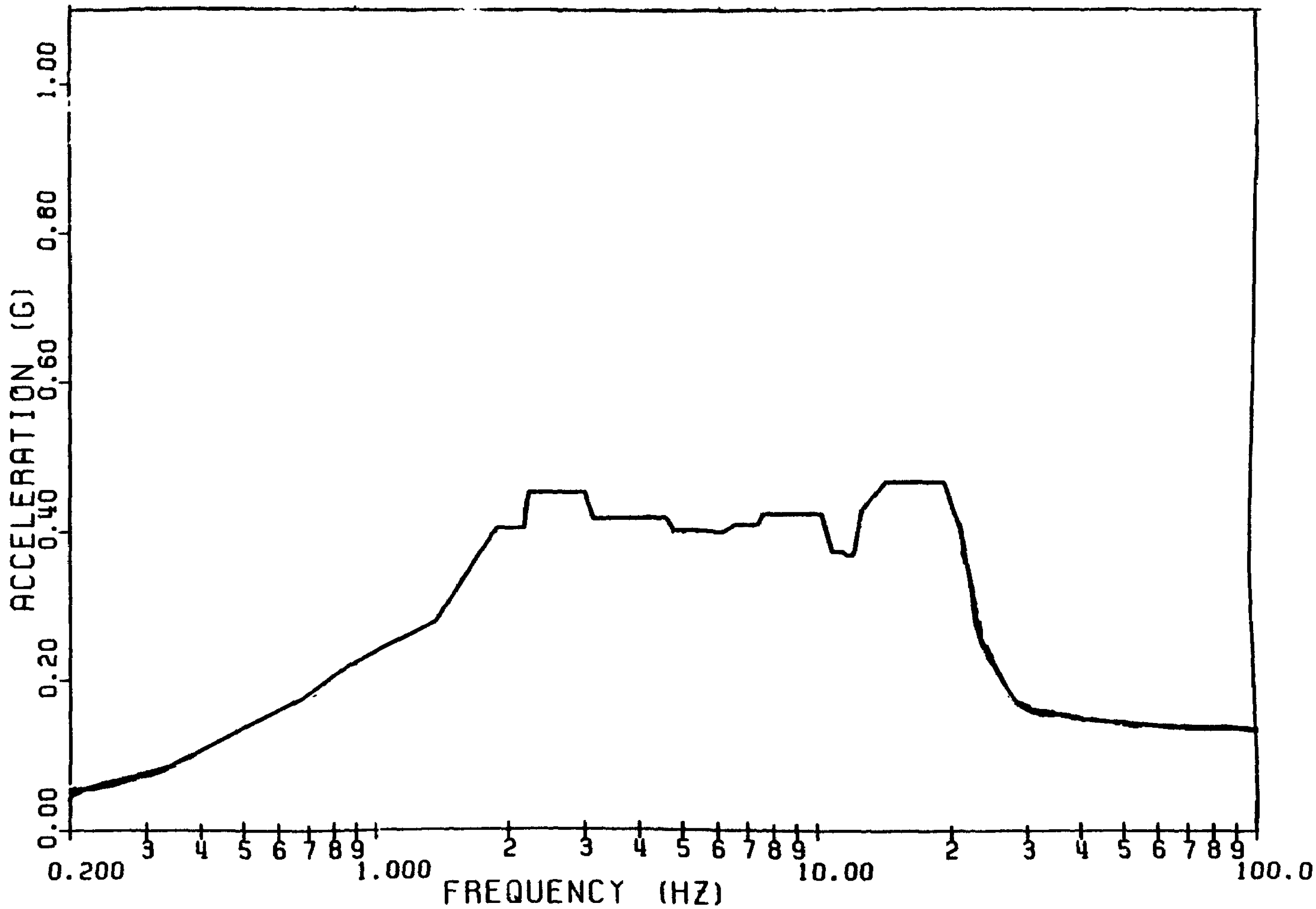
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL (DIESEL 'A-D')
E-W SSE

FIGURE 3.7B-72, Rev. 55

Auto-Cad Figure Fsar 3_7B_72.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: E-W
EARTHQUAKE: SSE
DAMPING: 0.030

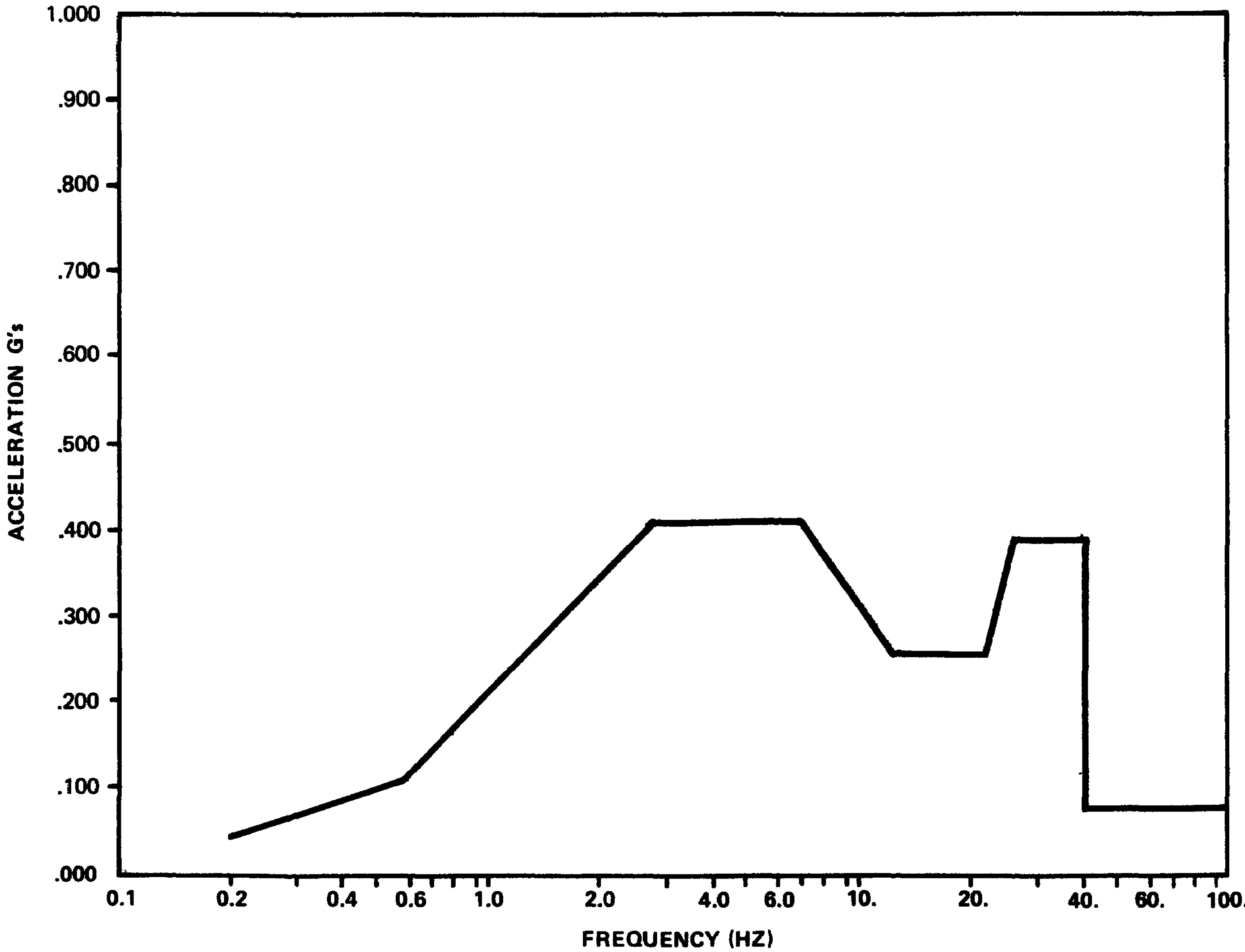
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL FOR DIESEL 'E'
E-W SSE

FIGURE 3.7B-73, Rev. 55

Auto-Cad Figure Fsar 3_7B_73.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL 'A-D'
DIRECTION: N-S
EARTHQUAKE: OBE
DAMPING: 0.005

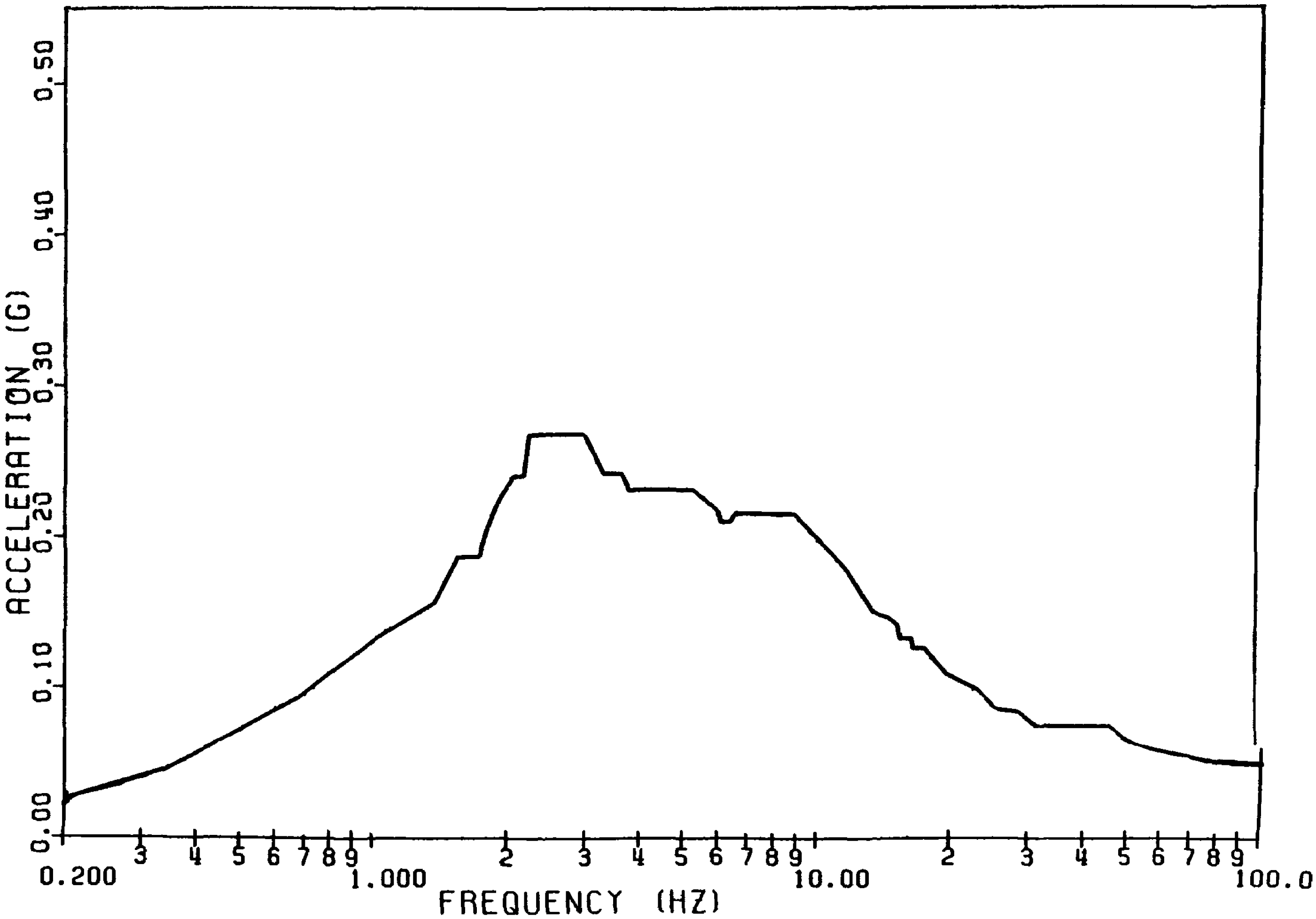
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL (DIESEL 'A-D')
E-W OBE

FIGURE 3.7B-74, Rev. 55

Auto-Cad Figure Fsar 3_7B_74.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: N-S
EARTHQUAKE: OBE
DAMPING: 0.020

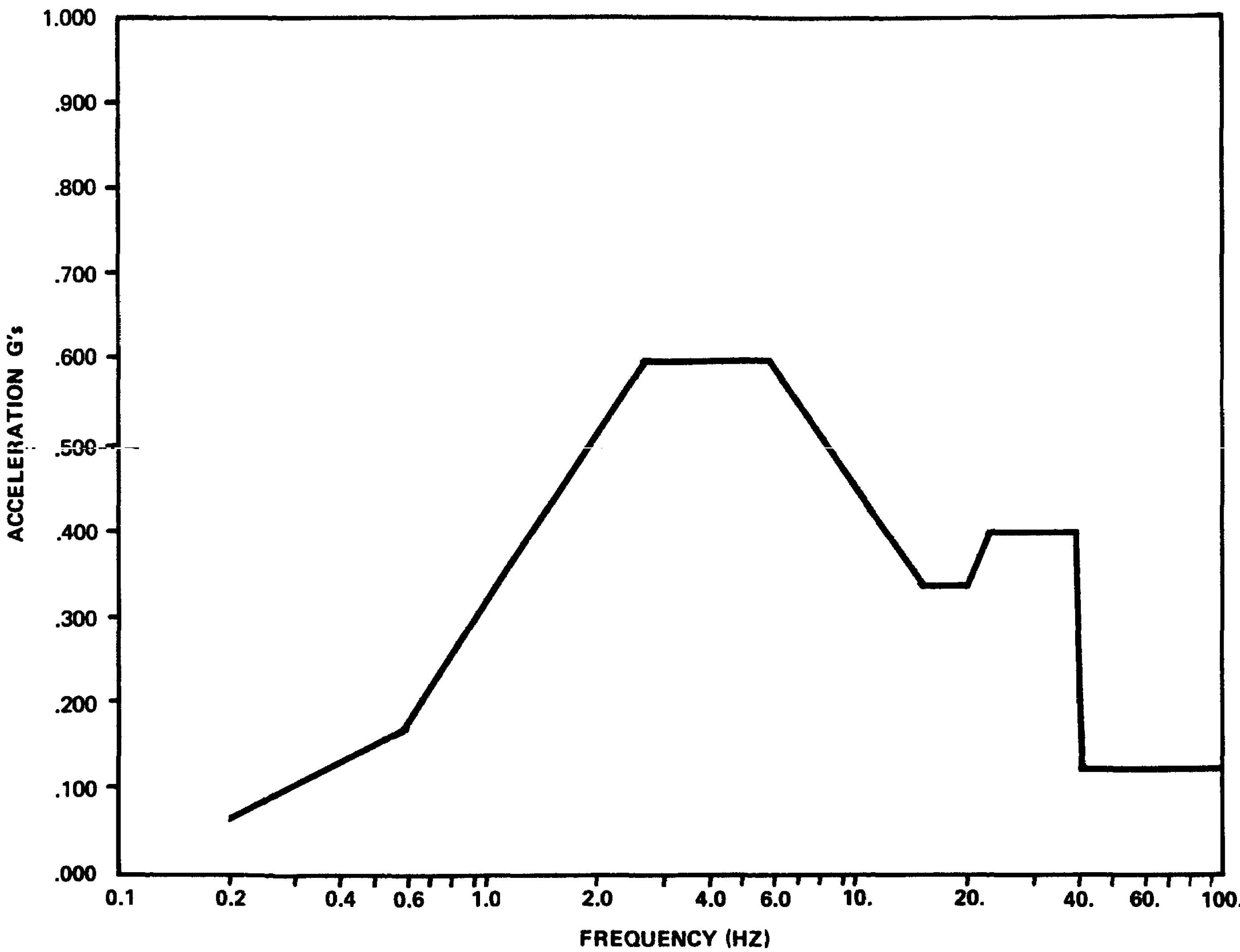
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL FOR DIESEL 'E'
N-S OBE

FIGURE 3.7B-75, Rev. 55

Auto-Cad Figure Fsar 3_7B_75.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL 'A-D'
DIRECTION: N-S
EARTHQUAKE: SSE
DAMPING: 0.010

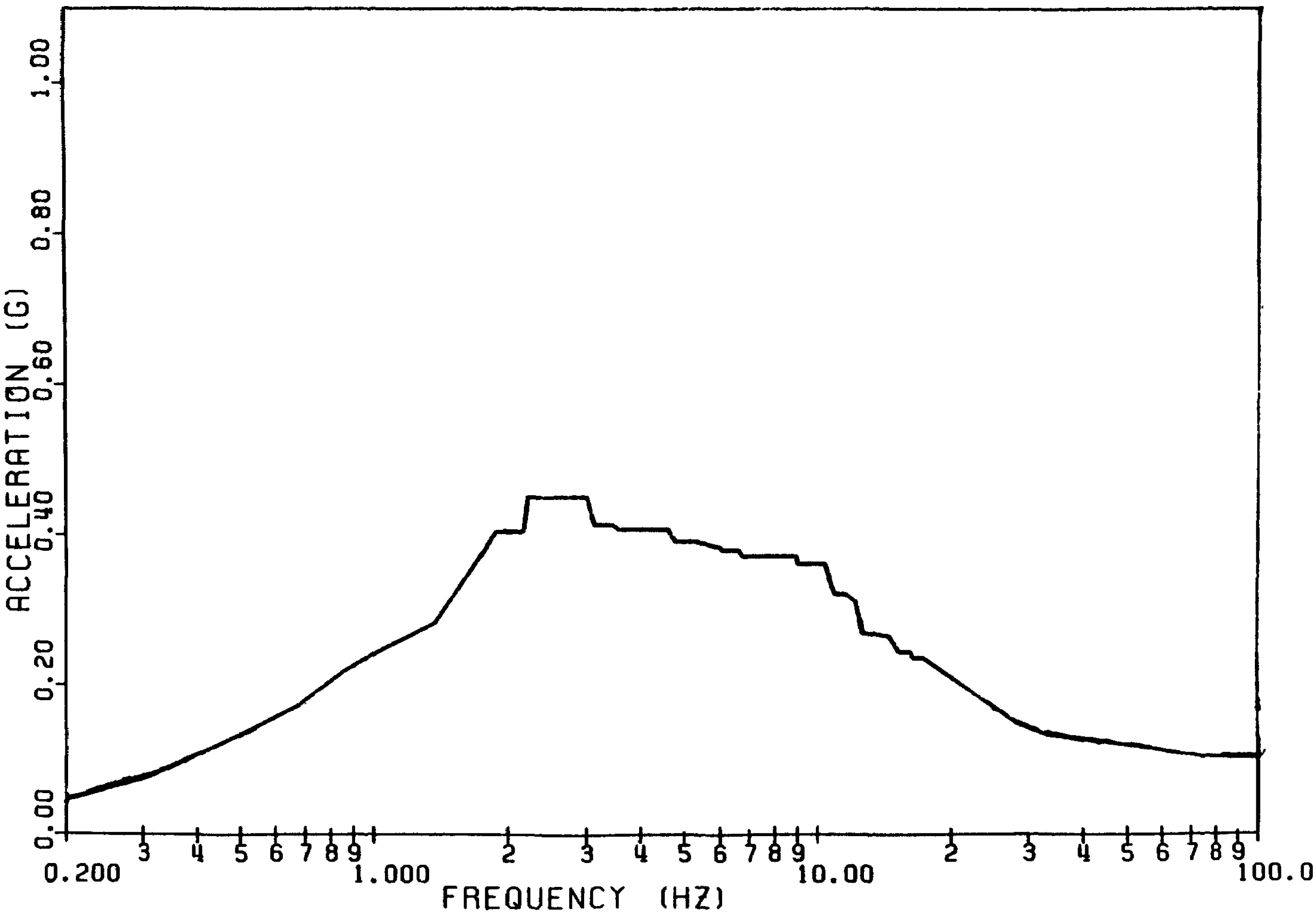
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL (DIESELS 'A-D')
N-S SSE

FIGURE 3.7B-76, Rev. 55

Auto-Cad Figure Fsar 3_7B_76.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: N-S
EARTHQUAKE: SSE
DAMPING: 0.030

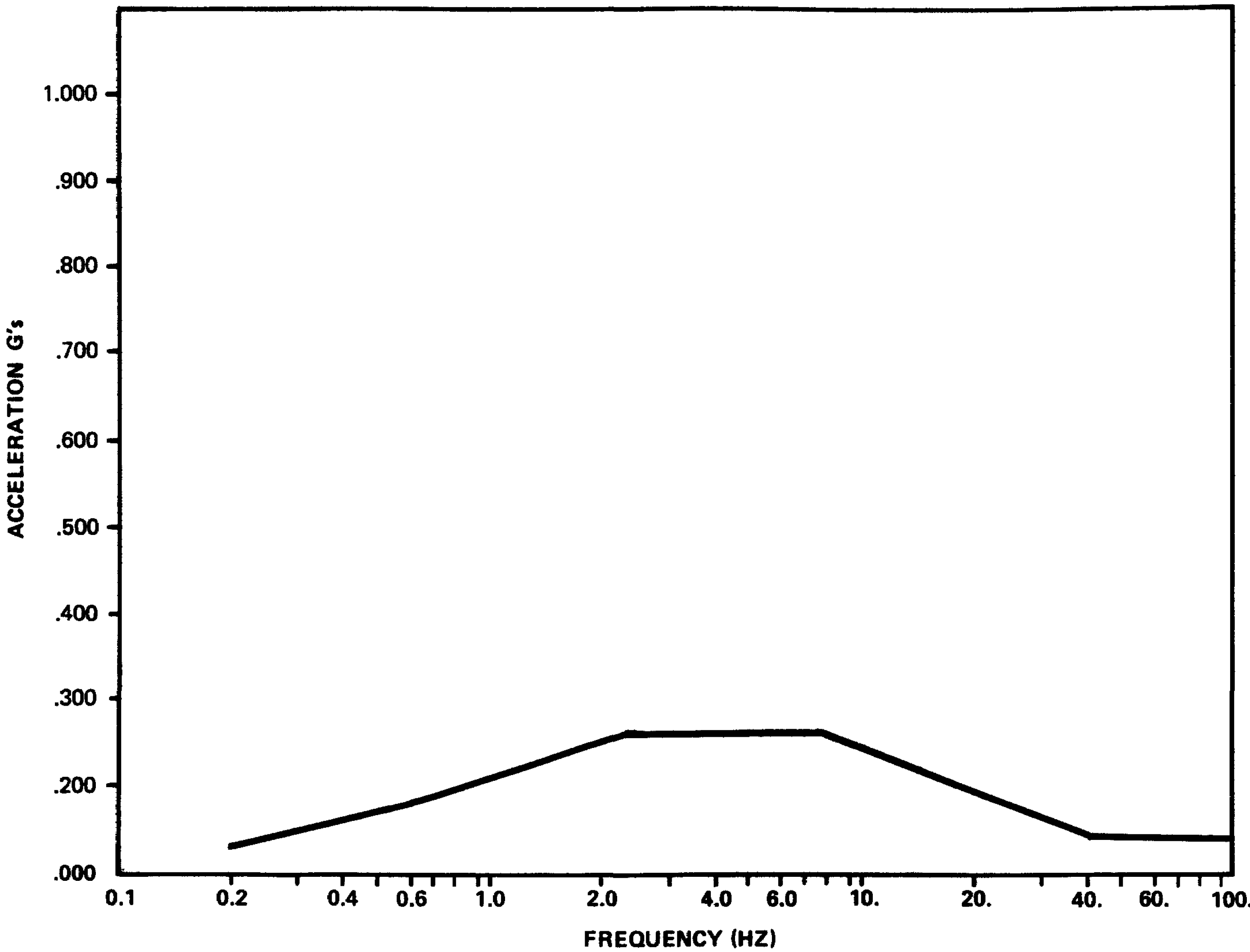
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL FOR DIESEL 'E'
N-S SSE

FIGURE 3.7B-77, Rev. 55

Auto-Cad Figure Fsar 3_7B_77.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL 'A-D'
DIRECTION: VERTICAL
EARTHQUAKE: OBE
DAMPING: 0.005

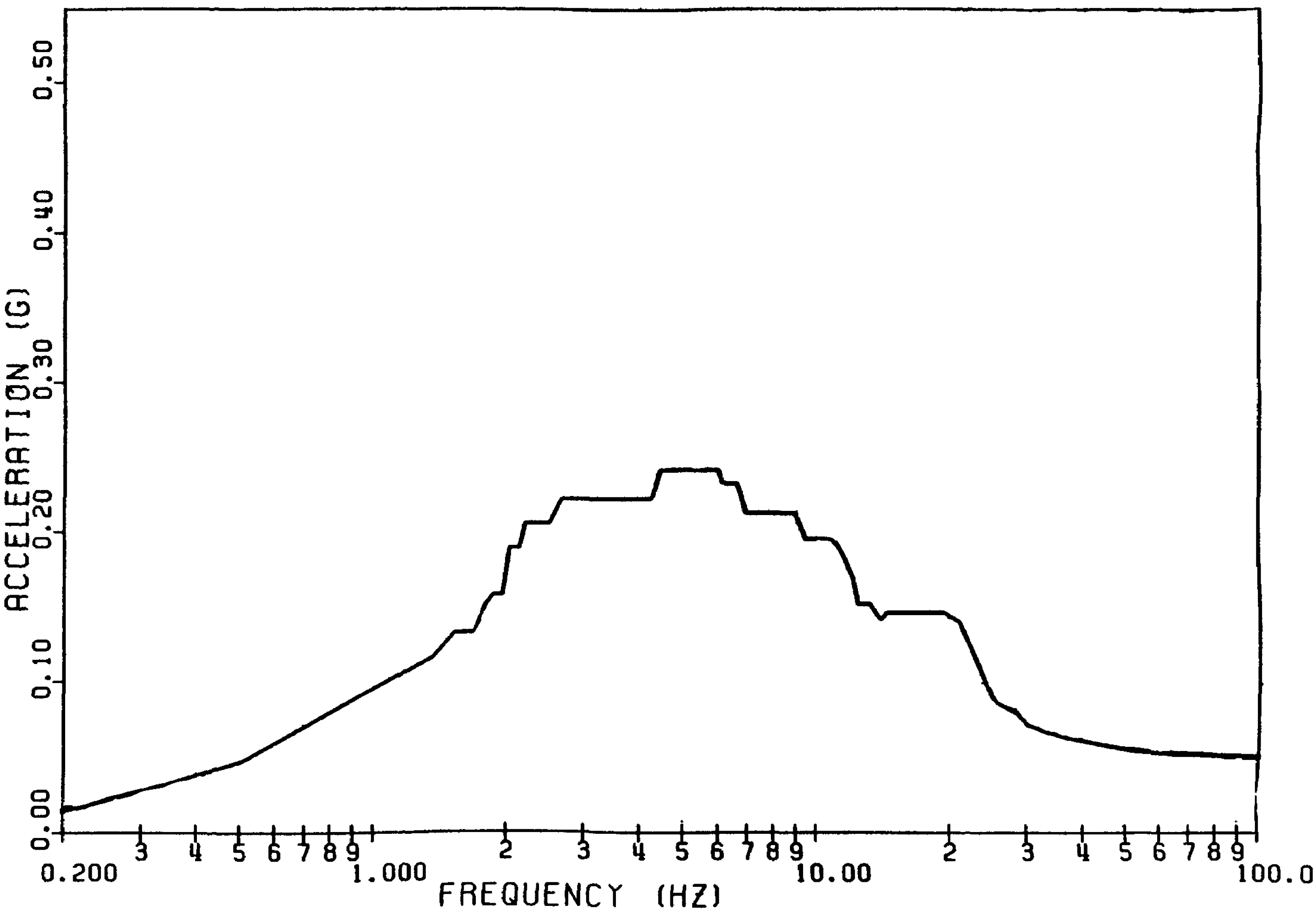
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL (DIESEL 'A-D')
VERTICAL OBE

FIGURE 3.7B-78, Rev. 55

Auto-Cad Figure Fsar 3_7B_78.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: VERTICAL
EARTHQUAKE: OBE
DAMPING: 0.020

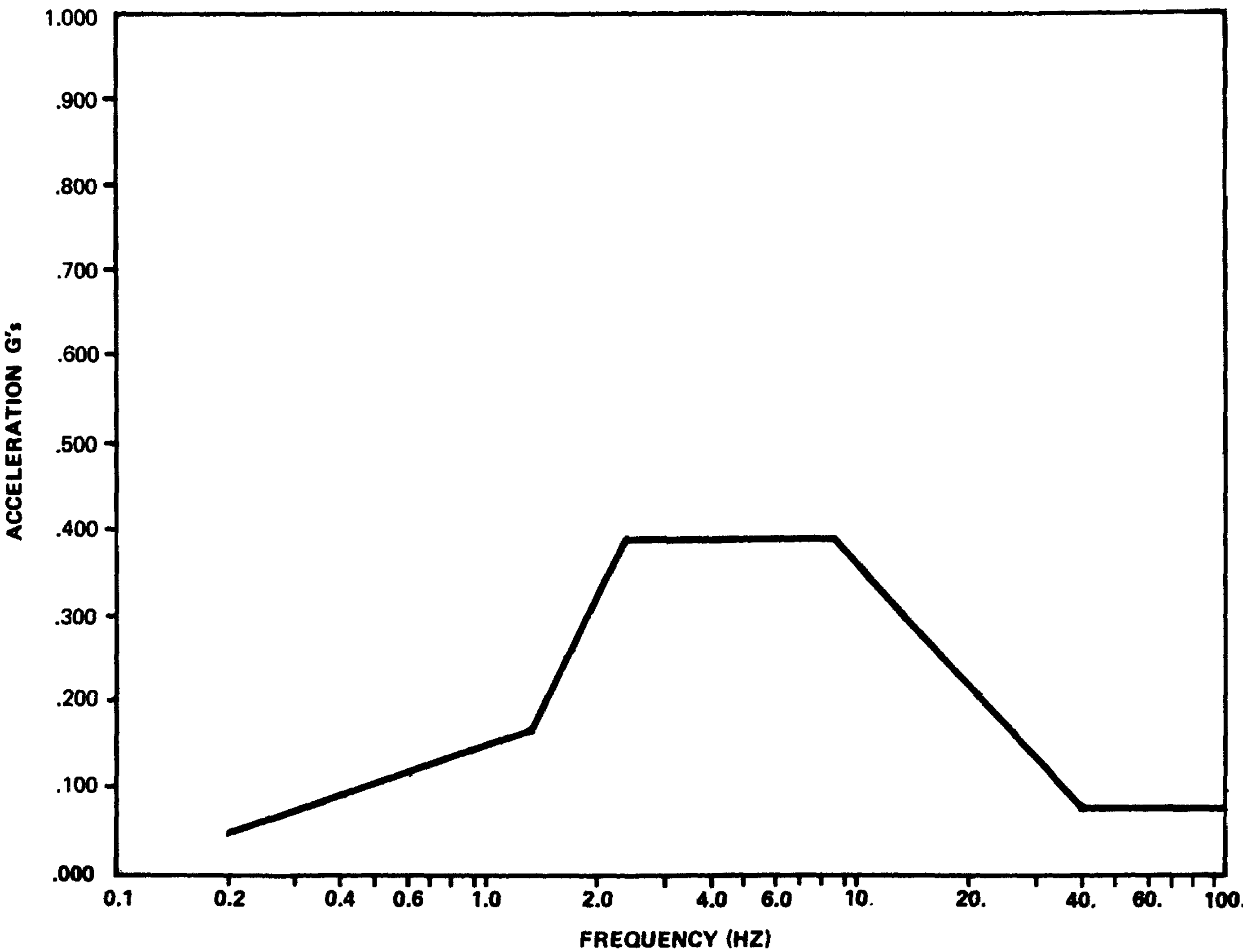
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL FOR DIESEL 'E'
VERTICAL OBE

FIGURE 3.7B-79, Rev. 55

Auto-Cad Figure Fsar 3_7B_79.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL 'A-D'
DIRECTION: VERTICAL
EARTHQUAKE: SSE
DAMPING: 0.010

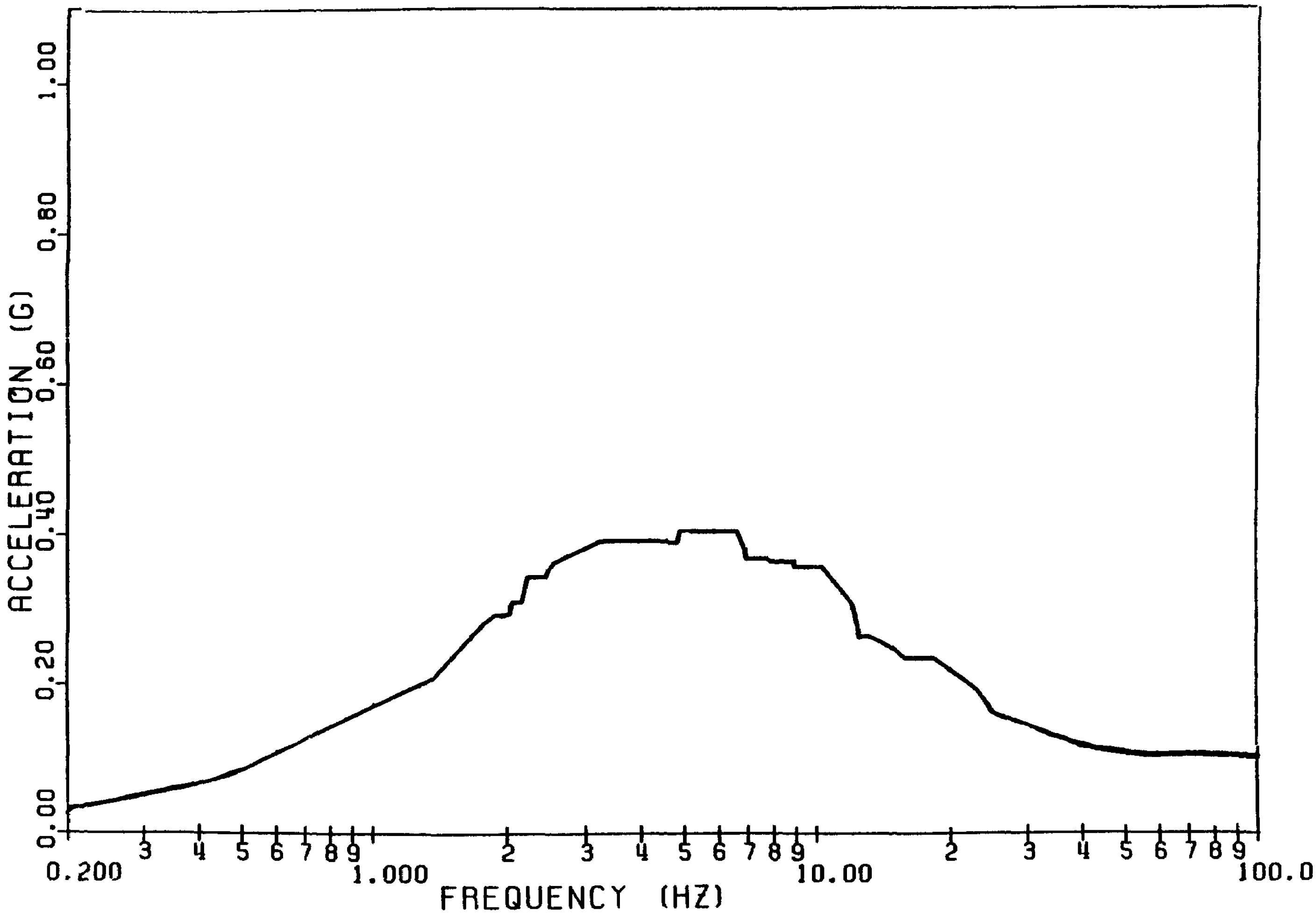
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL (DIESEL 'A-D')
VERTICAL SSE

FIGURE 3.7B-80, Rev. 55

Auto-Cad Figure Fsar 3_7B_80.dwg



LOCATION: TOP OF PEDESTAL FOR DIESEL E
DIRECTION: VERTICAL
EARTHQUAKE: SSE
DAMPING: 0.030

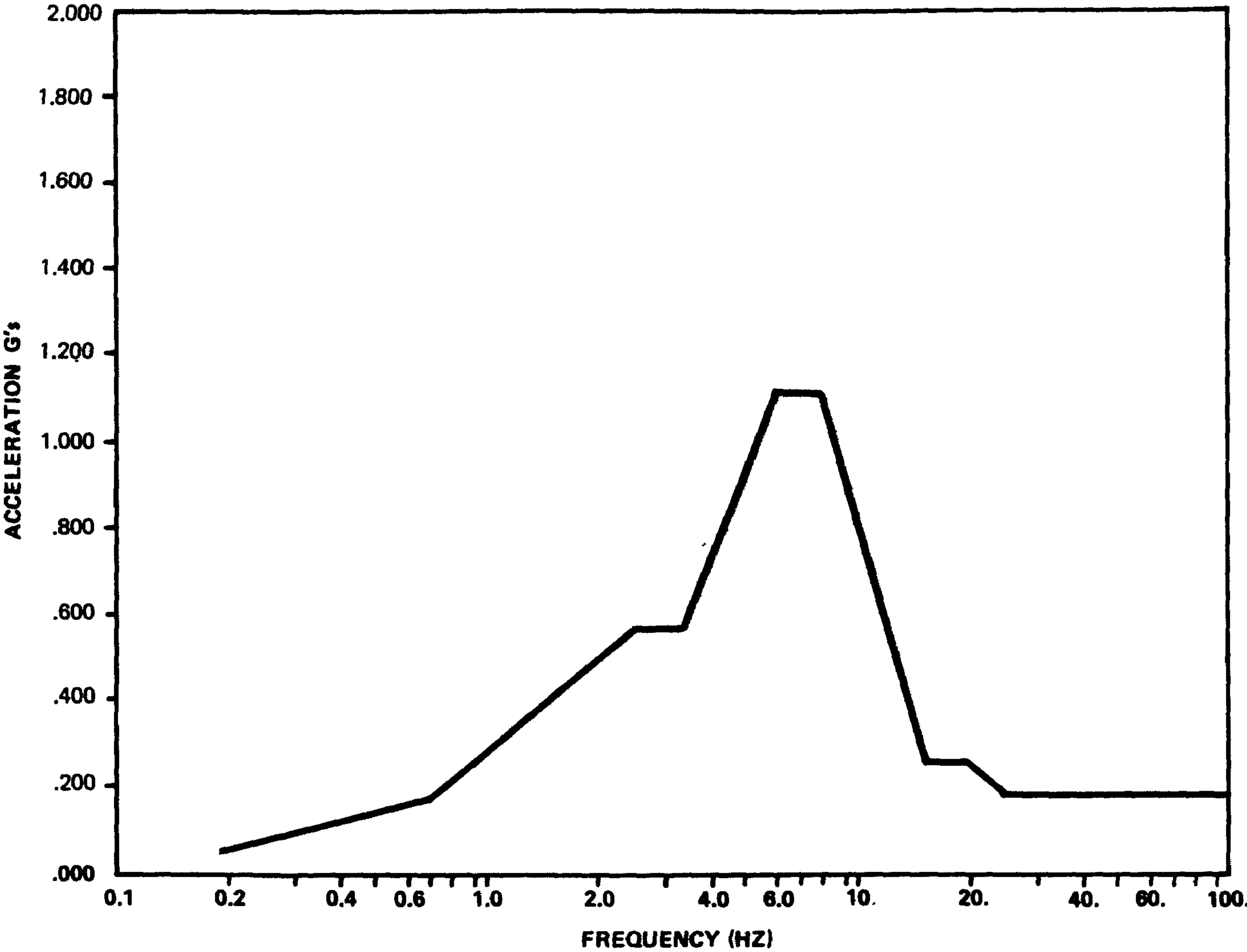
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT TOP OF PEDESTAL
FOR DIESEL GENERATOR 'E'
VERTICAL SSE

FIGURE 3.7B-81, Rev. 55

Auto-Cad Figure Fsar 3_7B_81.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: E-W
EARTHQUAKE: OBE
DAMPING: 0.005

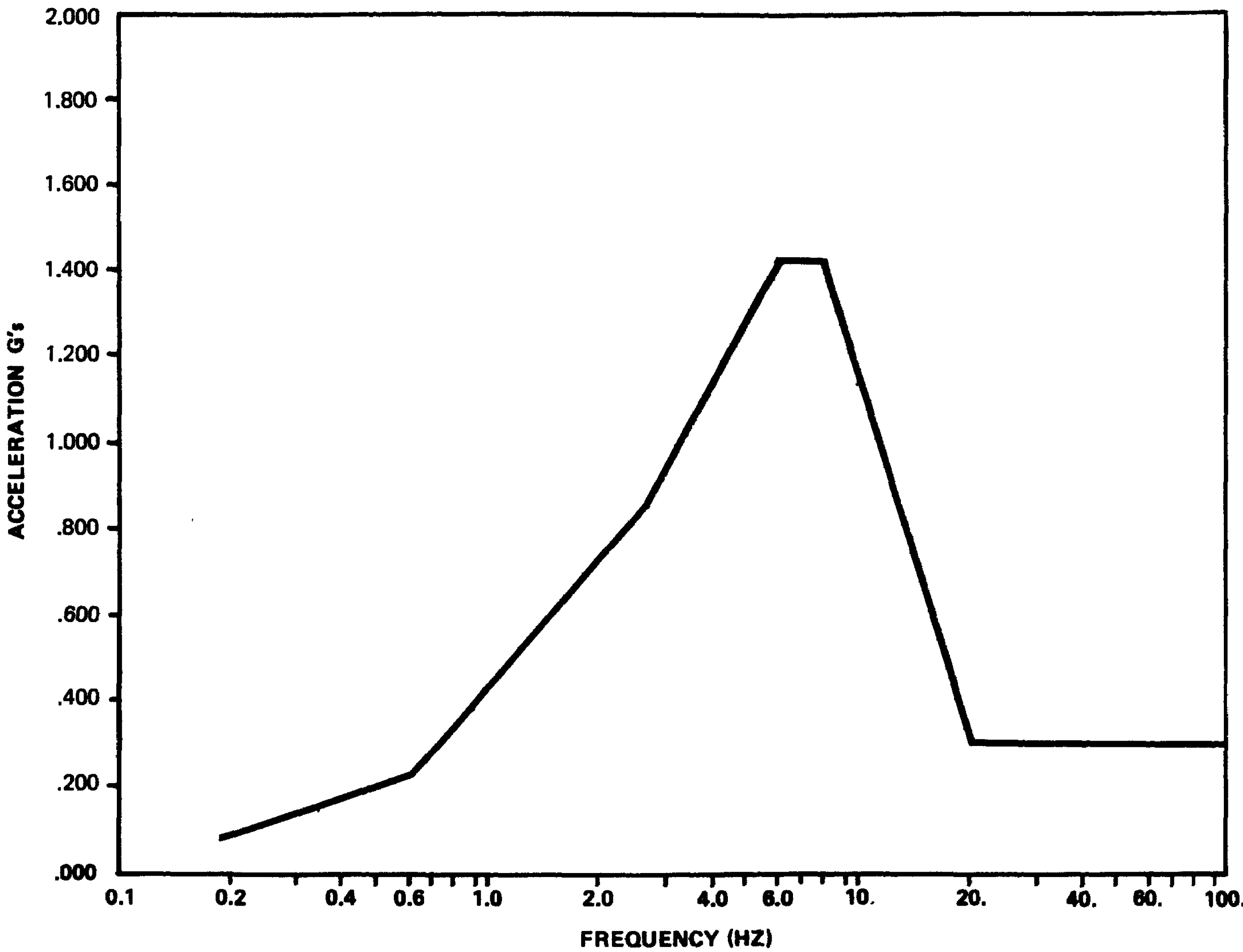
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
E-W OBE

FIGURE 3.7B-82, Rev. 55

Auto-Cad Figure Fsar 3_7B_82.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: E-W
EARTHQUAKE: SSE
DAMPING: 0.010

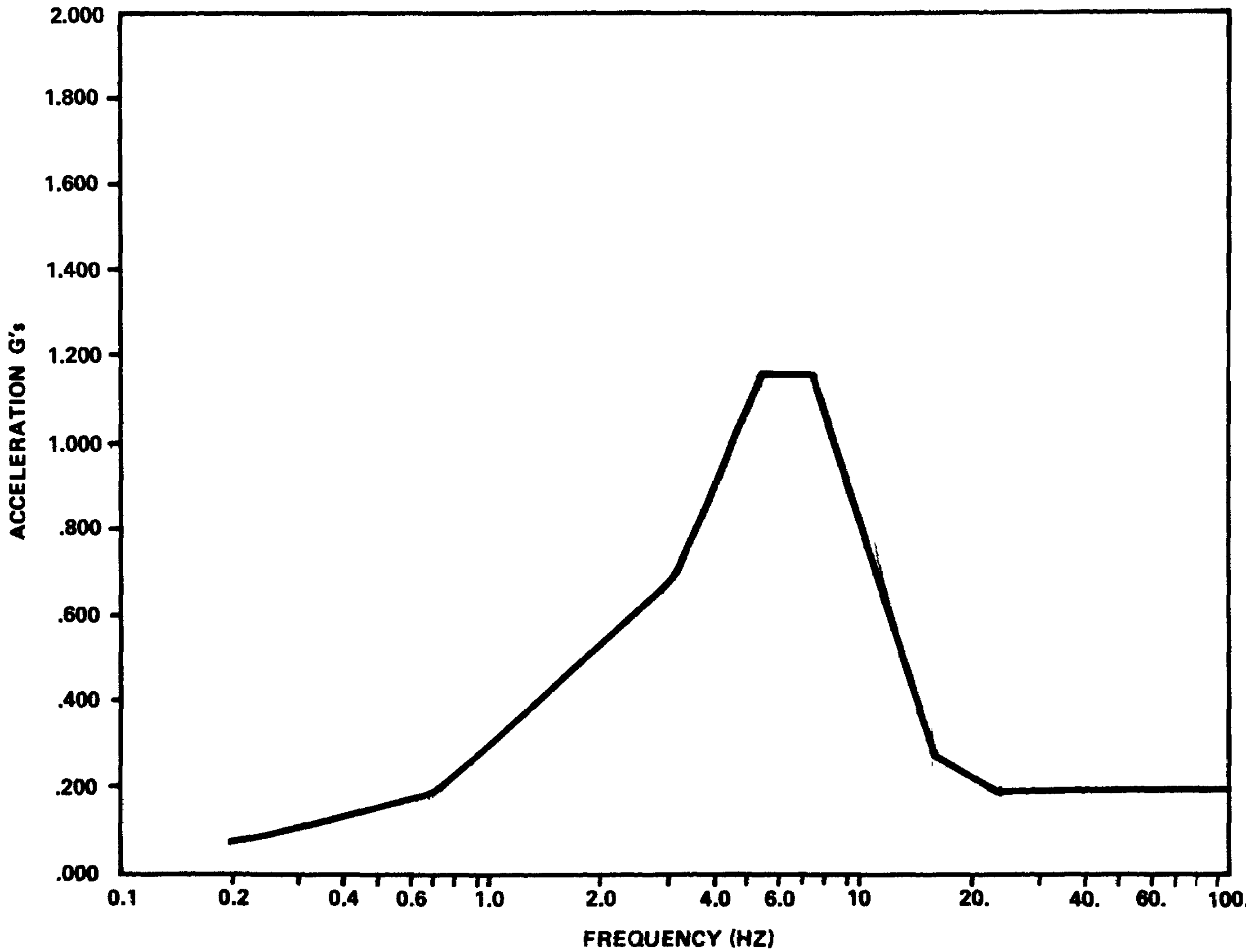
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
E-W SSE

FIGURE 3.7B-83, Rev. 55

Auto-Cad Figure Fsar 3_7B_83.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: N-S
EARTHQUAKE: OBE
DAMPING: 0.005

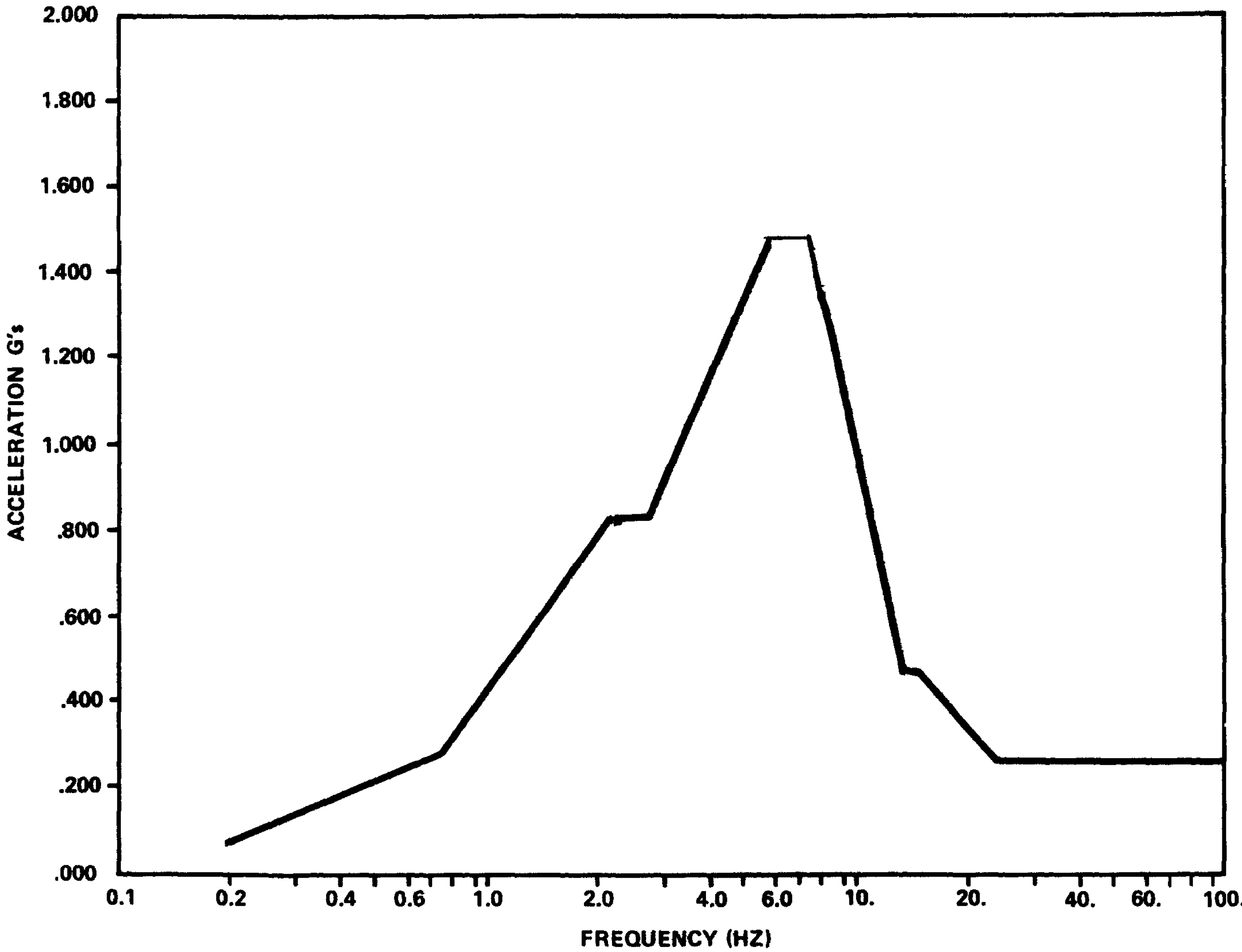
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
N-S OBE

FIGURE 3.7B-84, Rev. 55

Auto-Cad Figure Fsar 3_7B_84.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: N-S
EARTHQUAKE: SSE
DAMPING: 0.010

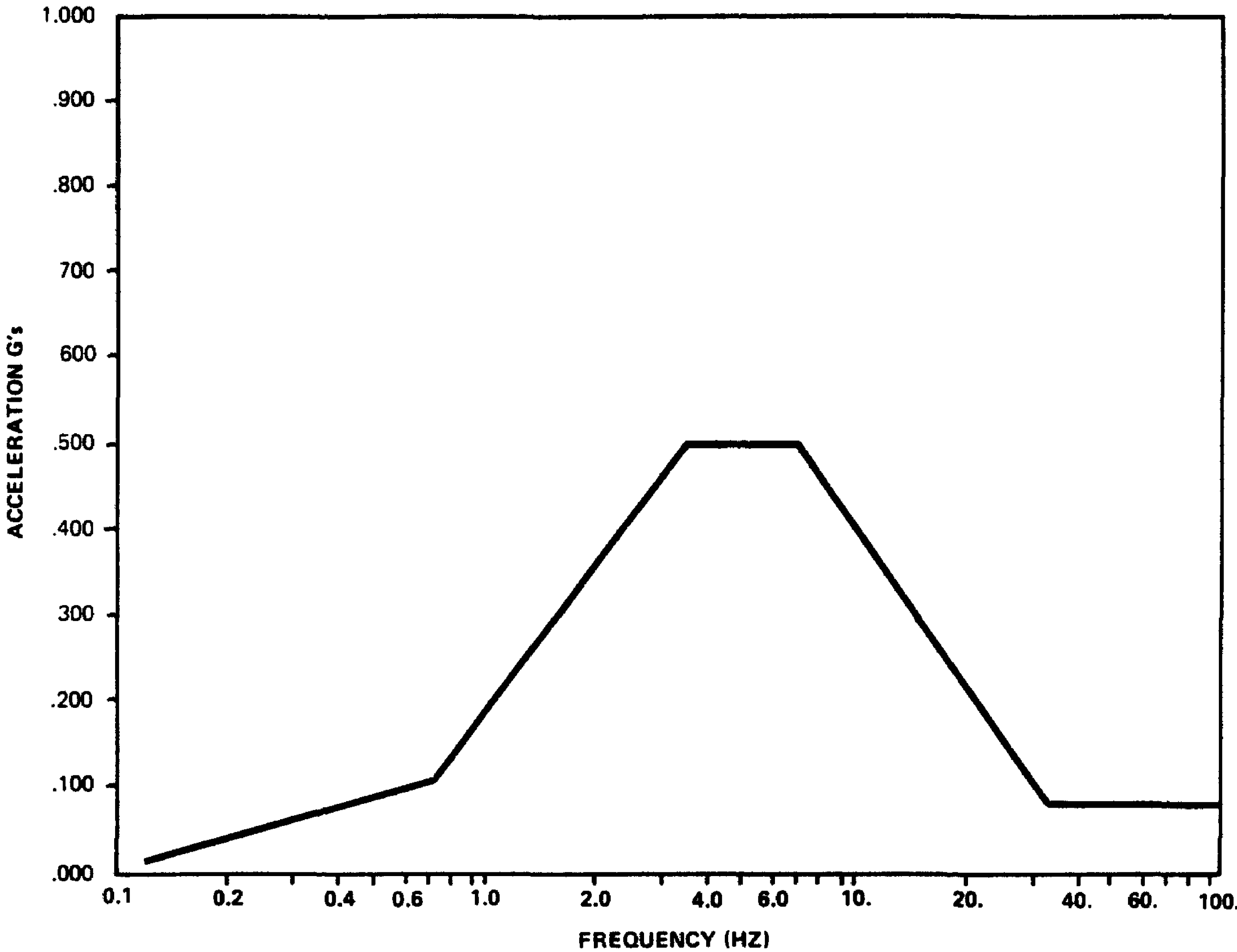
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
N-S SSE

FIGURE 3.7B-85, Rev. 55

Auto-Cad Figure Fsar 3_7B_85.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: VERTICAL
EARTHQUAKE: OBE
DAMPING. 0.005

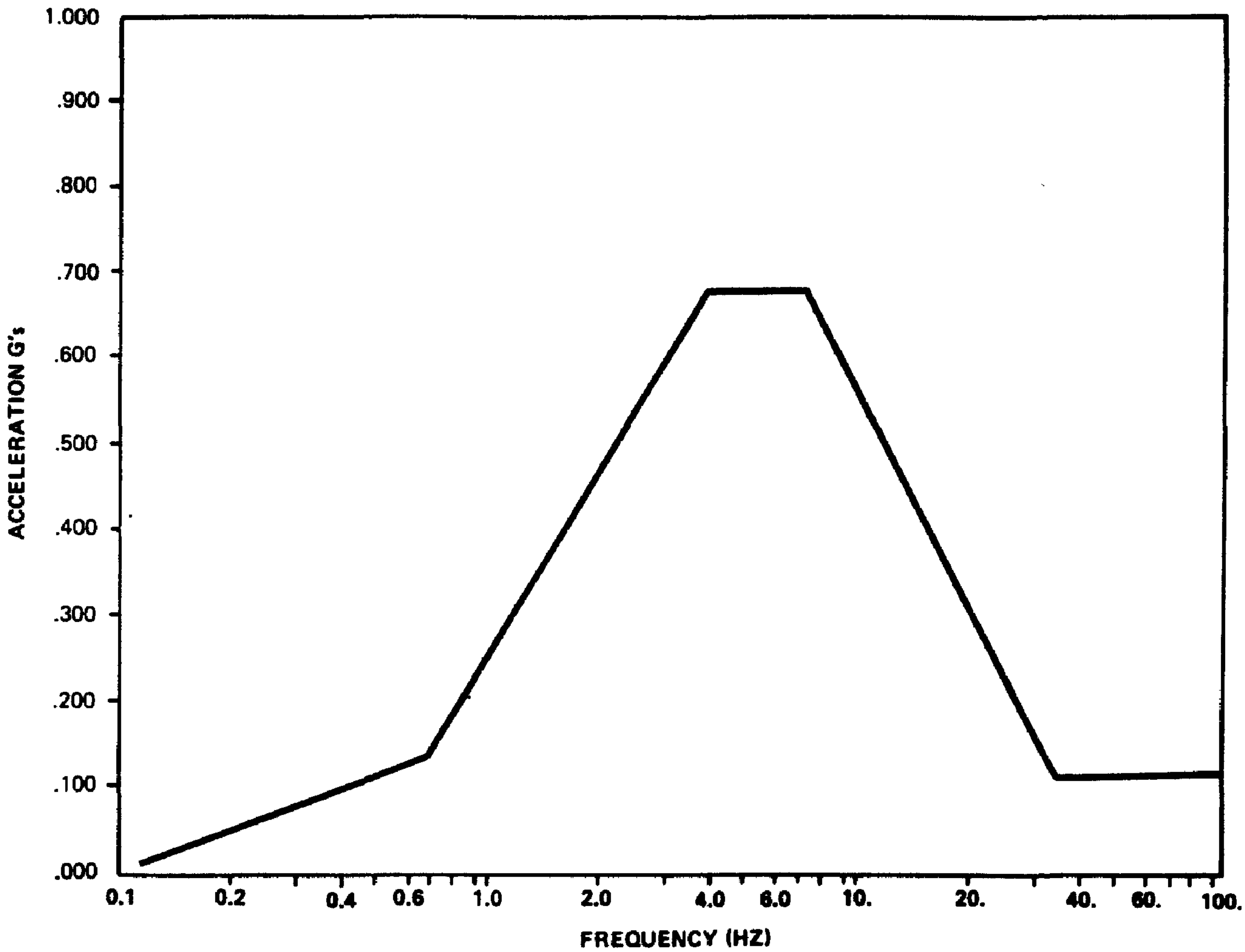
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
VERTICAL OBE

FIGURE 3.7B-86, Rev. 55

Auto-Cad Figure Fsar 3_7B_86.dwg



LOCATION: ESSW PUMPHOUSE (OPERATING FLOOR)
DIRECTION: VERTICAL
EARTHQUAKE: SSE
DAMPING: 0.010

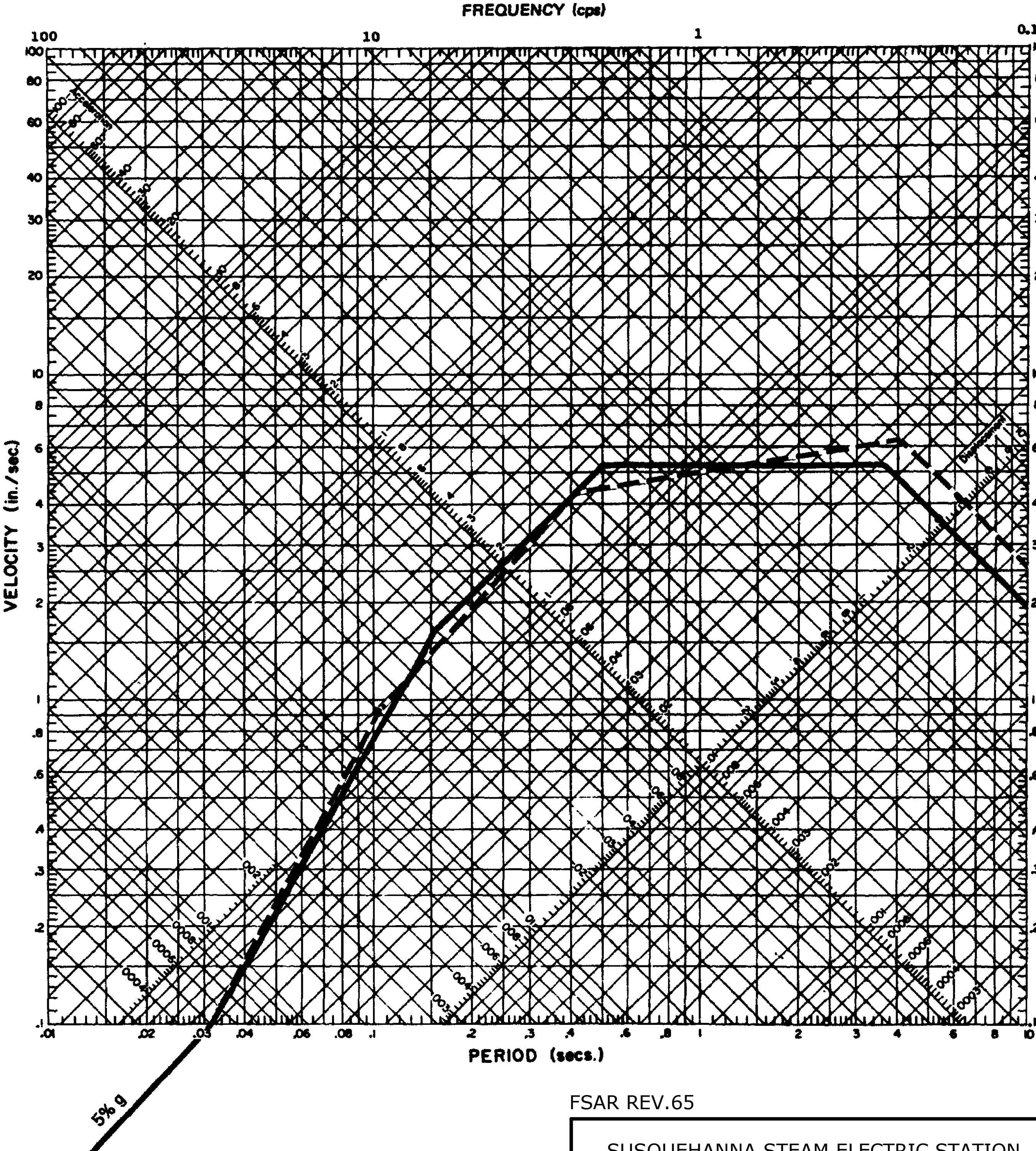
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RESPONSE SPECTRUM
AT OPERATING FLOOR OF ESSW
PUMPHOUSE
VERTICAL SSE

FIGURE 3.7B-87, Rev. 55

Auto-Cad Figure Fsar 3_7B_87.dwg



— DESIGN SPECTRUM (2% DAMPING) FOR ALL ROCK FOUNDED SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING

— — R.G. 1.60 SPECTRUM (4% DAMPING) USED FOR THE DESIGN OF THE DIESEL GENERATOR 'E' BUILDING

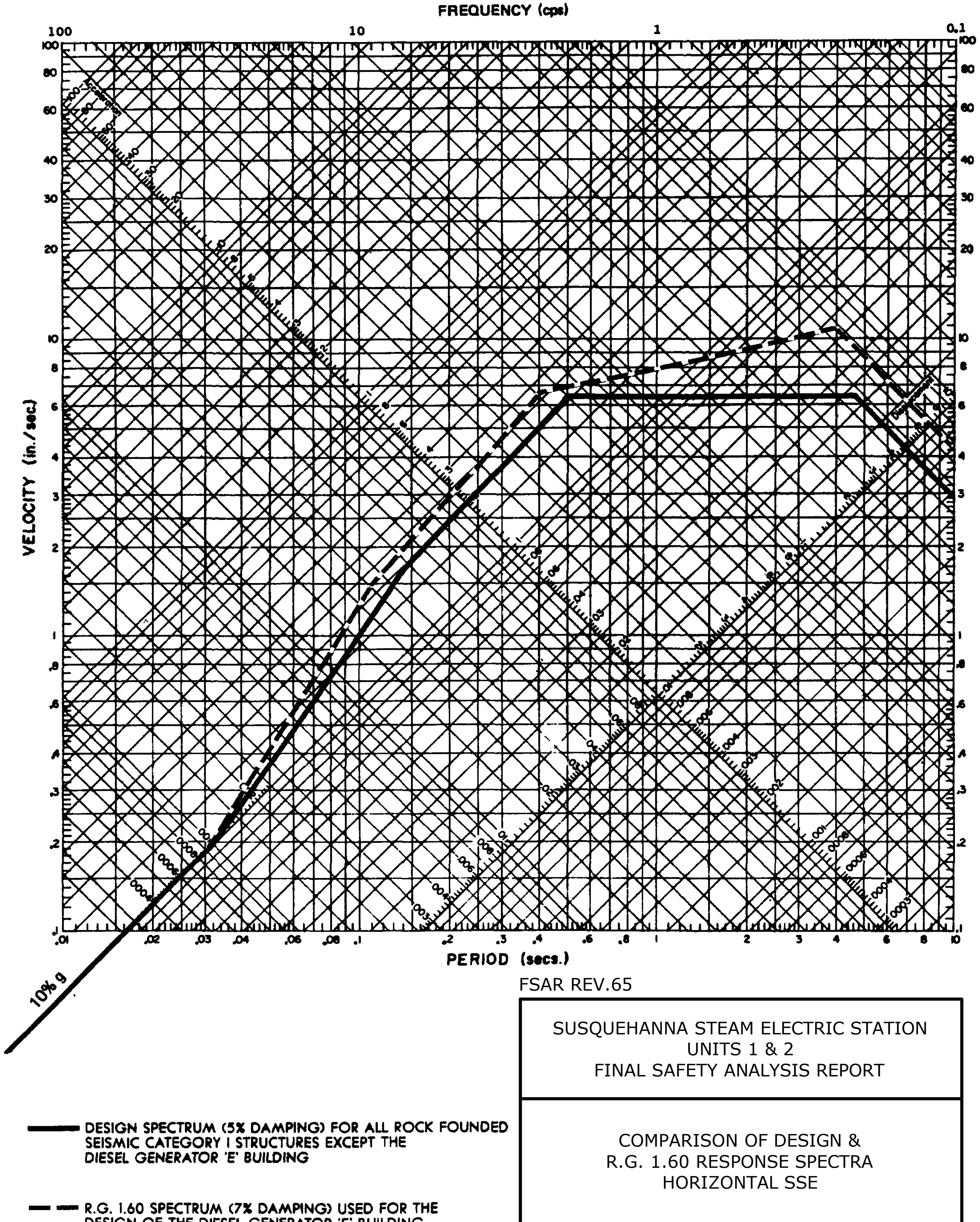
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF DESIGN &
R.G. 1.60 RESPONSE SPECTRA
HORIZONTAL OBE

FIGURE 3.7B-88, Rev. 55

Auto-Cad Figure Fsar 3_7B_88.dwg



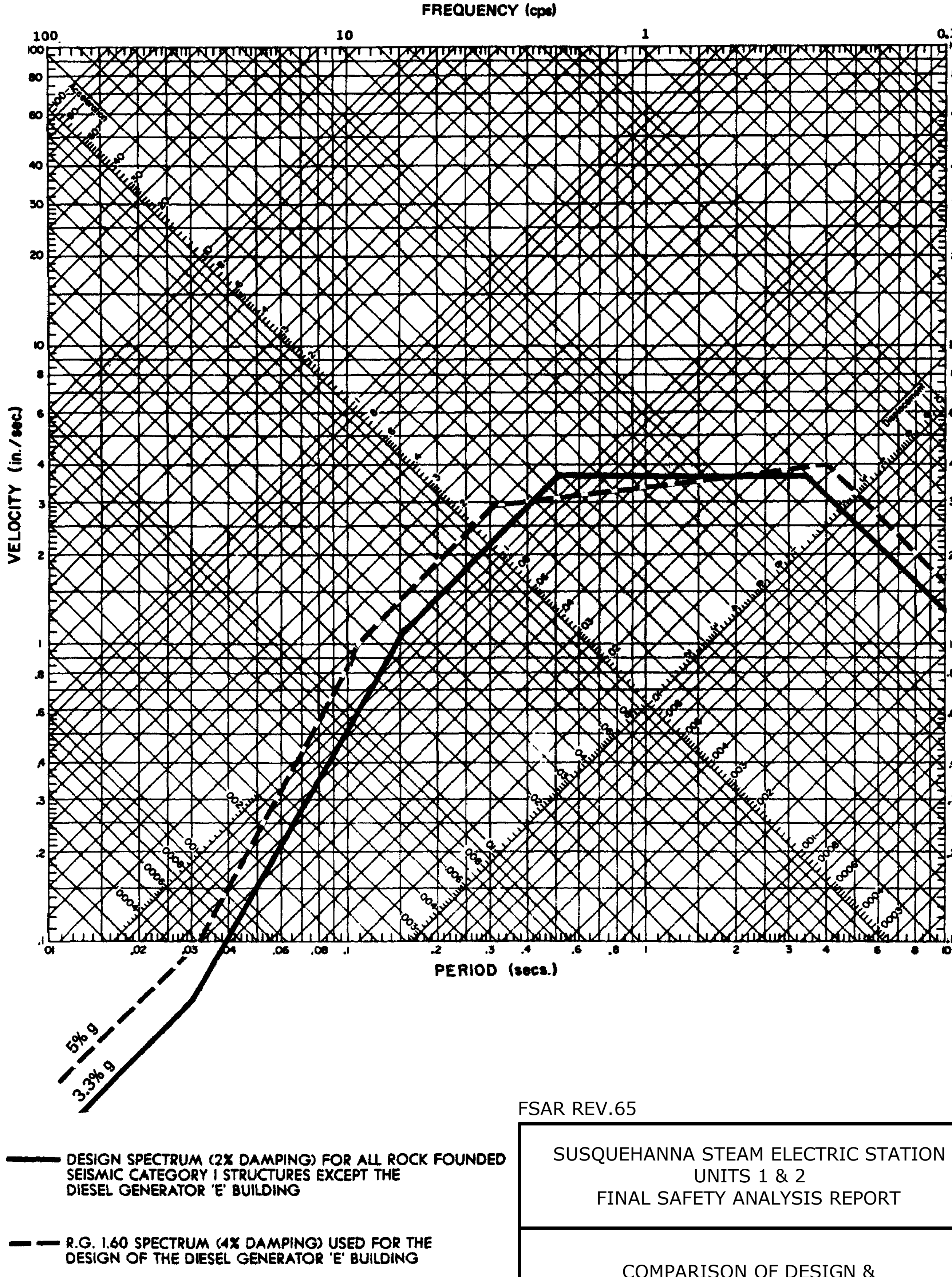
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF DESIGN &
R.G. 1.60 RESPONSE SPECTRA
HORIZONTAL SSE

FIGURE 3.7B-89, Rev. 55

Auto-Cad Figure Fsar 3_7B_89.dwg



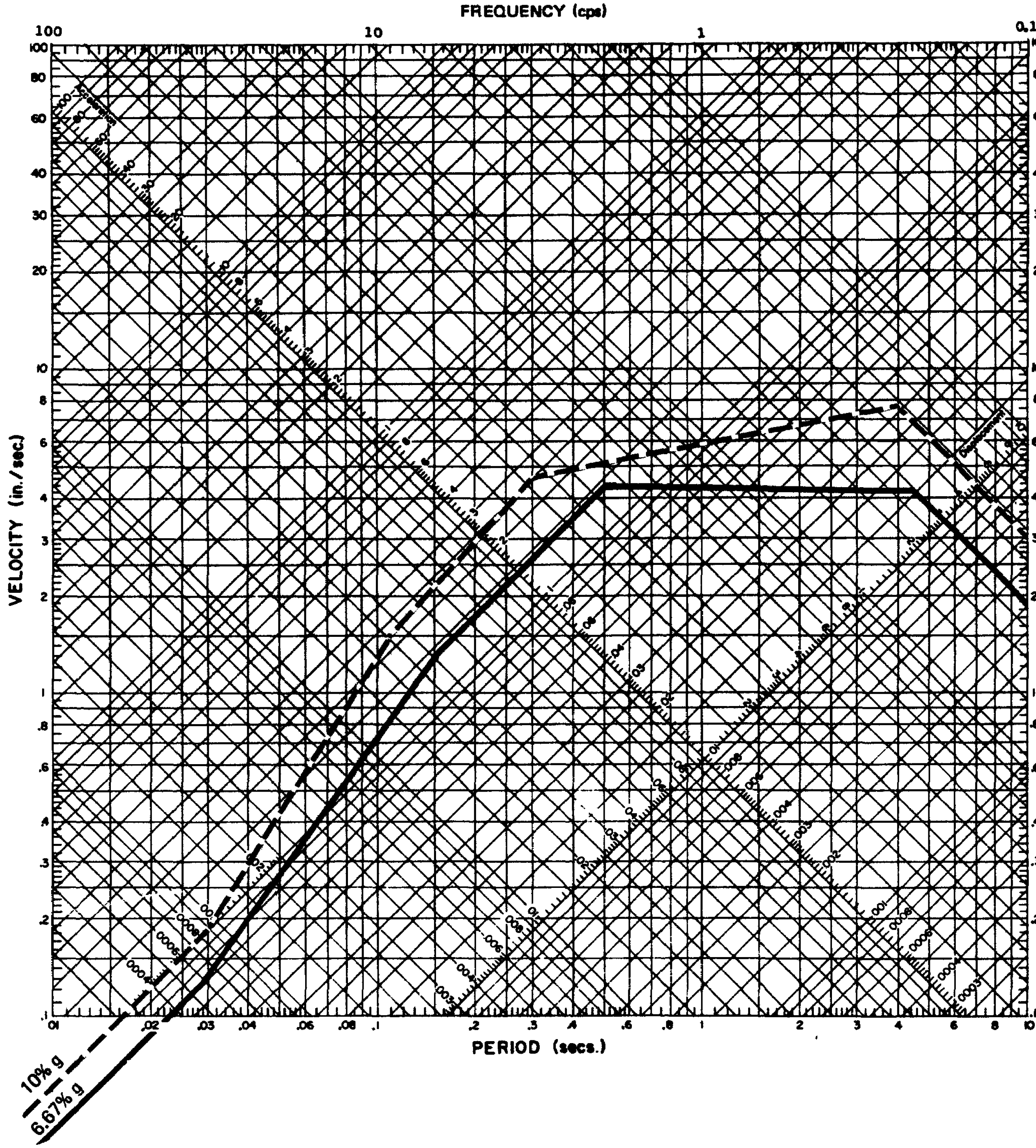
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF DESIGN &
R.G. 1.60 RESPONSE SPECTRA
VERTICAL OBE

FIGURE 3.7B-90, Rev. 55

Auto-Cad Figure Fsar 3_7B_90.dwg



DESIGN SPECTRUM (5% DAMPING) FOR ALL ROCK FOUNDED SEISMIC CATEGORY I STRUCTURES EXCEPT THE DIESEL GENERATOR 'E' BUILDING

R.G. 1.60 SPECTRUM (7% DAMPING) USED FOR THE DESIGN OF THE DIESEL GENERATOR 'E' BUILDING

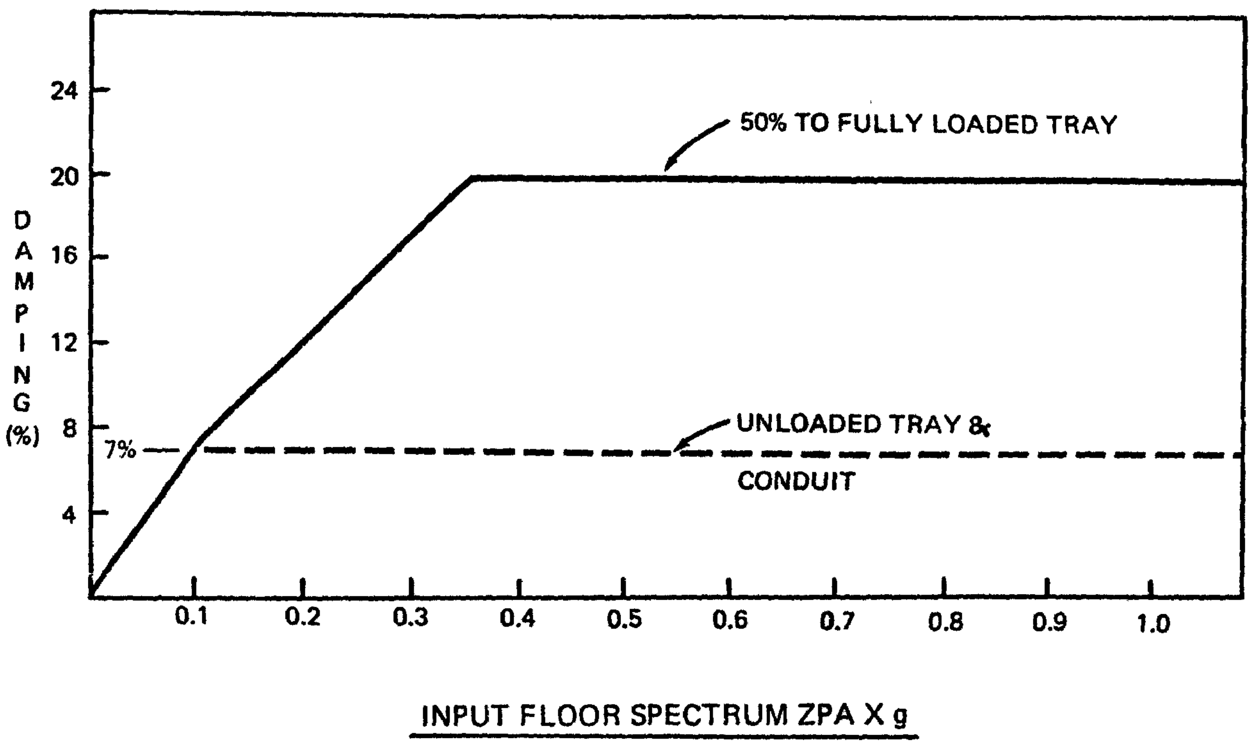
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

COMPARISON OF DESIGN &
R.G. 1.60 RESPONSE SPECTRA
VERTICAL SSE

FIGURE 3.7B-91, Rev. 55

Auto-Cad Figure Fsar 3_7B_91.dwg



SOURCE: REF. 3.7b-7

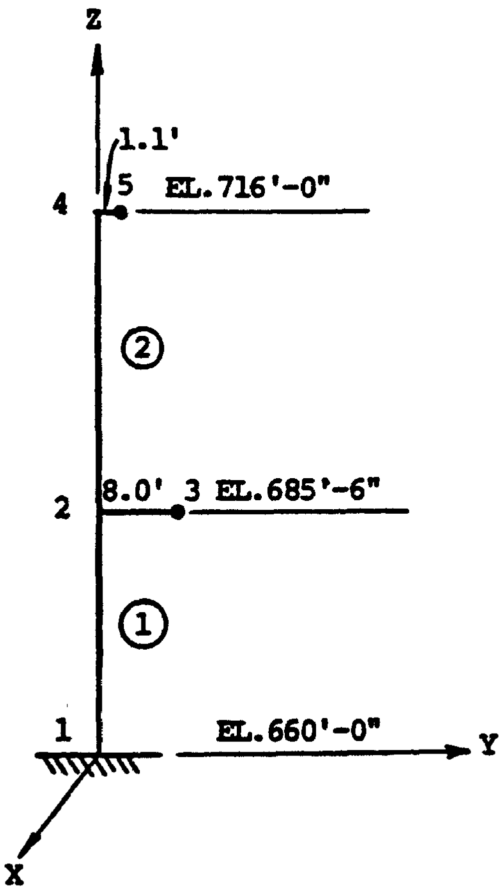
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DAMPING V/S ZPA FOR
RACEWAY SYSTEM

FIGURE 3.7B-92, Rev. 55

Auto-Cad Figure Fsar 3_7B_92.dwg



MASSES AT NODES 3 AND 5

COORDINATES			
NODES	X	Y	Z
1	0.0	0.0	660.0
2	0.0	0.0	685.5
3	0.0	8.0	685.5
4	0.0	0.0	716.0
5	0.0	1.1	716.0

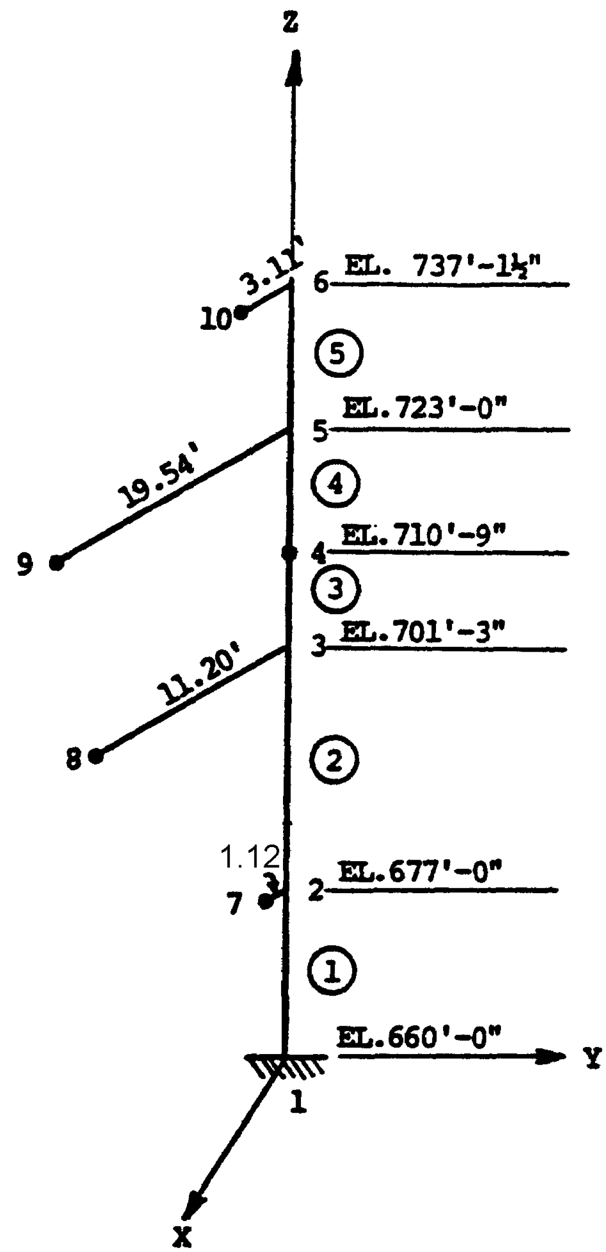
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

ESSW
PUMPHOUSE
3-D STICK MODEL

FIGURE 3.7B-93, Rev. 55

Auto-Cad Figure Fsar 3_7B_93.dwg



MASSES AT NODES 4,8,9,10

COORDINATES			
NODES	X	Y	Z
1	0.0	0.0	660.0
2	0.0	0.0	677.0
3	0.0	0.0	701.3
4	0.0	0.0	710.8
5	0.0	0.0	723.0
6	0.0	0.0	737.1
7	0.5	-1.0	677.0
8	8.9	-6.8	701.3
9	19.5	-1.3	723.0
10	0.3	-3.1	737.1

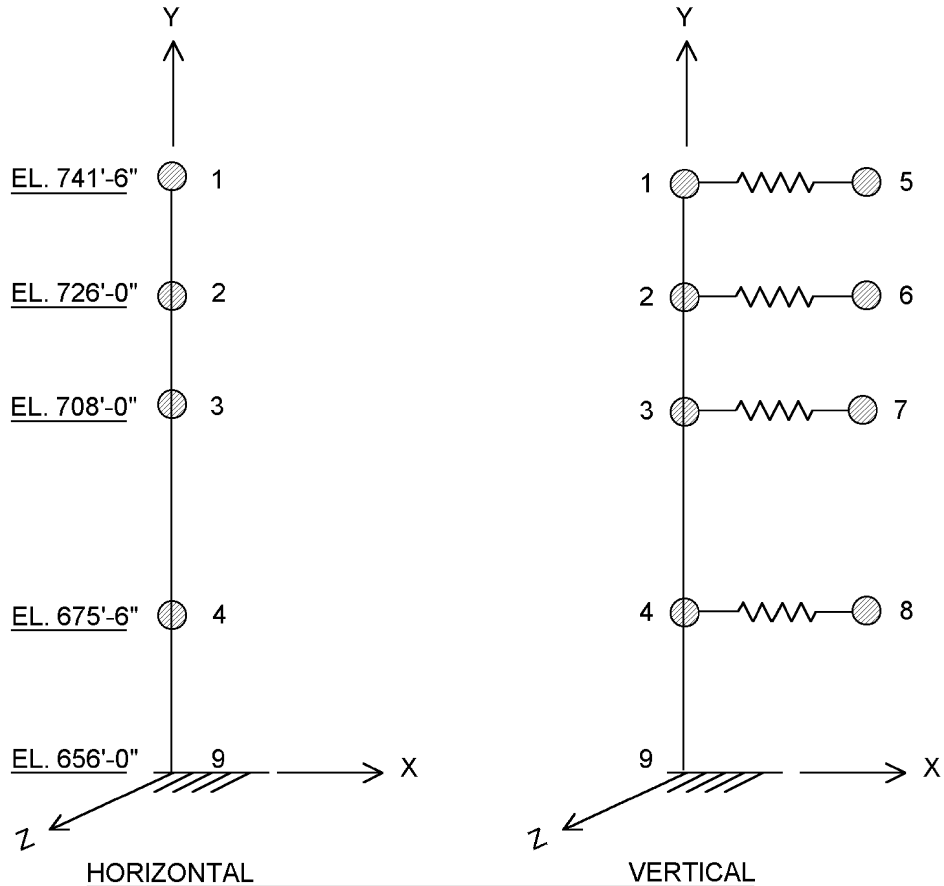
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR
'A-D' BUILDING
3D STICK MODEL

FIGURE 3.7B-94, Rev. 56

Auto-Cad Figure Fsar 3_7B_94.dwg



NODES	COORDINATES (ft)		
	X	Y	Z
1.5	25.4	741.5	0
2.6	2.0	726.0	0
3.7	0	708.0	0
4.8	0.6	675.5	-1.0
9	0	656.8	0

FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

DIESEL GENERATOR
'E' BUILDING
SEISMIC MODELS

FIGURE 3.7B-95, Rev. 55

Auto-Cad Figure Fsar 3_7B_95.dwg