Item #1.

EQE
ENGINEERING
CONSULTANTS

SEISMIC REANALYSIS OF REACTOR BUILDING
PILGRIM NUCLEAR POWER STATION

JULY1993

Prepared for:

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EQE

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EQE

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1. INTRODUCTION

This report describes the seismic reanalysis of the Pilgrim Nuclear Power Station (PNPS) Reactor Building as requested by Boston Edison in Reference 1 and subsequent correspondence.

The scope of work consisted of upgrading the Reactor Building dynamic model to current requirements; performing a soil-structure interaction (SSI) analysis using seismic inputs corresponding to (1) Regulatory Guide 1.60 ground response spectra anchored at 0.15g for SSE and 0.08g for OBE, and (2) PNPS FSAR (Housner) ground response spectra anchored at 0.15g for SSE and 0.08g for OBE; and generating new in-structure response spectra suitable for use in future design activities.

The Reactor Building model was revised to be a 3-D model, rather than 2-D as originally developed, incorporating vertical and torsional properties. Mass and stiffness properties were recalculated using plant drawings and equipment locations. Internal structures were modeled separately: (1) the drywell vessel, (2) the torus suppression pool, (3) the biological shield, (4) the reactor pressure vessel, and (5) the reactor pedestal. The building model properties were derived in a QA calculation (Reference 7) with all sources of information documented. A schematic of the dynamic model with elevations for generation of in-structure response specta is shown in Figure 1-1.

The SSI analysis was performed as a 3-D analysis in accordance with current practice. Input time histories to characterize the ground spectra were generated to meet current NRC requirements (Reference 2). Impedances and scattering functions were computed using soil layer properties determined by others (Reference 13). The soil properties were coupled with the upgraded building model for analysis of the coupled soil-structure system. Soil parameters were varied in accordance with Reference 2.

New in-structure response spectra were generated for both ground spectrum inputs (Regulatory Guide 1.60 and PNPS FSAR) and for SSE and OBE. The new spectra were generated at the points contained in BECo Specification C-114, the torus, and El. 27.17 on the drywell vessel. For the main building floor elevations, the new spectra consist of an envelope of the center of mass location and the four extreme corners of the floors in order to capture torsional effects. The spectra for the torus is an envelope of four points around the circumference of the vessel. All spectra envelop the best estimate, upper bound, and lower bound soil cases, and are broadened in accordance with current criteria. A flow chart of the analysis process is shown in Figure 1-2. The computer programs used in each step are shown in parenthesis in each box.

The new spectra for the Regulatory Guide 1.60 SSE ground spectrum input are contained in Attachment A to this report. All analysis was performed and documented in accordance with EQE QA procedures. Computer program inputs and outputs are saved on electronic media.

The following personnel performed work on this project:

- Modelling
  - Paul Baughman
  - James White
  - Gordon Bjorkman
- Analysis
  - Alejandro Asfura
  - David Doyle
  - Basilio Sumodobilia
- Design Review
  - James Johnson

Their resumes are contained in Attachment B to this report.

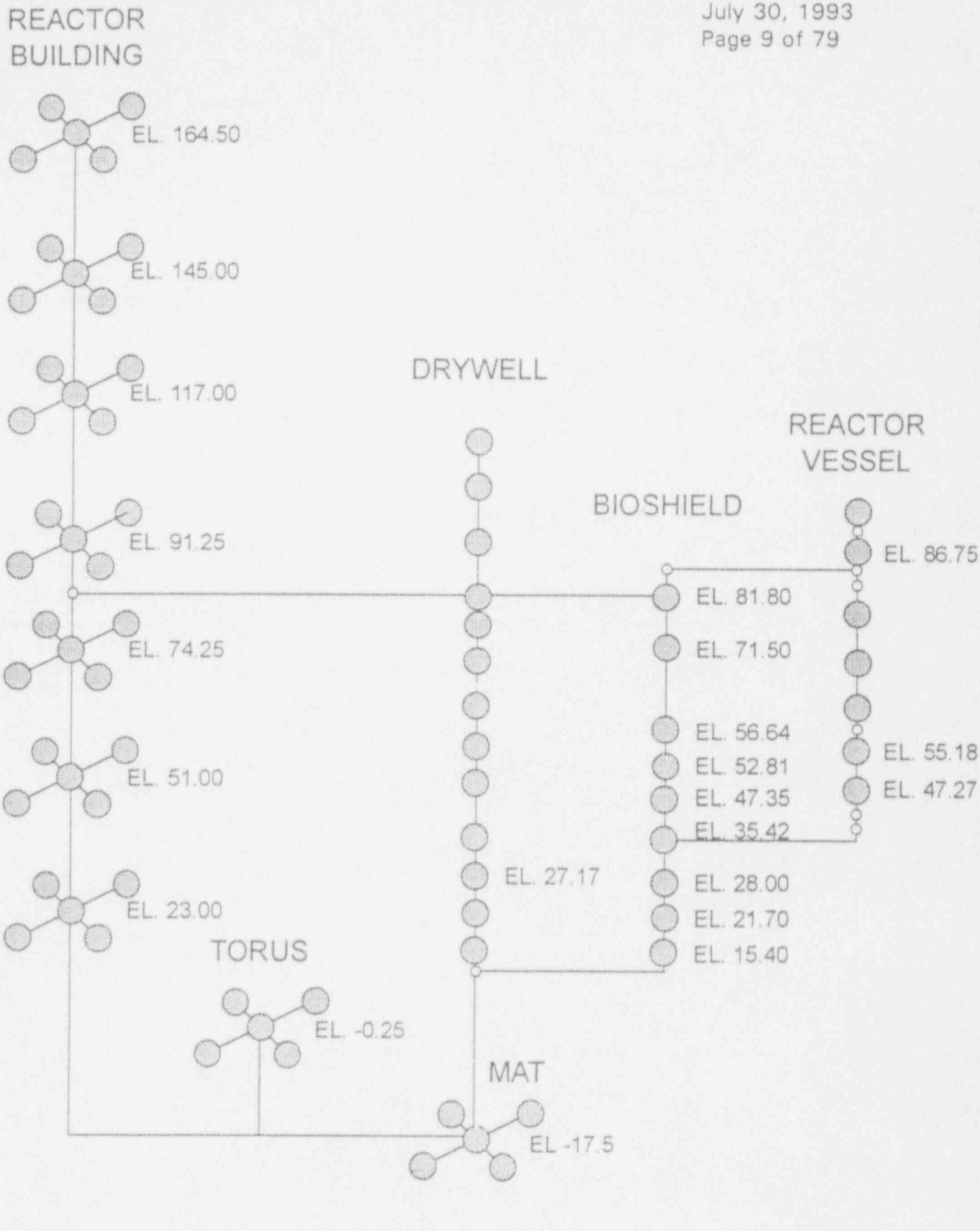

REACTOR
BUILDING
EL. 164.50
EL. 145.00
EL. 117.00
EL. 91.25
EL. 74.25
EL. 51.00
EL. 23.00
DRYWELL
EL. 27.17
REACTOR
VESSEL
BIOSHIELD
EL. 86.75
EL. 81.80
EL. 71.50
EL. 56.64
EL. 52.81
EL. 47.35
EL. 35.42
EL. 28.00
EL. 21.70
EL. 15.40
EL. 55.18
EL. 47.27
TORUS
EL. -0.25
MAT
EL -17.5

Figure 1-1


GROUND RESPONSE SPECTRUM
LOW STRAIN SOIL PROFILE
STRUCTURE MODEL
GENERATE TIME HISTORY TO FIT GROUND RESP SPECTRUM (FIT)
GENERATE HIGH STRAIN SOIL PROPS BEST EST, UP BND, LWR BND (SHAKE)
GENERATE IMPEDENCES, SCATTERING FUNCTIONS (SUPELM)
COMPUTE STRUCTURE DYNAMIC RESPONSE CHARACTERISTICS (MODSAP)
CHECK STRONG MOTION DURATION (ARIAS)
GENERATE TIME HISTORIES AT FOUNDATION LEVEL (SHAKE)
CALULATE STRUCTURAL RESPONSE OF COUPLED SOIL-STRUCTURE SYSTEM (SSIN)
CONVERT MODSAP OUTPUT TO SSIN INPUT FORMAT (INSSIN)
COMPUTE FOURIER SPECTRUM G2/DURATION (FOURIER)
GENERATE RESPONSE SPECTRUM AT FOUNDATION LEVEL (RSPEC)
CALCULATE RESPONSE SPECTRA FROM NODAL TIME HISTORIES (RSPEC)
NO
DURATION AND PSD SATISFACTORY?
YES
NO
FOUNDATION RESPONSE SPECTRUM ENVS 80% OF GRS?
YES
BROADEN RESPONSE SPECTRA (BROAD)
ENVELOP SPECTRA FLOOR EXTREMES THREE SOIL CASES (RSENV)
PLOT FINAL FLOOR RESPONSE SPECTRA (RSPLT)

Figure 1-2

2. TECHNICAL APPROACH

2.1 Overview

In this chapter, the technical process used by EQE to perform the soil-structure interaction (SSI) analysis of the PNPS Reactor Building is described. The major tasks involved in the seismic analysis of the PNPS Reactor Building are described here in general terms.

In the last decade, significant advances have been made in the area of SSI analysis. Better and more theoretically sound SSI analysis techniques have been developed and implemented, and experience has been gained in their use. Theoretical developments and experimental programs have furthered the understanding of the combined behavior of soil-structure systems with the spatial variation of ground motions. Better and more efficient techniques have been developed for the generation of site-specific seismic motions, and a significant amount of data has been collected. Questions regarding the location of the control motion for the analyses, acceptable radiation damping, soil material behavior, variability of the soil and structure properties have been addressed with analytical and experimental studies. All of these advances have culminated in regulatory revisions as evidenced by Revision 2 of the USNRC Standard Review Plan (SRP), Section 3.7, NUREG-0800 (Reference 2).

The overall approach is described here in the context of the substructure method to SSI. The substructure approach is particularly attractive for SSI analysis. It separates the SSI problem into a series of simpler problems, solves each independently, and superimposes the results. This approach allows one to examine meaningful intermediate results and perform sensitivity studies in a cost-effective fashion. The elements of the substructure approach as applied to structures subjected to earthquake excitations are: (1) specifying the free-field ground motion; (2) defining the soil profile; (3)

performing site response analysis; (4) calculating the foundation input motion; (5) calculating the foundation impedances; (6) determining the dynamic characteristics of the structure; and (7) performing the SSI analysis, i.e., combining the previous steps to calculate the response of the coupled soil-structure system. Figure 2-1 shows the several steps schematically. A brief discussion of each of these elements and their applicability to the PNPS Reactor Building is given below.

2.2 Free-field Ground Motion

Specification of the free-field ground motion entails specifying the control point, the frequency characteristics of the control motion (typically, time histories or response spectra), and the spatial variation of the motion. For the PNPS Reactor Building, the free-field ground motions are described by the PNPS FSAR (Housner) and Regulatory Guide 1.60 response spectra applied at finished grade in the free field (Reference 1). The SSI analysis will utilize artificial acceleration time histories generated to the criteria of NRC SRP Section 3.7.1 (Reference 2). Generating the time histories is a simple yet critical task. Any excess conservatism incorporated in the time histories in a frequency range including or close to the principal soil-structure system frequencies will be directly transmitted to the floor response spectra and impact the design and evaluation of plant components. Therefore, the reduction of unnecessary conservatism in the artificial time histories meeting the requirements of the SRP Section 3.7.1 deserves special attention. EQE proprietary computer code FIT has been developed to meet the SRP Section 3.7.1 requirements without introducing unnecessary conservatism by closely matching target response spectra. Figure 2-2 compares a representative response spectrum corresponding to an artificial acceleration time history generated with the program FIT using the horizontal SSE design spectrum at 5% damping for a typical site as the target. A very close match is observed. Figure 2-3 and 2-4 compare the response spectra of artificial acceleration time histories generated with the program FIT using Housner and Regulatory Guide 1.60 as the target spectra. Time histories generated in this fashion closely fit target response spectra, meet the SRP Section 3.7.1 criteria, and are realistic time functions as shown in Figure 2-2. They eliminate unwanted conservatism in the SSI analysis and in the generation of floor response spectra. In addition to enveloping the design response spectra, the artificial time histories must comply with requirements of compatibility of energy distributions with the target motions. To ensure that the artificial time histories do not have frequency ranges with deficient energy content, the power spectral density functions of the artificial time histories are compared with the requirements of Reference 2.

2.3 Soil Profile

Defining the soil profile for SSI analysis first involves defining the low strain soil properties as a function of depth. This is usually done from site data compiled by the geotechnical engineer. The important parameters for the SSI analysis are soil shear modulus, soil material damping, Poisson's ratio, mass density, and water table location--all as a function of depth in the soil. An additional aspect of defining the soil properties is the variation in soil shear modulus and soil material damping with shear strain level, i.e., the reduction in shear modulus and the increase in damping as shear strain increases. The low strain soil profile for this work was provided by Boston Edison (Reference 13).

2.4 Site Response Analysis

A site response analysis serves two purposes: (1) estimate shear strain compatible equivalent linear soil properties, and (2) calculate motions at foundation depth in the free field to compare with SRP requirements.

The generation of shear-strain compatible soil properties is an important step in the SSI analysis. Strain compatible soil shear modulus and soil material damping will affect the motion at the foundation of the structure and thus the seismic response. It is common practice, lacking site-specific laboratory test data, to use the soil material properties versus shear-strain relationships developed by Seed and Idriss (Reference 3) in conjunction with the computer program SHAKE (Reference 4) to estimate equivalent linear soil properties compatible with the soil shear strains induced by the design basis response spectrum. The program SHAKE is a commonly used and well-accepted program in the nuclear industry for the development of equivalent linear strain compatible soil properties and for the calculation of time histories of motion at any location in the soil column. SHAKE is based upon one-dimensional vertical propagation of shear waves through linear viscoelastic soils consisting of homogeneous horizontal layers extending to infinity in the horizontal direction and overlying a homogeneous half-space. Figure 2-5 shows an example of variations of soil shear wave velocity and soil material damping compatible with soil shear strains obtained with the program SHAKE.

Based on Reference 1, the location of the control motion for the PNPS site is defined in the free field at the ground surface. In anticipation of the need to perform SSI analyses for three soil profiles--a best estimate, a lower range profile, and a higher range profile-- three site response analyses will be performed for each earthquake level (OBE and SSE) and each design response spectrum (PNPS FSAR and Regulatory Guide 1.60).

To comply with the requirement in the SRP Section 3.7.2 (Reference 2) which states that the spectral amplitude of the horizontal acceleration response spectra in the free field at the foundation depth shall be not less than 60% of the corresponding design response spectra at the finished grade in the free field, a site response analysis is performed with the program SHAKE to generate the acceleration time histories (and response spectra) at the free-field foundation level for each of the cases defined above and for each earthquake. Treating each case as a triplet, the three foundation level response spectra are enveloped and the result compared with 60% of the surface spectra. If deficiencies exist that cannot be corrected by slight changes in soil properties, then the control motion will be altered. To do so, the power spectral density functions of the motions at the surface and foundation level are calculated. In the frequency ranges where the foundation level spectra do not meet the SRP 60% requirement, the corresponding frequencies of the foundation level power spectral density function are amplified by the square of the ratio of 0.6 times the surface spectral values to the foundation level spectral values at those noncomplying frequencies. The corrected power spectral density function can then be used to generate a new acceleration time history at the foundation level and, by convolution, a new design time history at the surface level that will fully comply with the 60% requirement. This procedure will minimize the conservatism added in the frequency ranges where the 60% requirement was originally met. Iterations are performed as necessary with the express intent of not adding unnecessary conservatism to the artificial time histories. All SRP Section 3.7 criteria are then reverified.

2.5 Implementation of the Substructure Approach in SSI Analysis

The three remaining steps in the substructure approach (determining the foundation input motion, calculating foundation impedances, and modeling the structure) are discussed next. For this approach to be valid, one important assumption needs to be verified, i.e., that the foundation behaves rigidly with respect to the surrounding soil. This is the case for the PNPS Reactor Building due to the stiffness of the foundation itself and the effective stiffness of the interconnecting walls and slabs.

2.5.1 Foundation Input Motion

The foundation input motion differs from the free-field ground motion in all cases, except for surface foundations subjected to vertically incident waves. The motions differ for two reasons. First, the free-field motion varies with soil depth. Second, the soil-foundation interface scatters waves because points on the foundation are constrained to move according to its geometry and stiffness. The foundation input motion (u^*) is related to the free-field ground motion by means of a transformation defined by a scattering matrix [s(w)], which is complex valued and frequency dependent:

$$\{u^*(w)\} = [s(w)] \; \{f(w)\}$$

The vector {f(w)} is the complex Fourier transform of the free-field ground motion, which contains its complete description.

As already discussed in Section 2.4, the three foundation level response spectra corresponding to the foundation input motion from the three soil cases are enveloped and the result is compared to 60% of the surface spectra. If deficiencies exist that cannot be corrected by slight changes in soil properties, then the control motion is altered.

2.5.2 Foundation Impedances

Foundation impedances $[k_s(w)]$ describe the force-displacement characteristics of the soil. They depend on the soil configuration and material behavior, the frequency of the excitation, and the geometry of the foundation. In general, for a linear elastic or viscoeleastic material and a uniform or horizontally stratified soil deposit, each element of the impedance matrix is complex-valued and frequency dependent. For a rigid foundation, the impedance matrix is a 6 X 6 which relates a resultant set of forces and moments to the six rigid body degrees-of-freedom.

The embedment of the PNPS Reactor Building foundation is one of the most significant parameters on structure response, and modeling this embedment is essential. The computer code SUPELM (Reference 5) is used for this purpose. SUPELM is based on a rigid circular foundation embedded in a layered medium with infinite boundaries. These assumptions are appropriate for the PNPS Reactor Building and equivalent properties are computed. EQE has verified SUPELM under its QA program by comparing to SASSI. SASSI is a well-known computer code which has been reviewed and approved by the NRC for its use in the nuclear industry and has been extensively used for nuclear projects.

Horizontal ground motions are assumed to be composed of vertically propagating shear waves, and vertical ground motions are assumed to be composed of vertically propagating compressional waves. These assumptions are consistent with current practice and it has been demonstrated that they result in realistic structural and soil responses (Reference 3).

2.5.3 Structure Model

Depending on the end use of the SSI analysis, the dynamic model can exhibit various levels of refinement from a detailed member specific model to a single equivalent beam lumped mass model In addition, depending on the complexity of the structure between floors (e.g., curved or skewed wall systems) detailed finite element models can be constructed to derive the equivalent beam properties (shear area, moments of inertia and center of rigidity) or element stiffness matrices. The details of the PNPS Reactor Building model are described in Chapter 3.

Using an appropriate finite element model (i.e., a lumped mass equivalent beam model for spectra generation) the dynamic properties of the structure are described by the fixed-base eigensystem and the individual modal damping ratios. The modal damping ratios are the composite viscous damping ratios for the fixed-base structure expressed as a fraction of critical damping. The structures' dynamic properties are then projected to a point on the foundation at which the total motion of the foundation, including SSI effects, is determined.

2.6 SSI Analysis

The final step in the substructure approach is the actual SSI analysis. The results of the previous steps (foundation input motion, foundation impedances, and structure model) are combined to solve the equations of motion for the coupled soil-structure system. For a single rigid foundation, the SSI response computation requires the solution of, at most, six simultaneous equations - the response of the foundation. Solution is obtained by first representing the response in the structure in terms of the foundation motions and then applying that representation to the equation defining the balance of forces at the soil/foundation interface. The formulation is in the frequency domain. Hence, one can write the equation of motion for the unknown harmonic foundation response $\{u_b\} \exp(i\omega t)$, for any frequency ω, about a reference point selected on the foundation. The computer program SSIN is used to combine the several steps to give the final structure response.

The computer code CLASSI (Continuum Linear Analysis for Soil-structure Interaction) consists of a set of subprograms for analyzing the effect of soil-structure interaction on the response of structures. Basically, the CLASSI program may be divided into two parts, CLAN and SSIN, using a special substructure method developed by Wong and Luco. The CLAN portion applies the theory of linear continuum mechanics to analyze the harmonic interaction between the rigid foundation mat and the underlying soil medium. The information generated by CLAN is the impedance and scattering matrices. The impedance matrix describes the harmonic force-displacement relationship of the response to incident waves. The SSIN part of the program completes the substructuring process by combining the stiffness matrix of the structure at the base level and the impedance matrix to determine the unknown foundation motions and structural responses. For this project, SUPELM is used in place of CLAN, so only the SSIN portion of CLASSI is used.

Time histories generated in the SSI analysis are converted to floor response spectra for each of the three soil cases. The three floor response spectra in each direction are enveloped and then broadened and smoothed according to the requirements specified in SRP 3.7.2 and Regulatory Guide 1.122, considering however that uncertainties in soil properties and SSI will be included in the SSI analysis.

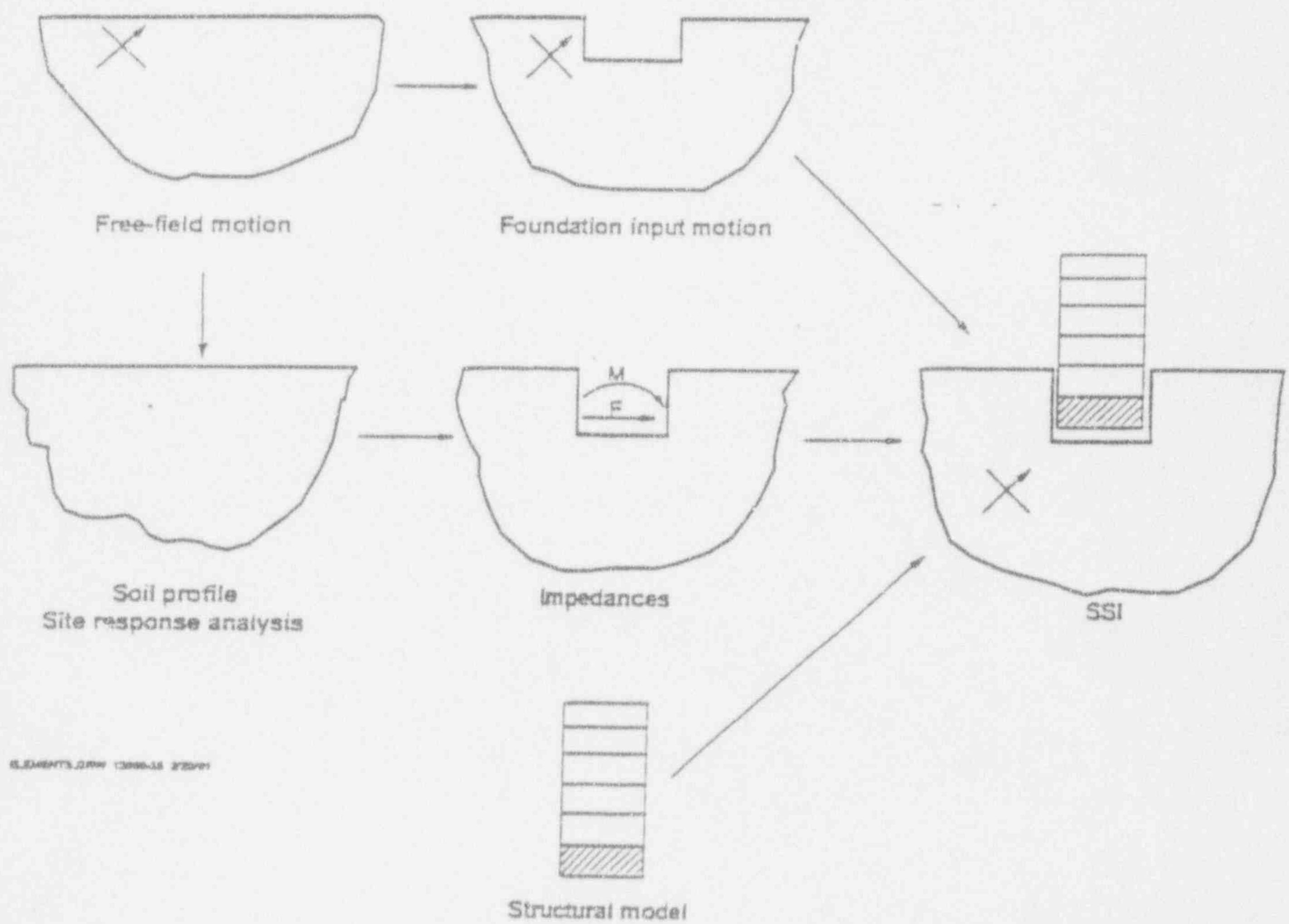
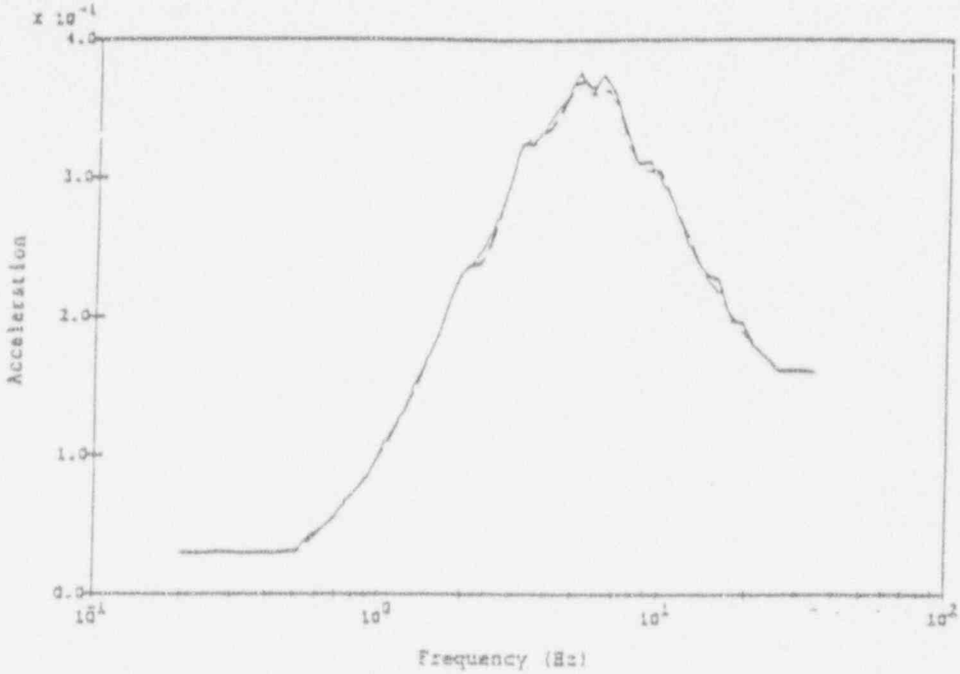

Free-field motion
Foundation input motion
M
F
Soil profile
Site response analysis
Impedances
SSI
Structural model

Figure 2-1



Legend:		Notes:
Synthetic T/H	————	Accelerations in g's
OCNGS Horizontal	— — — —	5% spectral Damping

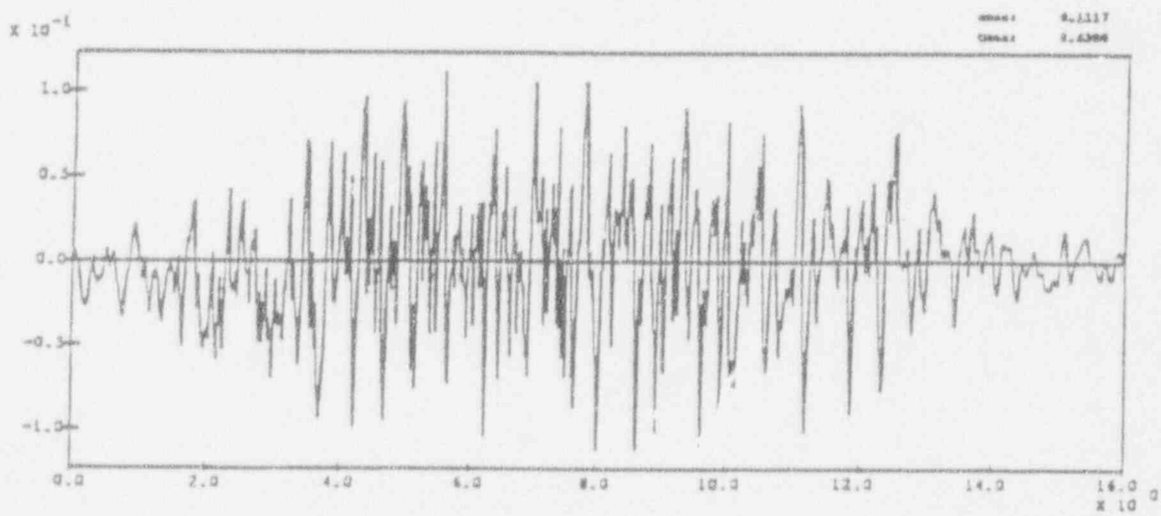
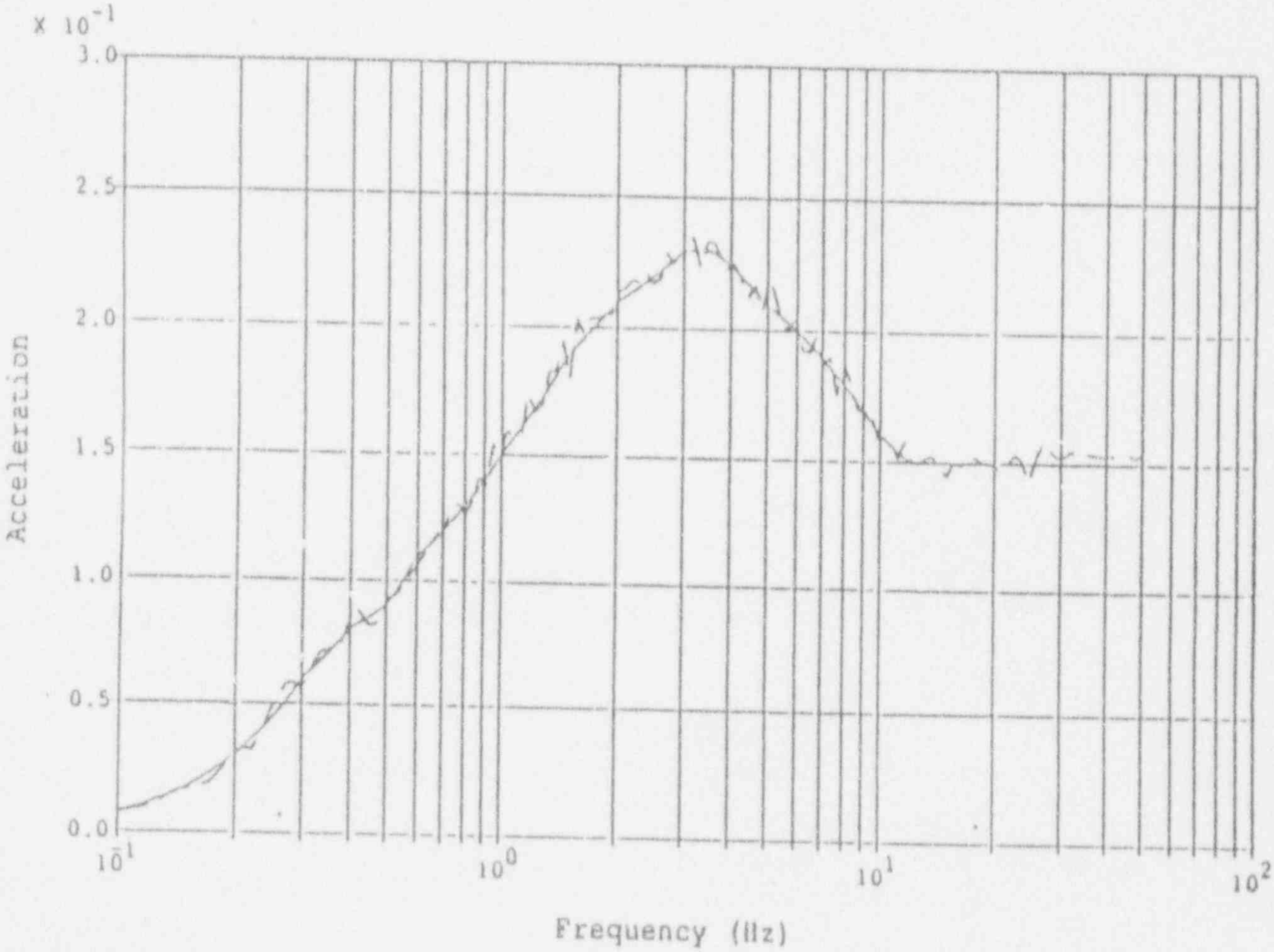


Figure 2-2



Legend:

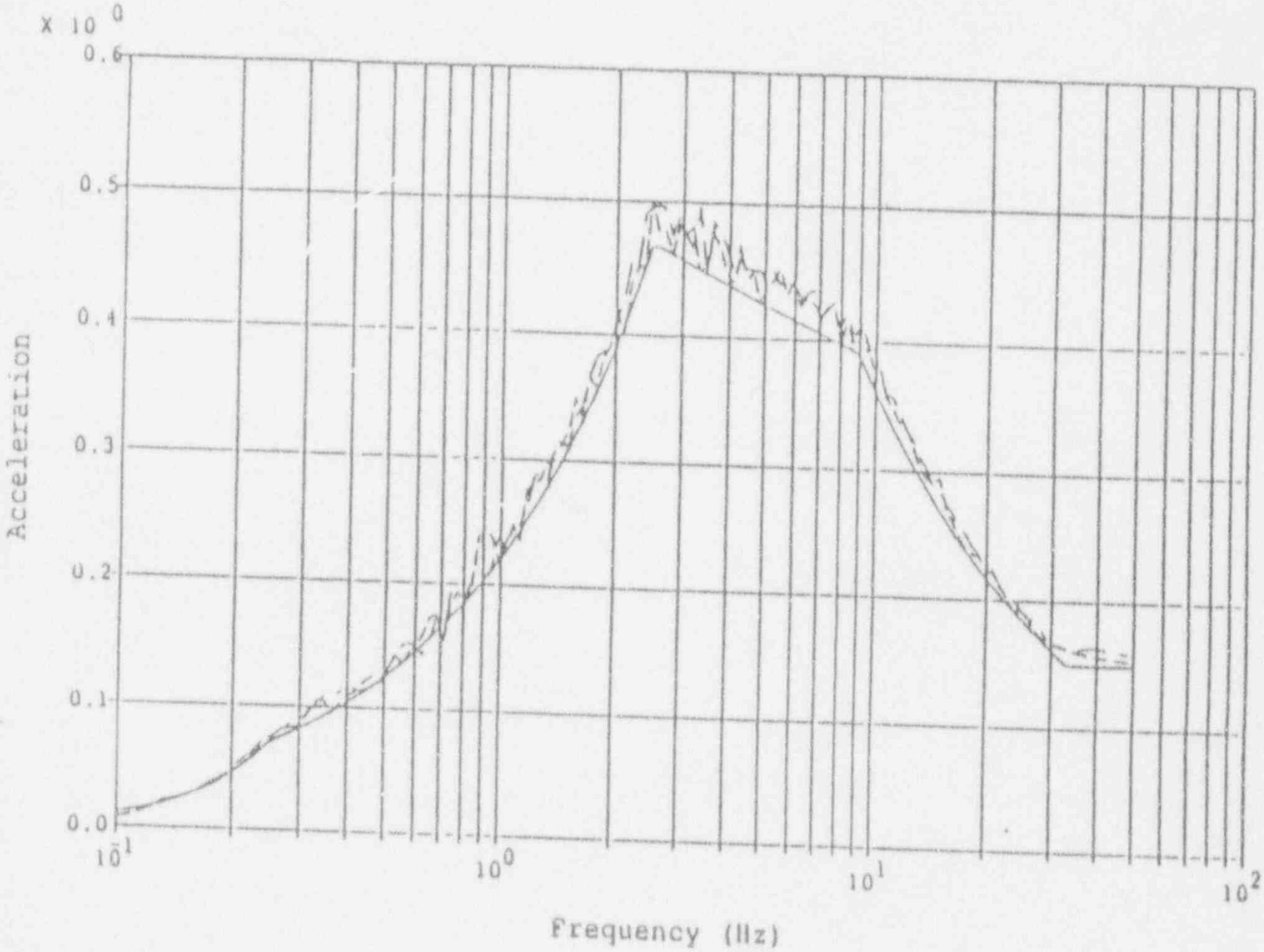
Horizontal Housner (FSAR) Spectrum ————————

Horizontal Matching Spectrum, X-Dir:EW — — — — —

Notes:

5.0 % Spec. Damping
Accelerations in g's
1 SSE Level = 0.15g

Figure 2-3



Legend:

Horizontal RG 1.60 Design Spectrum ————

Horizontal Matching Spectrum, X-Dir:EW — — — —

Horizontal Matching Spectrum, Y-Dir:NS - - - - - -

Notes:

5.0 % Spec. Damping
Accelerations in g's
1 SSE Level = 0.15g

Figure 2-4

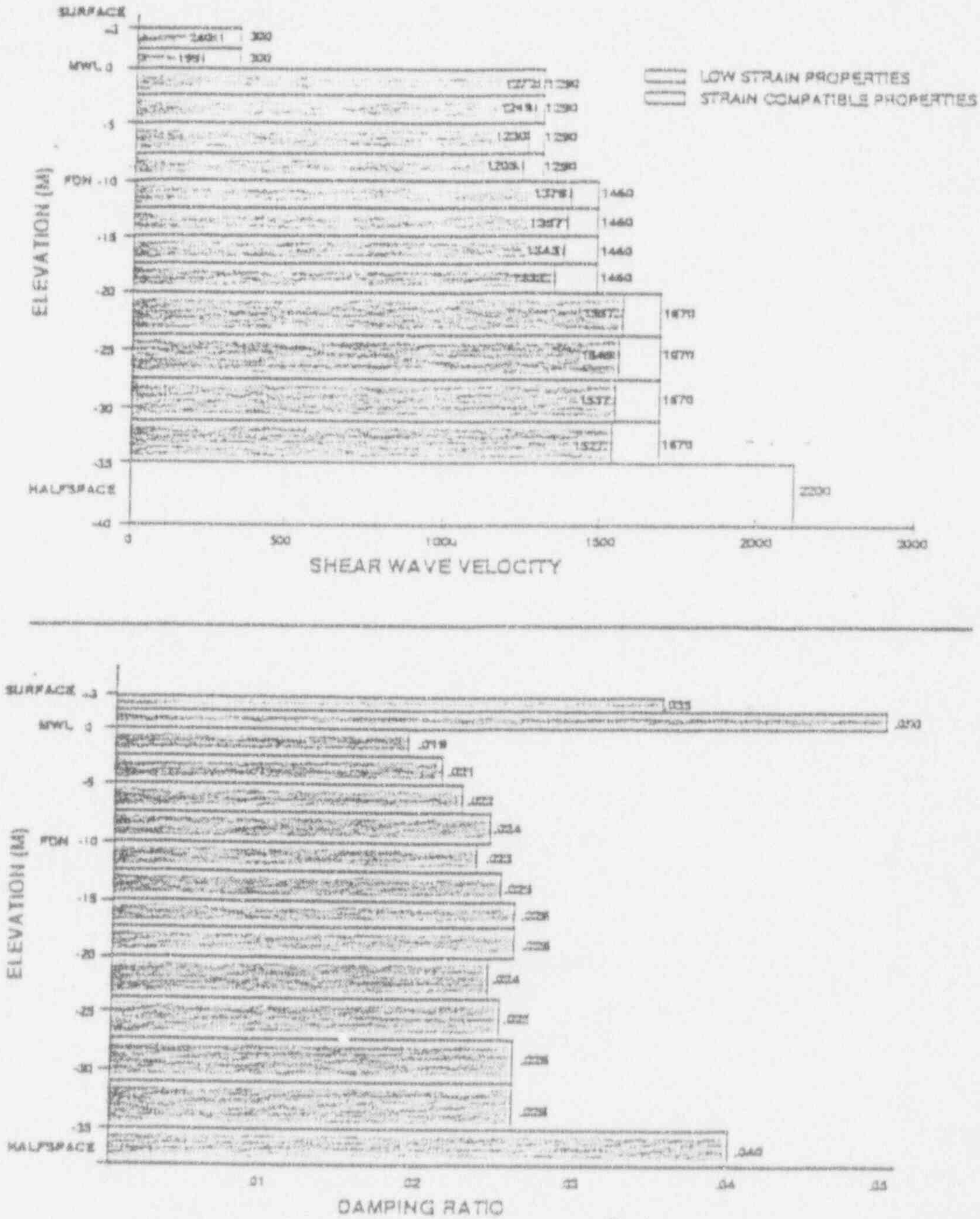

SURFACE
MWL 0
FDN -10
HALFSPACE
ELEVATION (M)
LOW STRAIN PROPERTIES
STRAIN COMPATIBLE PROPERTIES
300
1290
1460
1670
2200
0
500
1500
2000
3000
SHEAR WAVE VELOCITY
.035
.019
.021
.024
.040
.01
.02
.03
.04
.05
DAMPING RATIO

Figure 2-5

3. BUILDING MODEL

3.1 Introduction

This chapter presents an overview of the structural model of the Reactor Building and Internal structures used in the SSI analysis and response spectra generation. The development of the model is documented in Reference 7. Figure 1-1 shows a schematic of the model with the mass points indicated. Table 3-1 and 3-2 contain the nodal properties and element properties of the model.

3.2 Description of the Reactor Building and Internal Structures

The Reactor Building is a rectangular reinforced concrete structure up to the refueling floor at EL. 117. Above that it is a steel frame with exterior precast concrete panels.

The foundation mat is 144.5 feet square and 10 feet thick with the finished top surface at El. -17.5. It rests on a 6 inch thick concrete working slab. There is an extension of about 40 feet by 60 feet on the northwest side comprising the HPCI compartment under the Auxiliary Bay. The exterior shape of the building is essentially rectangular for the remainder of its height, with an interior grid of walls between floor levels. Figures 3-1 through 3-10 show cross-sections at different elevations. Site grade is at El. 23. The shear centers and centers of mass of the Reactor Building are not coincident over the height of the building, introducing the potential for significant torsional response.

The drywell containment vessel is an axisymmetric steel structure surrounded by a reinforced concrete shield wall which follows the contour of the vessel from the foundation of the drywell up to the operating floor. The drywell shield is an integral part of the main building structure. The centerline of the drywell vessel is not coincident with the centerline of the reactor building. The torus suppression pool is located below the drywell and is supported by the mat.

The reactor pressure vessel is supported by a reinforced concrete pedestal inside the drywell. The vessel is surrounded by a biological shield wall built up of welded steel sections and infill concrete. The biological shield is supported on the reactor pedestal. The pedestal and drywell are supported on a solid concrete section extending about 25 feet above the top of the mat.

The reactor pressure vessel, biological shield wall and drywell structures are braced to the Reactor Building structure at El. 81.8. The reactor vessel is braced to the top of the biological shield by a stabilizer system which resists lateral movement and torsion but not vertical movement (it also allows radial growth, but this is not relevant to seismic response). The biological shield is braced to the drywell by the star truss which acts similarily to the stabilizer. The drywell is connected to the drywell shield concrete by heavy steel lugs which also restrain only lateral and torsional movement.

3.3 Model Stiffness Properties

The floors of the Reactor Building are connected by a grid of walls and the drywell shield structure. This irregular pattern makes it difficult to simulate using composite beam element properties. Therefore, finite element models were constructed to obtain stiffness properties. The models are shown in Figures 3-11 through 3-15. All reinforced concrete walls extending from floor to floor with adequate length to develop shear resistance were included. Walls with small openings infilled with block were considered continuous if it was judged that the block infill would transmit shear. Full height reinforced block walls two feet or more thick were also included, although the modulus of elasticity was adjusted to reflect the lower stiffness of concrete block construction. The change in wall sections and the floor slab in the Auxiliary Bay at El. 3 was modeled explicitly in the finite element model from El. -17.5 to El. 23 (Figure 3-11).

The nodes at the top and bottom of the wall meshes were rigidly connected to nodes at the z-axis (reactor centerline). These nodes were then given unit displacements and rotations. Using the reaction forces, stiffness matrices were assembled. The finite element models also yielded mass properties for the walls. These were distributed to the floors above and below in the mass property calculations.

The drywell lugs are connected to the Reactor Building at El. 81.8 which is between floors. The lugs are embedded in the drywell shield concrete. To model this connection a node (5) was introduced between El. 74.25 and 91.25. This node was connected to the floors by beam elements representing the drywell shield cross-section. The stiffness of this cross-section was then subtracted from the stiffness matrix of the element connecting the two floors. This provided a good representation of the stiffness restraint for the drywell lugs while also providing a good representation of the stiffness between the two floor elevations.

The superstructure above the operating floor at El. 117.0 consists of steel columns with exterior precast concrete panels. Investigation determined that the panels were adequately connected to the columns to provide shear transfer. The stiffness properties were then determined based on a composite of the precast panels and the columns at the perimeter of the building. This could be well represented in the model by an equivalent beam element.

The torus structure was determined to be rigid based on review of drawings and References 11 and 12. It was modeled as four nodes around the circumference of the vessel joined by rigid elements to the base mat center of mass. The mass properties of the torus were combined into the base mat mass properties.

The drywell vessel stiffness was calculated assuming that it consists of a series of cylindrical sections. This simplification was considered acceptable because the drywell is light and stiff relative to the overall building and is connected at the top and bottom. The approximation as a series of cylinders somewhat underestimates the stiffness; thus, the approximation is conservative. The drywell lugs which connect the drywell to the drywell shield structure were simulated with high stiffness values since the lugs are very stiff.

The stiffness properties of the biological shield, reactor vessel and reactor pedestal were taken from prior work by Bechtel and General Electric (References 9 and 10). The documentation of this was reviewed and felt to be acceptable. Likewise, the stiffnesses of the star truss and stabilizer were taken from this documentation. The torsional stiffnesses for the star truss and stabilizer were estimated using the lateral (tangential) stiffness and mean radius between the connected structures.

3.4 Model Mass Properties

The Reactor Building mass was lumped at eight locations corresponding to the main floor levels, the crane rail elevation and the roof. Mass properties of the floors were determined using finite element representations. The weights of the concrete, steel framing, secondary walls, platforms and major equipment were combined to determine the total mass. Allowances for piping, miscellaneous equipment and live loads were added to the mass based on judgment. Judgments are acceptable because the dynamic response is not sensitive to moderate changes in these parameters. This was then spread over the floor area to determine the centroid and mass moments of inertia. The centroid, mass, and mass moments of inertia of the primary walls were determined in the stiffness calculations and distributed to the floors above and below. The floor and wall properties were then combined to determine the net mass, centroid, and mass moments of inertia. Massless nodes were specified at the extreme corners of the floors for use in obtaining torsional effects. The final response spectra were an envelope of the spectra from the centroid and the extreme points.

The Auxiliary Bay was included in the model because it is integral with the Reactor Building. This was not done in the original analysis. A review of the Radwaste and Turbine Building drawings and Reference 8 showed that these are not integral with the Reactor Building. However, certain portions of the buildings are supported on the Reactor Building, and a suitable portion of this mass was included in the model.

The following interface locations were considered:

- Reactor Building Auxiliary Bay Roof (El. 50)
- Turbine Building El. 50
- Turbine Auxiliary Bay Roof (El. 82)
- Radwaste Building Roof (El. 51)

All other interface points (e.g., Turbine Building El. 23 and 37, Radwaste Building El. 37) have insignificant mass contribution. The mass contribution of these areas were considered covered by the dead load allowances used at these floor levels.

The mass properties for the drywell were calculated based on the weight of the spherical or cylindrical sections. Because the rotational inertias would have negligible effect on the response of the model, they were not calculated.

The mass properties of the biological shield, reactor vessel and reactor pedestal were taken from prior work by Bechtel and General Electric (Reference 9 and 10). The mass of the reactor internals was condensed and lumped at the point of connection with the vessel. This simplification was considered acceptable because the high stiffness of the vessel would isolate it from effects of the internals. This was supported by examination of the original vessel spectra in Reference 10 which showed a single predominant peak at the fundamental Reactor Building frequency.

3.5 Element Damping

Dampings of different portions of the model were selected based on the materials involved. Dampings for the Reg. Guide 1.60 input cases were taken from Reg. Guide 1.61. Dampings for the PNPS FSAR input cases were taken from the original PNPS FSAR, but were adjusted as judged appropriate for use with Housner spectra.

The Reactor Building main structure was considered reinforced concrete including the superstructure. The superstructure was considered reinforced concrete because the main earthquake resisting elements are the precast panels attached to the exterior building columns. For the PNPS FSAR input cases, damping ratios of 5% for SSE and 2% for OBE were used rather than 7.5% and 5% as specified in the PNPS FSAR. The values used were judged more appropriate for use with Housner spectra.

The drywell was considered a welded steel structure per Reg. Guide 1.61 or welded assembly per PNPS FSAR. The biological shield wall was considered a welded ste structure per Reg. Guide 1.61 (this is conservative) or internal concrete structure/equipment support per PNPS FSAR. The pedestal was assigned the same damping as the shield wall. This is conservative, but the pedestal would not be subject to high earthquake stress; hence, lower damping than the standard for reinforced concrete is appropriate. The reactor vessel was considered equipment/large diameter piping per Reg. Guide 1.61 or welded assembly per PNPS FSAR. The values used for the PNPS FSAR input cases agree with those used in Reference 10.

The element damping ratios are summarized below:

	Element Damping Ratio (Percent)			
	Reg. Guide 1.60		PNPS FSAR	
	SSE	OBE	SSE	OBE
Reactor Building	7	4	5	2
Drywell	4	2	2	1
Bio-Shield & Pedestal	4	2	3	2
Reactor Vessel	3	2	2	1

3.6 Floor Flexibility

Floor sections in the Reactor Building main structure were checked for flexibility and potential for resonance in the vertical direction of excitation. Four sections were checked at El. 117, three at EL. 91.25 and one at El. 74.25. These were judged to be the bounding cases for all elevations. The frequencies were calculated using composite concrete-steel elastic cross-sections continuous over supports (i.e., fixed end boundary conditions). The calculated frequencies ranged from 22.7 Hz. to 47.3 Hz. Since the predominant vertical response of the coupled soil-structure system for the main building structure was expected to be below 10 Hz., local floor resonance potential was judged not significant and special modeling was not necessary.

TABLE 3-1

NODES.XLS

	REACTOR BUILDING MODEL NODAL PROPERTIES							
NODE	ELEV	X	Y	Z	MASS	MOM X	MOM Y	MOM Z
			REACTOR BLDG					
1	-17.50	3.18	13.03	-4.00	1752.50	4390211	3063357	7453567
2	23.00	-1.34	20.76	39.30	1272.40	3759749	2374697	6134446
3	51.00	-5.14	0.79	67.50	678.90	1414880	1277062	2691942
4	74.25	7.21	5.96	90.30	594.20	1094994	596840	1691834
5	81.80	0.00	0.00	99.30				
6	91.25	7.77	6.90	108.20	442.60	841887	450498	1292385
7	117.00	10.96	7.27	133.80	363.40	711800	409675	1121475
8	145.00	17.13	-7.63	162.50	60.30	189646	110563	300209
9	164.50	17.13	0.00	182.00	29.50	64703	40218	104920
	REACTOR BLDG WALL MEMBER END POINTS							
81	-17.50	0.00	0.00	-4.00				
82	23.00	0.00	0.00	39.30				
83	51.00	0.00	0.00	67.50				
84	74.25	0.00	0.00	90.30				
86	91.25	0.00	0.00	108.20				
87	117.00	0.00	0.00	133.80				
97	117.00	17.13	0.00	133.80				
88	145.00	17.13	0.00	162.50				
	REACTOR BLDG FLOOR EXTREME POINTS							
101	-17.50	72.30	109.00	-4.00				
201	-17.50	72.30	-72.30	-4.00				
301	-17.50	-72.30	-72.30	-4.00				
401	-17.50	-72.30	72.30	-4.00				
102	23.00	68.50	121.40	39.30				
202	23.00	68.50	-68.50	39.30				
302	23.00	-67.80	-68.50	39.30				
402	23.00	-71.30	134.10	39.30				
103	51.00	68.80	68.80	67.50				
203	51.00	68.80	-68.80	67.50				
303	51.00	-71.30	-70.80	67.50				
403	51.00	-71.30	85.10	67.50				
104	74.25	69.30	68.80	90.30				
204	74.25	69.30	-68.80	90.30				
304	74.25	-35.00	-68.80	90.30				
404	74.25	-35.00	68.80	90.30				
106	91.25	69.50	69.50	108.20				
206	91.25	69.50	-69.50	108.20				

TABLE 3-1 (Continued)

NODES.XLS

306	91.25	-35.30	-69.50	108.20				
406	91.25	-35.30	69.50	108.20				
107	117.00	70.80	70.80	133.80				
207	117.00	70.80	-70.80	133.80				
307	117.00	-36.50	-70.80	133.80				
407	117.00	-36.50	70.80	133.80				
108	145.00	70.80	70.80	162.50				
208	145.00	70.80	-70.80	162.50				
308	145.00	-36.50	-70.80	162.50				
408	145.00	-36.50	70.80	162.50				
109	164.50	70.80	70.80	182.00				
209	164.50	70.80	-70.80	182.00				
309	164.50	-36.50	-70.80	182.00				
409	164.50	-36.50	70.80	182.00				
		RPV PEDESTAL						
20	9.12	0.00	0.00	26.62				
10	15.40	0.00	0.00	32.90	7.97			
11	21.70	0.00	0.00	39.20	15.08			
12	28.00	0.00	0.00	45.50	10.11			
13	35.42	0.00	0.00	52.92	18.25			
		BIOLOGICAL SHIELD WALL						
14	47.35	0.00	0.00	64.85	7.34			
15	52.81	0.00	0.00	70.31	2.75			
16	56.64	0.00	0.00	74.14	9.29			
17	71.50	0.00	0.00	89.00	11.07			
18	81.80	0.00	0.00	99.30	2.75			
19	82.10	0.00	0.00	99.60				
		REACTOR PRESSURE VESSEL						
29	36.88	0.00	0.00	54.38				
30	40.75	0.00	0.00	58.25				
31	47.27	0.00	0.00	64.77	66.22			
32	55.18	0.00	0.00	72.68	9.91			
33	58.68	0.00	0.00	76.18				
34	61.93	0.00	0.00	79.43	8.70			
35	68.43	0.00	0.00	85.93	10.13			
36	76.08	0.00	0.00	93.58	9.55			
37	80.43	0.00	0.00	97.93				
38	82.10	0.00	0.00	99.60				
39	86.75	0.00	0.00	104.25	8.26			
40	92.03	0.00	0.00	109.53				
41	93.65	0.00	0.00	111.15	5.38			

TABLE 3-1 (Continued)

NODES.XLS

			DRYWELL					
50	16.43	0.00	0.00	33.93	1.84			
51	23.69	0.00	0.00	41.19	1.29			
52	27.17	0.00	0.00	44.67	1.27			
53	36.08	0.00	0.00	53.58	1.76			
54	44.98	0.00	0.00	62.48	1.55			
55	53.89	0.00	0.00	71.39	1.86			
56	59.82	0.00	0.00	77.32	1.59			
57	69.19	0.00	0.00	86.69	0.85			
58	78.56	0.00	0.00	96.06	0.71			
59	81.80	0.00	0.00	99.30	0.87			
60	88.81	0.00	0.00	106.31	1.92			
61	97.81	0.00	0.00	115.31	1.95			
62	106.39	0.00	0.00	123.89	0.63			
			TORUS					
70	-0.25	-65.75		17.25				
71	-0.25		65.75	17.25				
72	-0.25	65.75		17.25				
73	-0.25		-65.75	17.25				

TABLE 3-2

MEMPROP.XLS

		REACTOR BUILDING MODEL ELEMENT PROPERTIES								
REF	FROM	TO	A1	A2	A3	I1	I2	I3	E	POI
			REACTOR BLDG WALLS							
	82	81	STIFFNESS MATRIX K21							
	83	82	STIFFNESS MATRIX K32							
	84	83	STIFFNESS MATRIX K43							
	86	84	STIFFNESS MATRIX K64							
	87	86	STIFFNESS MATRIX K76							
		REACTOR BLDG WALL MEMBER END POINT CONNECTIONS								
	1	81	RIGID							
	2	82	RIGID							
	3	83	RIGID							
	4	84	RIGID							
	6	86	RIGID							
	7	87	RIGID							
	7	97	RIGID							
	8	88	RIGID							
		DRYWELL SHIELD WALL HOLDING DRYWELL LUGS								
	84	5	765.30	382.65	382.65	322340	161170	161170	519000	0.17
	5	86	765.30	382.65	382.65	322340	161170	161170	519000	0.17
			REACTOR BLDG SUPERSTRUCTURE							
8	97	88	262.88	112.40	150.48	1544428	890235	654193	519000	0.17
9	88	9	262.88	112.40	150.48	1544428	890235	654193	519000	0.17
			RPV PEDESTAL							

TABLE 3-2 (Continued)

MEMPROP.XLS

10	20	10	278.50	139.00	139.00	35330	17665	17665	457000	0.17
11	10	11	278.50	139.00	139.00	35330	17665	17665	457000	0.17
12	11	12	278.50	139.00	139.00	35330	17665	17665	457000	0.17
13	12	13	354.00	177.00	177.00	40606	20303	20303	457000	0.17
			BIOLOGICAL SHIELD WALL							
14	13	14	241.80	120.50	120.50	34058	17029	17029	457000	0.17
15	14	15	196.00	98.00	98.00	26381	13212	13169	457000	0.17
16	15	16	105.00	[illegible]	52.30	15014	7507	7507	457000	0.17
17	16	17	306.40	153.30	153.30	46902	23451	23451	457000	0.17
18	17	18	152.90	76.00	76.50	22113	9290	12823	457000	0.17
19	18	19	RIGID							
				RPV SKIRT						
26	13	29	50.00	25.00	25.00	3800	1900	1900	3950000	0.265
27	29	30	8.56	4.28	4.28	570	285	285	3950000	0.265
			REACTOR PRESSURE VESSEL							
28	30	31	14.10	7.05	7.05	978	489	489	3740000	0.265
29	31	32	33.92	16.96	16.96	3154	1577	1577	3740000	0.265
30	32	33	33.92	16.96	16.96	3154	1577	1577	3740000	0.265
31	33	34	28.86	14.43	14.43	2684	1342	1342	3740000	0.265
32	34	35	28.86	14.43	14.43	2684	1342	1342	3740000	0.265
33	35	36	28.86	14.43	14.43	2684	1342	1342	3740000	0.265
34	36	37	28.86	14.43	14.43	2684	1342	1342	3740000	0.265
35	37	38	33.92	16.96	16.96	3154	1577	1577	3740000	0.265
36	38	39	33.92	16.96	16.96	3154	1577	1577	3740000	0.265
37	39	40	33.92	16.96	16.96	3154	1577	1577	3740000	0.265
38	40	41	67.22	33.61	33.61	6574	3287	3287	3740000	0.265
				DRYWELL						

TABLE 3-2 (Continued)

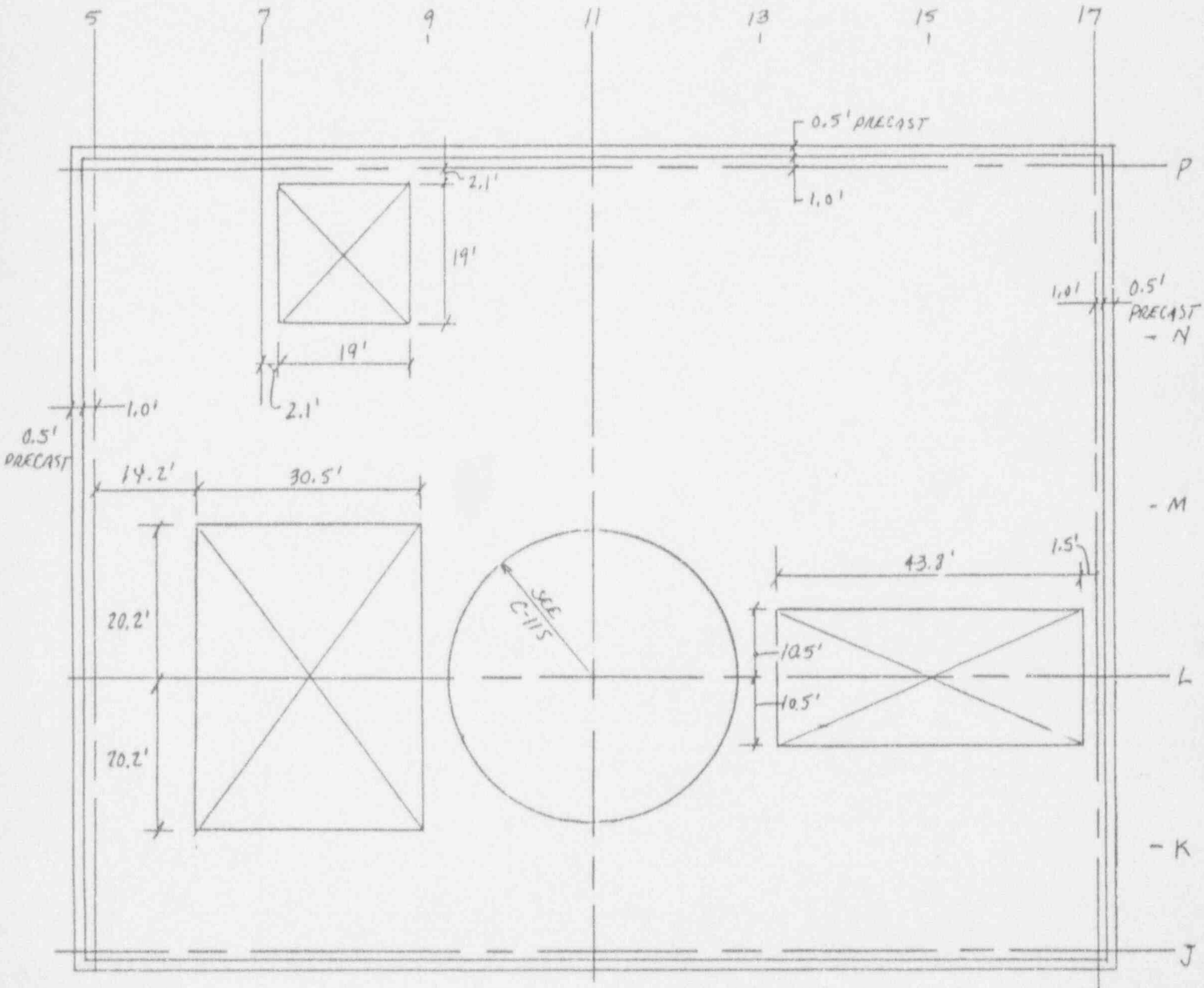
MEMPROP.XLS

50	20	50	15.09	7.55	7.55	11102	5551	5551	4176000	0.3
51	50	51	16.93	8.47	8.47	15668	7834	7834	4176000	0.3
52	51	52	13.50	6.76	6.76	13586	6793	6793	4176000	0.3
53	52	53	13.43	6.72	6.72	13381	6691	6691	4176000	0.3
54	53	54	12.59	6.30	6.30	11006	5503	5503	4176000	0.3
55	54	55	10.28	5.14	5.14	5996	2998	2998	4176000	0.3
56	55	56	25.77	12.89	12.89	9060	4530	4530	4176000	0.3
57	56	57	5.99	3.00	3.00	1748	874	874	4176000	0.3
58	57	58	5.99	3.00	3.00	1748	874	874	4176000	0.3
59	58	59	11.18	5.59	5.59	3262	1631	1631	4176000	0.3
60	59	60	11.18	5.59	5.59	3262	1631	1631	4176000	0.3
61	60	61	25.76	12.83	12.83	9940	4970	4970	4176000	0.3
62	61	62	9.66	4.83	4.83	1585	792	792	4176000	0.3
				TORUS						
70	1	70	RIGID							
71	1	71	RIGID							
72	1	72	RIGID							
73	1	73	RIGID							
				DRYWELL LUGS						
			KXX	KYY	KZZ	KRXX	KRYY	KRZZ		
	5	59	1.0E8	1.0E8	0	0	0	1.0E10		
				STAR TRUSS						
			KXX	KYY	KZZ	KRXX	KRYY	KRZZ		
	59	18	3.095E5	3.095E5	0	0	0	6.964E7		
				RPV STABILIZER						
			KXX	KYY	KZZ	KRXX	KRYY	KRZZ		
	19	38	4.801E4	4.801E4	0	0	0	5.809E6		

TABLE 3-2 (Continued)

MEMPROP.XLS

		REACTOR FLOOR EXTREME POINTS								
	1	101	RIGID							
	1	201	RIGID							
	1	301	RIGID							
	1	401	RIGID							
	2	102	RIGID							
	2	202	RIGID							
	2	302	RIGID							
	2	402	RIGID							
	3	103	RIGID							
	3	203	RIGID							
	3	303	RIGID							
	3	403	RIGID							
	4	104	RIGID							
	4	204	RIGID							
	4	304	RIGID							
	4	404	RIGID							
	6	106	RIGID							
	6	206	RIGID							
	6	306	RIGID							
	6	406	RIGID							
	7	107	RIGID							
	7	207	RIGID							
	7	307	RIGID							
	7	407	RIGID							
	8	108	RIGID							
	8	208	RIGID							
	8	308	RIGID							
	8	408	RIGID							
	9	109	RIGID							
	9	209	RIGID							
	9	309	RIGID							
	9	409	RIGID							



REF: C-69, C-70
C-115

PLAN EL. 117'-0"

Figure 3-1

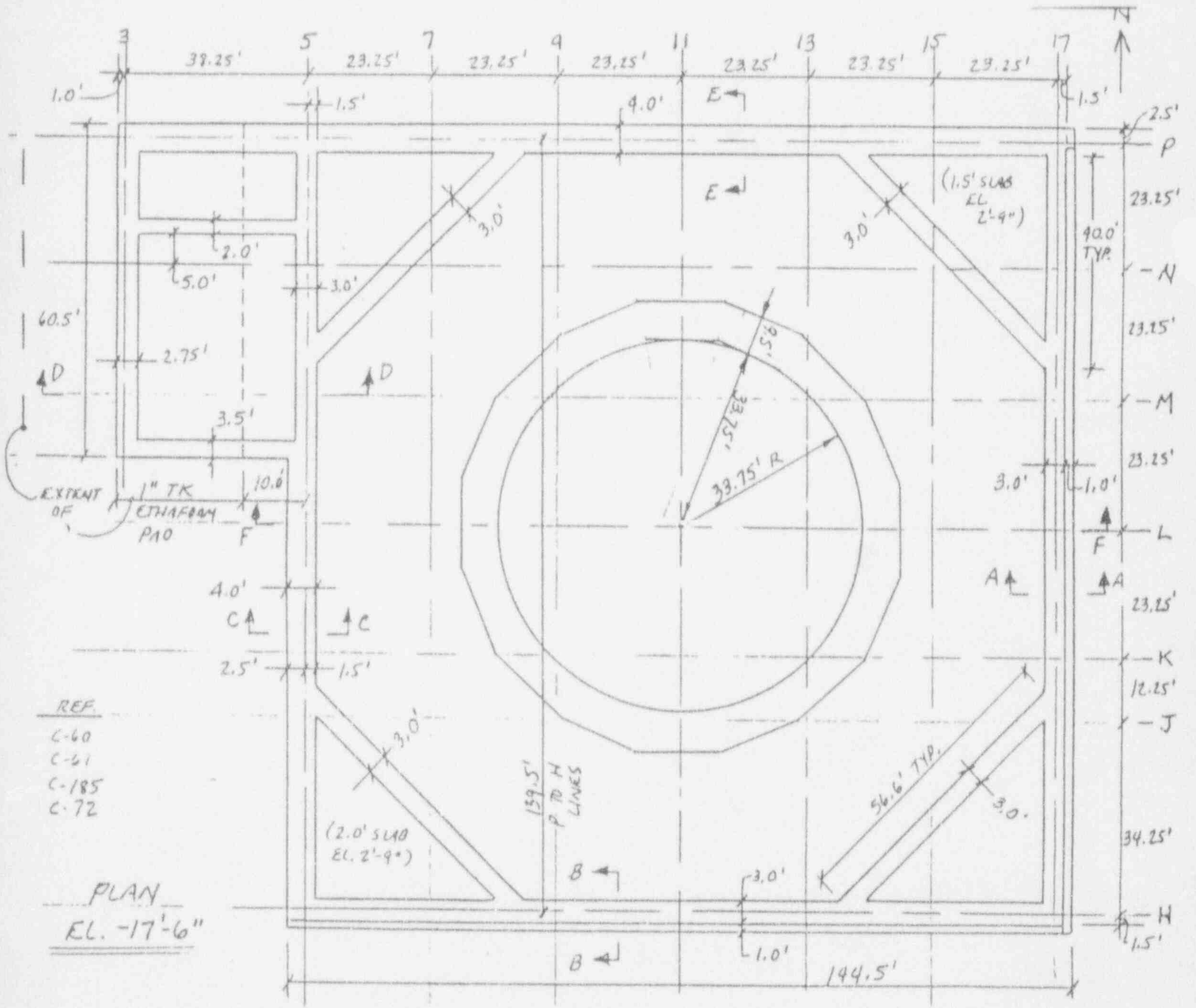

3
5
7
9
11
13
15
17
N
38.25'
23.25'
1.0'
1.5'
4.0'
E
2.5'
P
(1.5' SLAB EL. 2'-9")
3.0'
2.0'
5.0'
40.0' TYP.
N
60.5'
2.75'
D
9.5'
33.75'
33.75' R
M
3.5'
EXTENT OF 1" TK ETHAFOAM PAD
10.0'
F
3.0'
1.0'
L
4.0'
A
C
2.5'
K
12.25'
REF.
C-60
C-61
C-185
C-72
J
139.5' P TO H LINES
56.6' TYP.
34.25'
(2.0' SLAB EL. 2'-9")
B
PLAN
EL. -17'-6"
H
144.5'

Figure 3-2

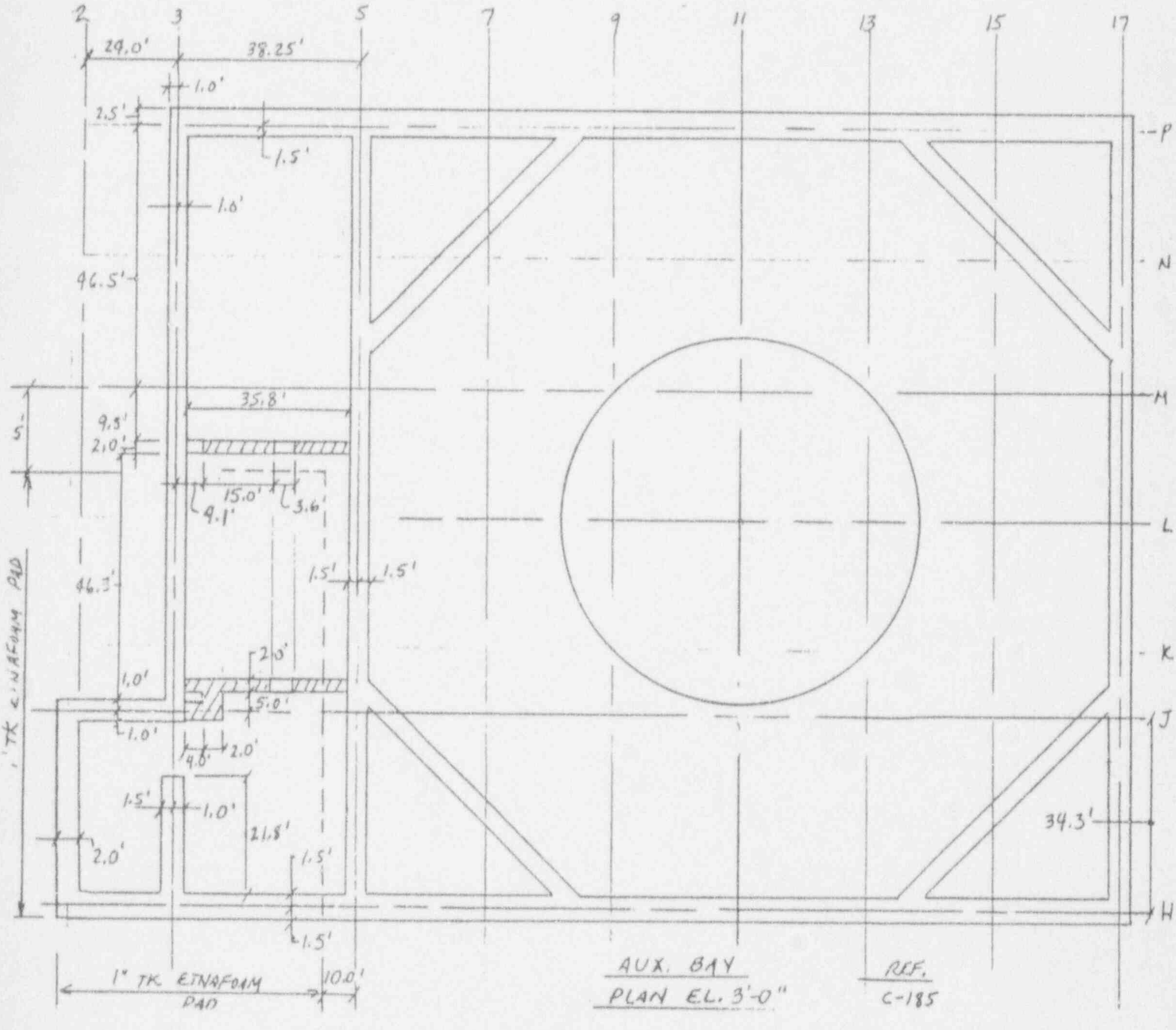

2
3
5
7
9
11
13
15
17
24.0'
38.25'
1.0'
2.5'
1.5'
1.0'
96.5'
P
N
M
L
K
J
H
35.8'
9.5'
2.0'
5'
15.0'
3.6'
9.1'
1.5'
1.5'
46.3'
1" TK ETNAFOAM PAD
2.0'
1.0'
5.0'
1.0'
4.0'
2.0'
1.5'
1.0'
21.8'
1.5'
2.0'
1.5'
34.3'
10.0'
AUX. BAY
PLAN EL. 3'-0"
REF.
C-185

Figure 3-3

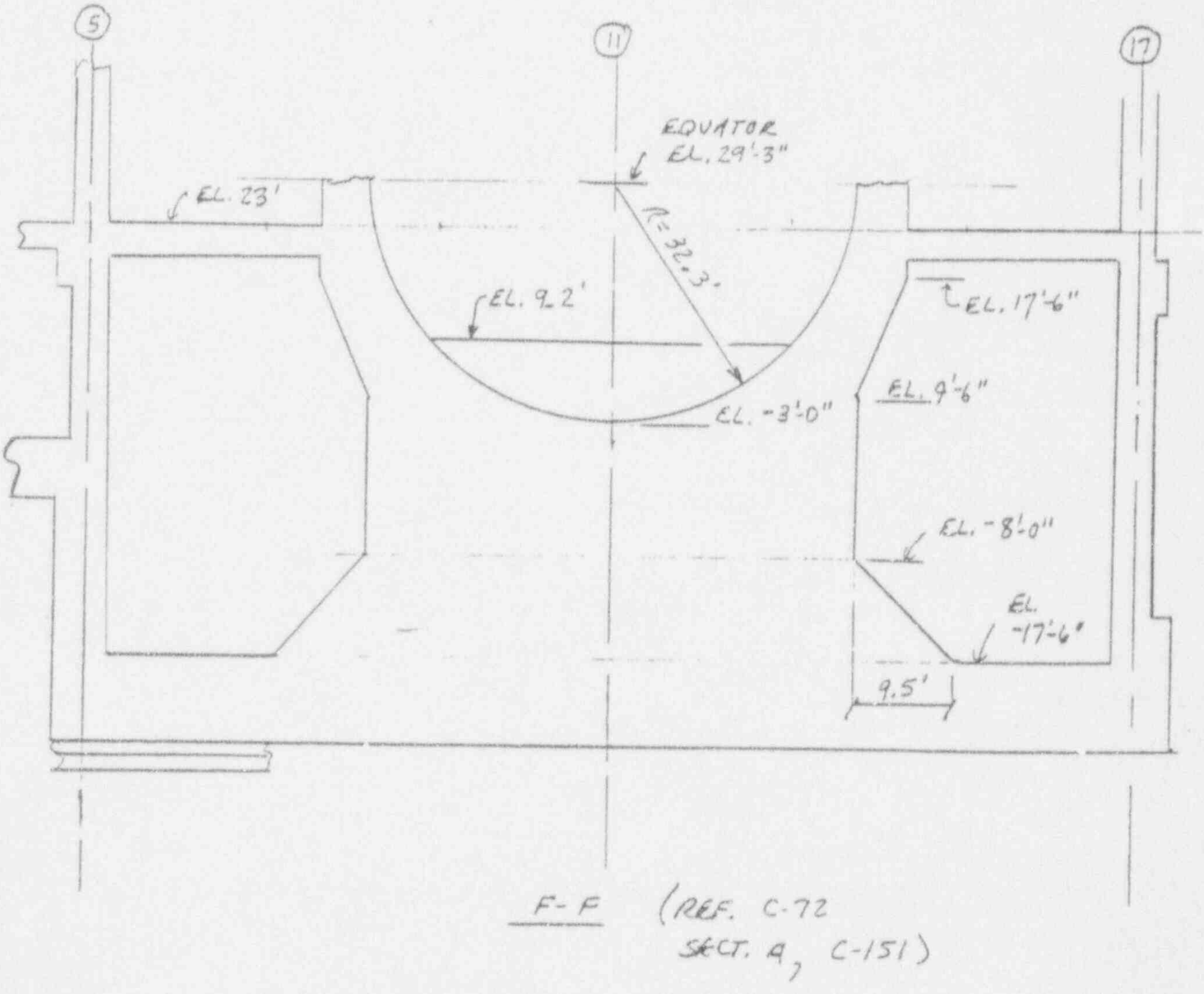
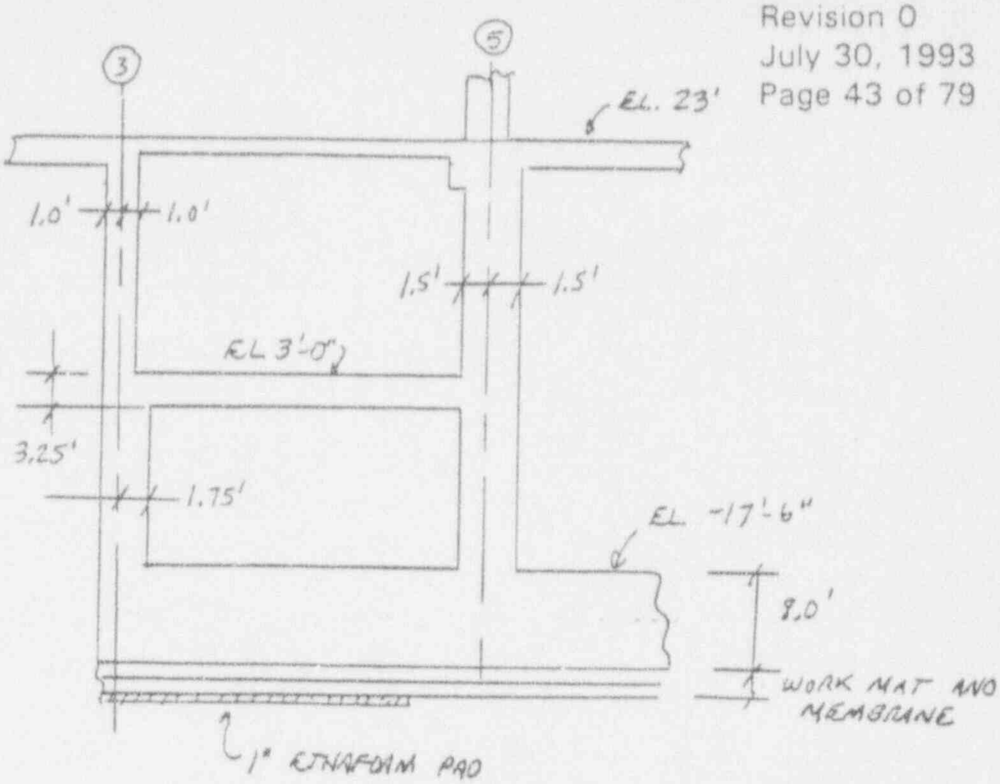
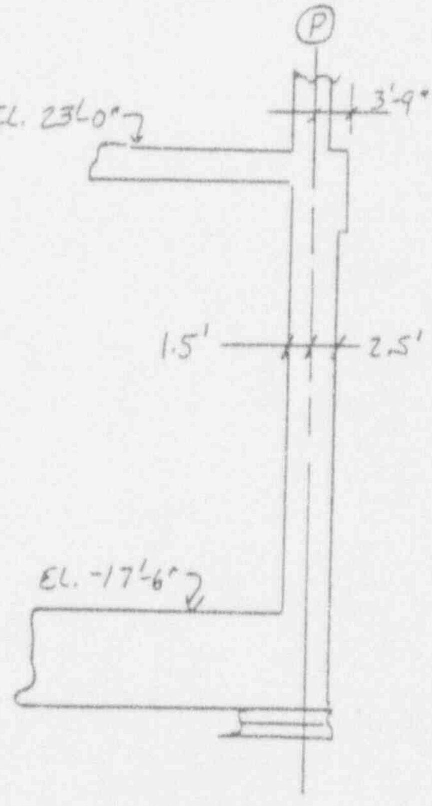

5
11
17
EQUATOR
EL. 29'-3"
EL. 23'
R = 32.3'
EL. 9.2'
EL. 17'-6"
EL. 9'-6"
EL. -3'-0"
EL. -8'-0"
EL.
-17'-6"
9.5'
F-F (REF. C-72
SECT. A, C-151)

Figure 3-4



D-D (REF. C-186 SECT. F)



E-E (REF. C-73 SECT. J, K, N)

Figure 3-5

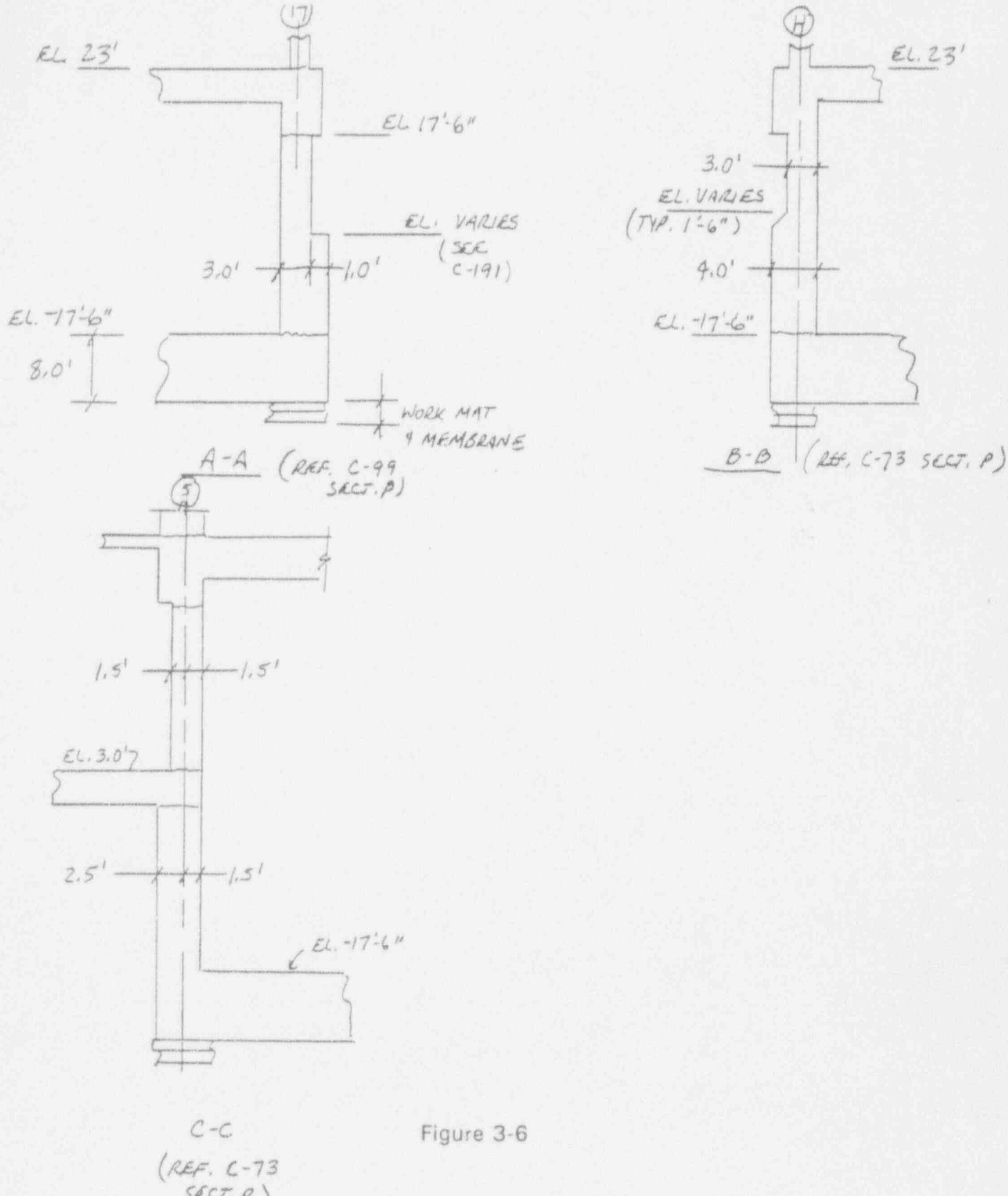

17
EL. 23'
EL. 17'-6"
EL. VARIES
(SEE C-191)
3.0'
1.0'
EL. -17'-6"
8.0'
WORK MAT & MEMBRANE
A-A
(REF. C-99 SECT. P)
H
EL. 23'
3.0'
EL. VARIES
(TYP. 1'-6")
4.0'
EL. -17'-6"
B-B
(REF. C-73 SECT. P)
5
1.5'
1.5'
EL. 3.0'
2.5'
1.5'
EL. -17'-6"
C-C
(REF. C-73 SECT. R)

Figure 3-6

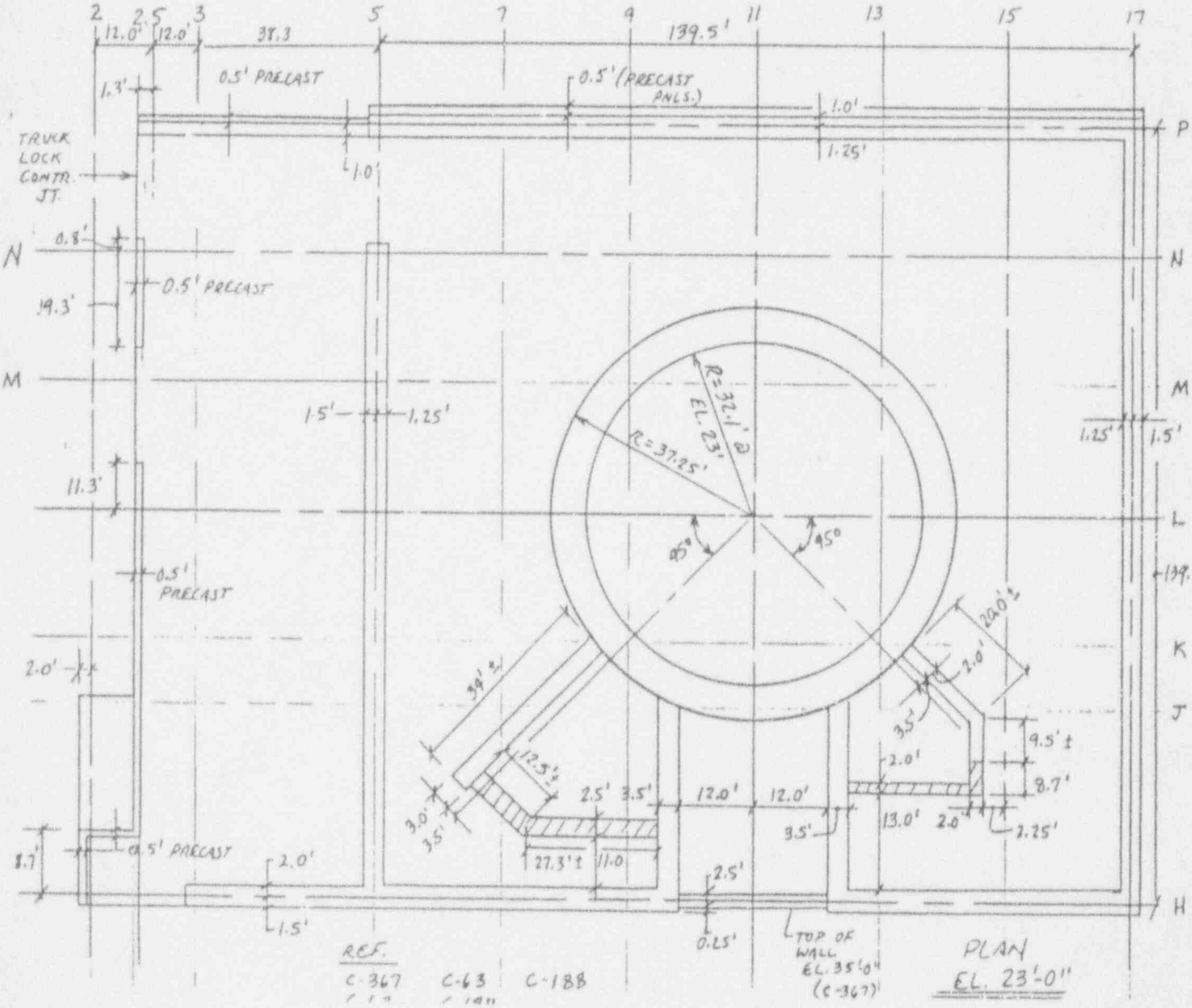

TRUCK LOCK CONTR. JT.
0.5' PRECAST
0.5' (PRECAST PNLS.)
139.5'
R=32.1' @ EL. 23'
R=37.25'
45°
PLAN
EL. 23'-0"
REF.
C-367
C-63
C-188
TOP OF WALL EL. 35'-0" (C-367)

Figure 3-7

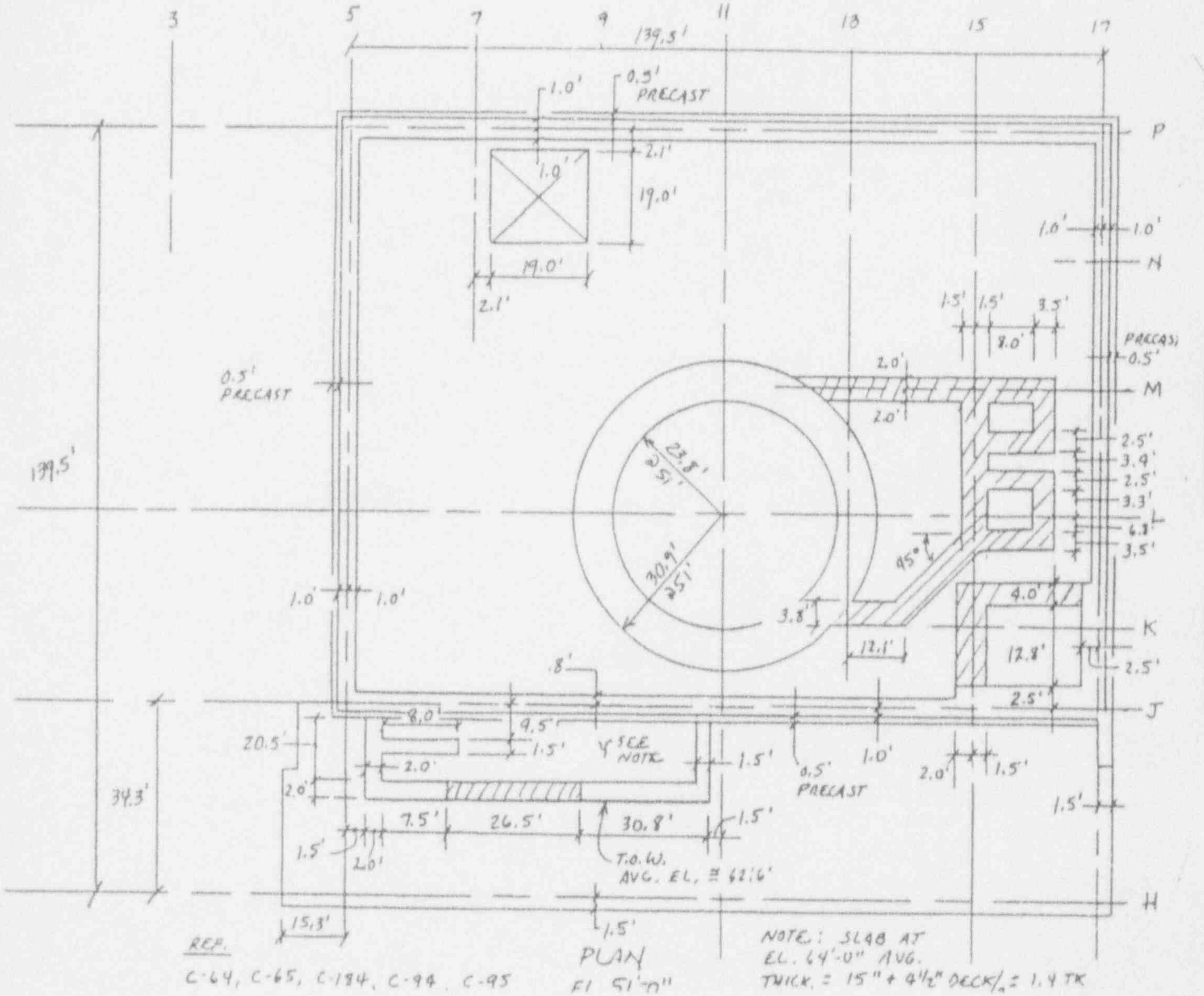


Figure 3-8

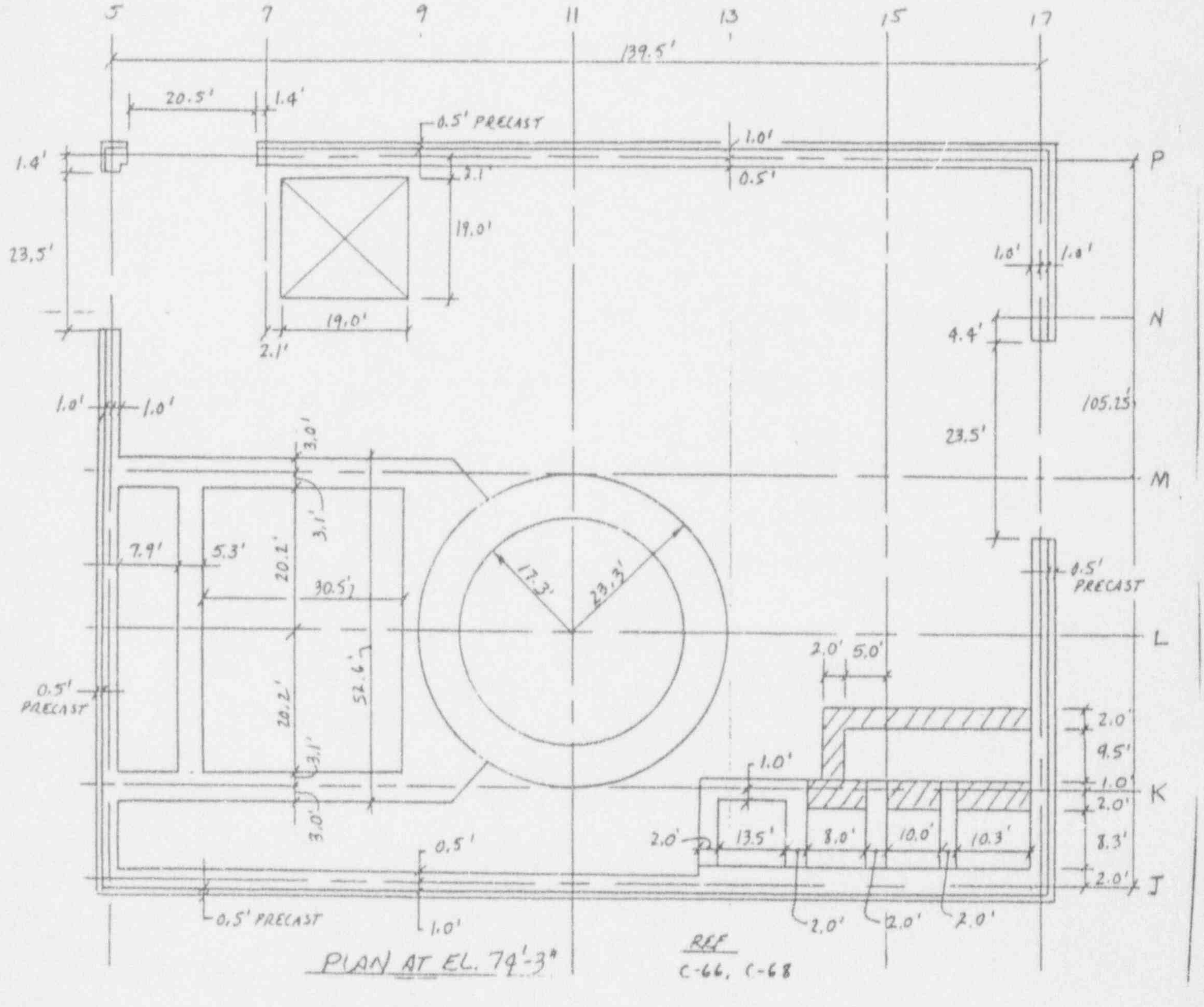

5
7
9
11
13
15
17
139.5'
20.5'
1.4'
0.5' PRECAST
1.0'
0.5'
2.1'
1.4'
23.5'
19.0'
19.0'
2.1'
P
N
M
L
K
J
1.0'
1.0'
4.4'
105.25'
23.5'
0.5' PRECAST
3.0'
3.1'
7.9'
5.3'
20.2'
30.5'
52.6'
20.2'
3.1'
3.0'
17.3'
23.3'
0.5' PRECAST
2.0'
5.0'
2.0'
9.5'
1.0'
2.0'
8.3'
2.0'
1.0'
2.0'
13.5'
8.0'
10.0'
10.3'
0.5'
0.5' PRECAST
1.0'
2.0'
2.0'
2.0'
PLAN AT EL. 79'-3"
REF
C-66, C-68

Figure 3-9

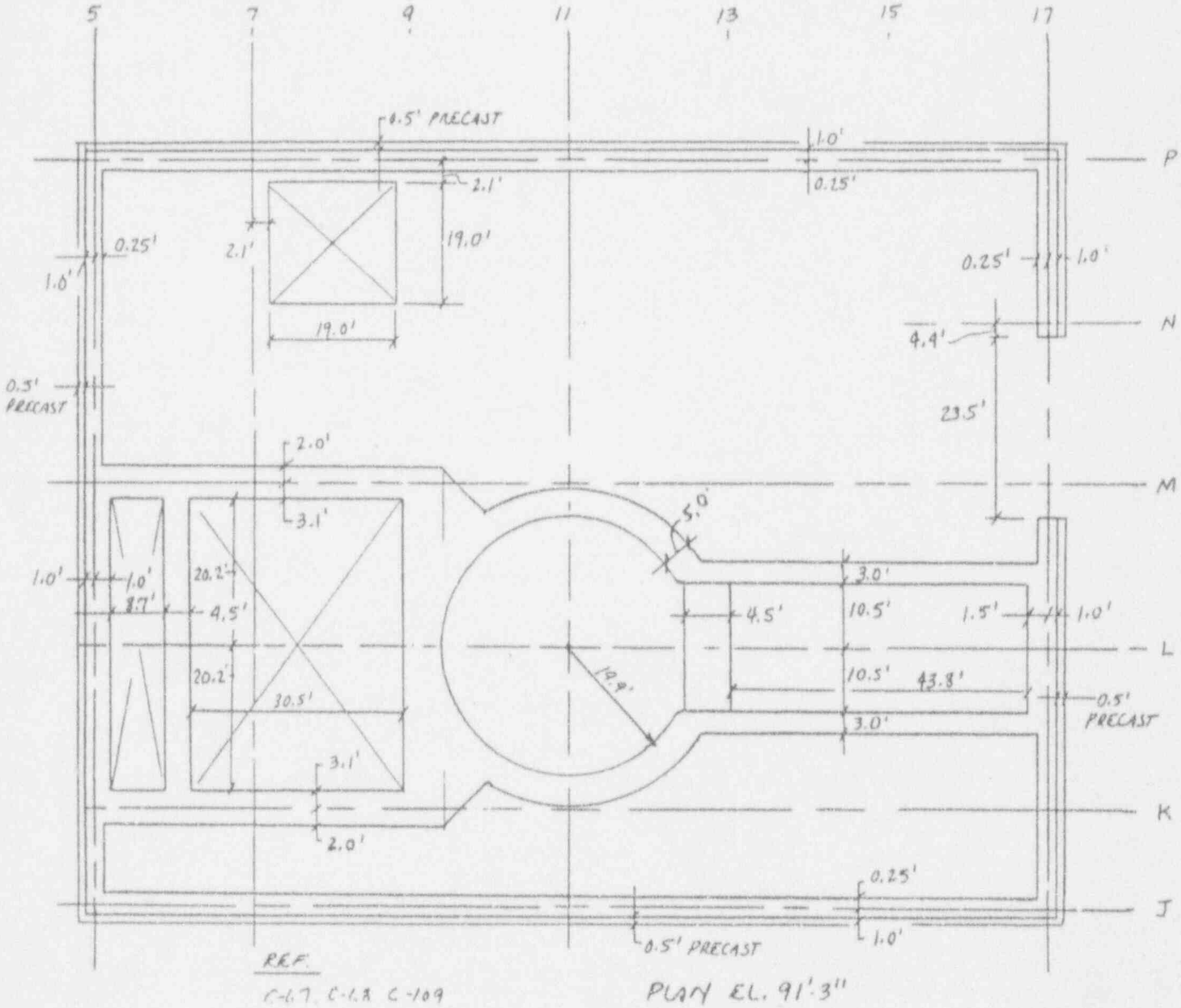

5
7
9
11
13
15
17
0.5' PRECAST
1.0'
0.25'
P
2.1'
19.0'
2.1'
0.25'
1.0'
0.25'
1.0'
19.0'
N
4.4'
0.5' PRECAST
23.5'
2.0'
M
3.1'
5.0'
3.0'
1.0'
1.0'
8.7'
4.5'
20.2'
4.5'
10.5'
1.5'
1.0'
L
20.2'
19.9'
10.5'
43.8'
0.5' PRECAST
30.5'
3.0'
3.1'
K
2.0'
0.25'
J
0.5' PRECAST
1.0'
REF.
C-67, C-68, C-109
PLAN EL. 91'-3"

Figure 3-10

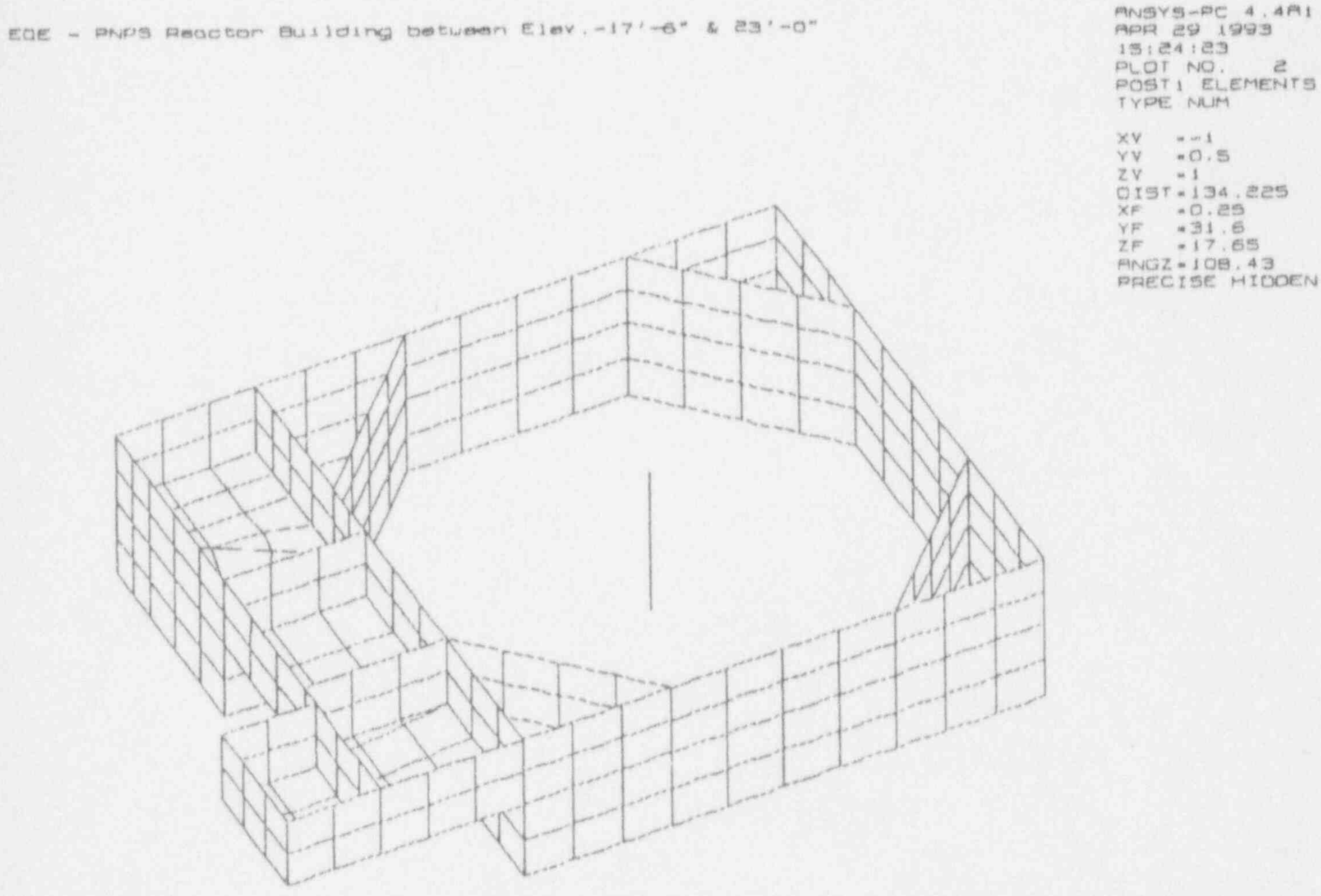

EQE - PNPS Reactor Building between Elev.-17'-6" & 23'-0"
ANSYS-PC 4.4A1
APR 29 1993
15:24:23
PLOT NO. 2
POST1 ELEMENTS
TYPE NUM
XV =-1
YV =0.5
ZV =1
DIST=134.225
XF =0.25
YF =31.6
ZF =17.65
ANGZ=108.43
PRECISE HIDDEN

Figure 3-11

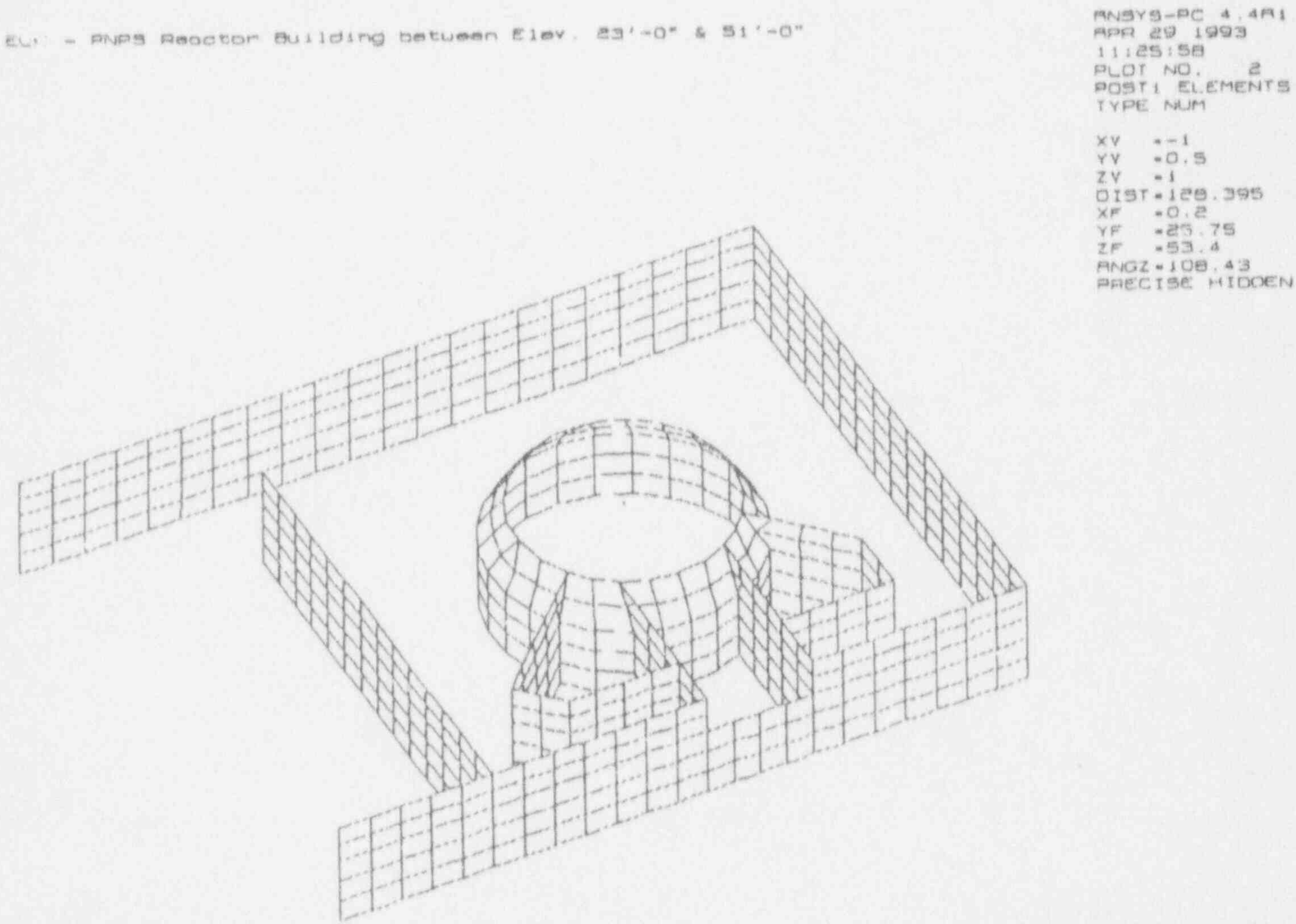
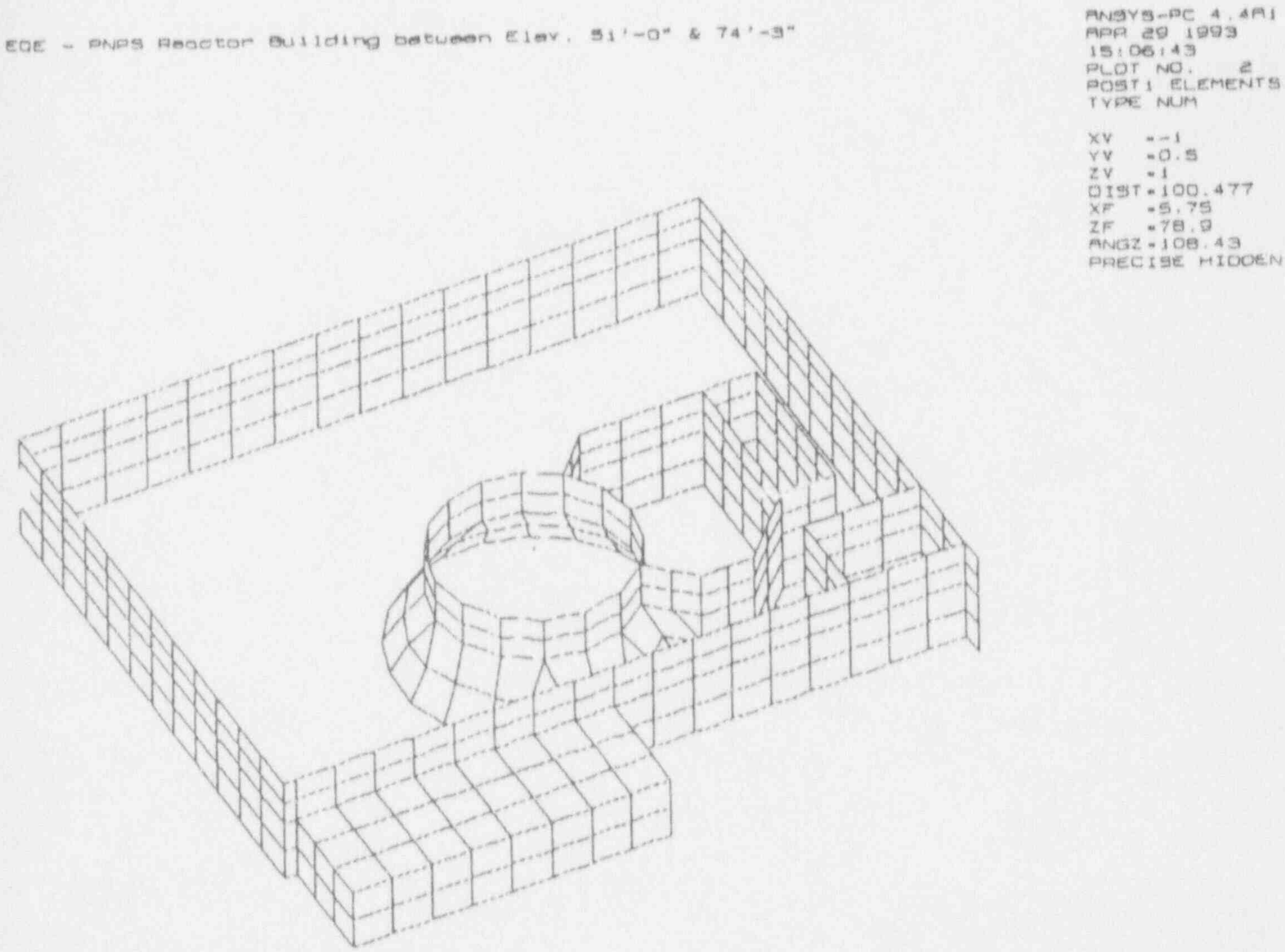

- PNPS Reactor Building between Elev. 23'-0" & 51'-0"
ANSYS-PC 4.4A1
APR 29 1993
11:25:58
PLOT NO. 2
POST1 ELEMENTS
TYPE NUM
XV =-1
YV =0.5
ZV =1
DIST=128.395
XF =0.2
YF =25.75
ZF =53.4
ANGZ=108.43
PRECISE HIDDEN

Figure 3-12


EQE - PNPS Reactor Building between Elev. 51'-0" & 74'-3"
ANSYS-PC 4.4A1
APR 29 1993
15:06:43
PLOT NO. 2
POST1 ELEMENTS
TYPE NUM
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ZV =1
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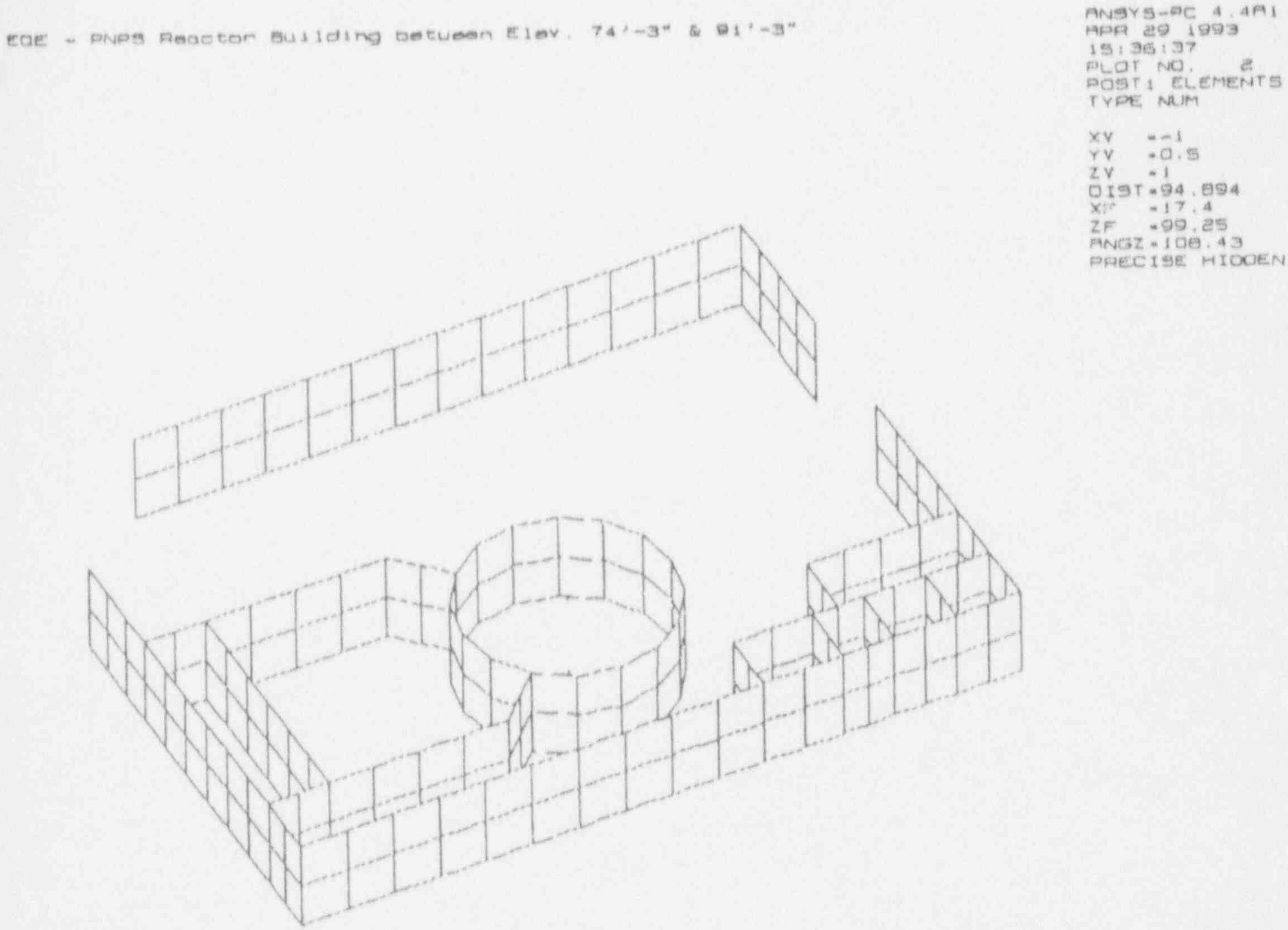
XF =5.75
ZF =78.9
ANGZ=108.43
PRECISE HIDDEN

Figure 3-13


EQE - PNPS Reactor Building between Elev. 74'-3" & 91'-3"
ANSYS-PC 4.4A1
APR 29 1993
15:36:37
PLOT NO. 2
POST1 ELEMENTS
TYPE NUM
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ZV =1
DIST=94.894
XF =17.4
ZF =99.25
ANGZ=108.43
PRECISE HIDDEN

Figure 3-14

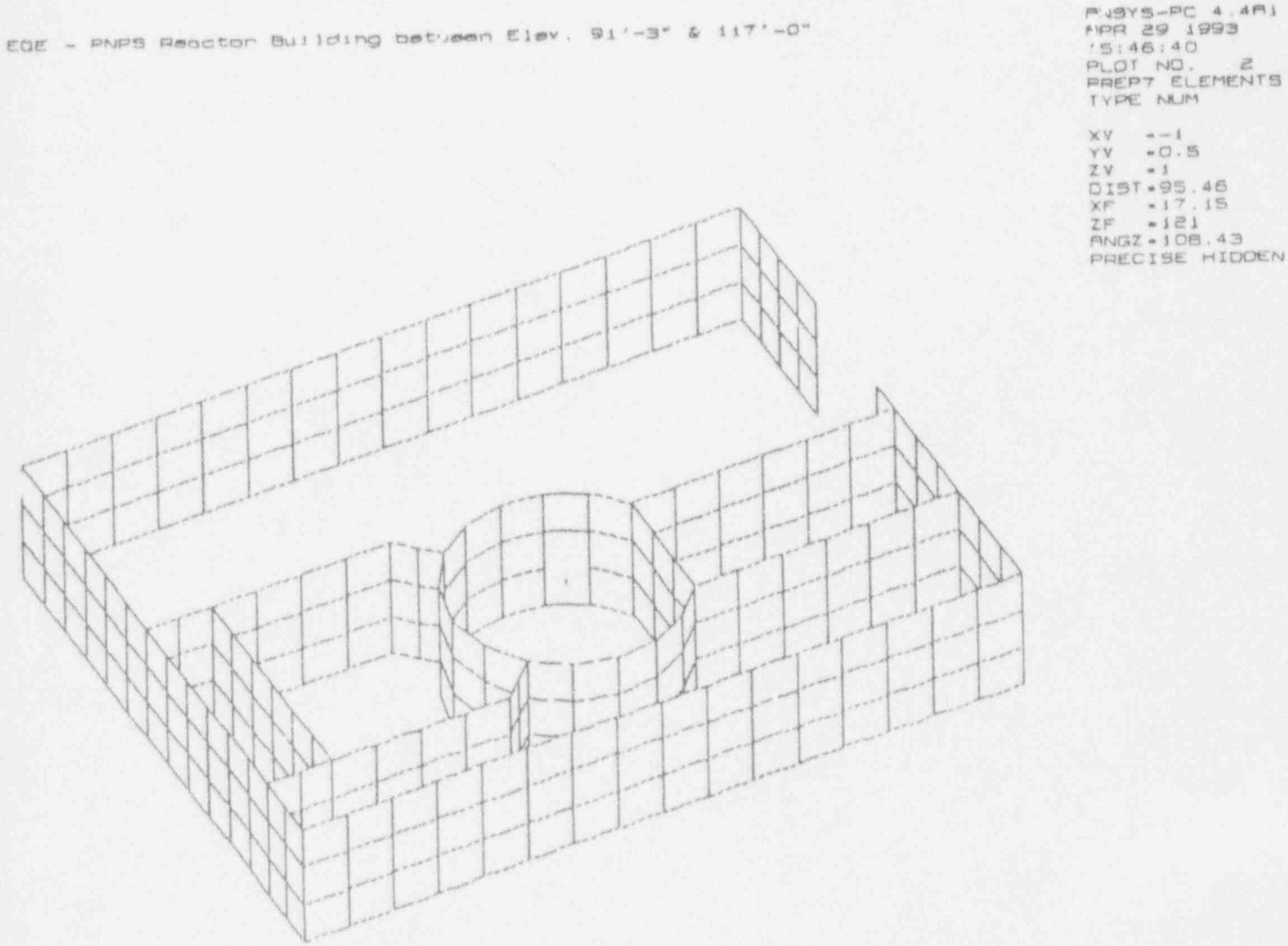

EQE - PNPS Reactor Building between Elev. 91'-3" & 117'-0"
ANSYS-PC 4.4A1
APR 29 1993
15:46:40
PLOT NO. 2
PREP7 ELEMENTS
TYPE NUM
XV =-1
YV =0.5
ZV =1
DIST=95.46
XF =17.15
ZF =121
ANGZ=108.43
PRECISE HIDDEN

Figure 3-15

4. ANALYSIS RESULTS

4.1 Time Histories

Three statistically independent ground motion time histories were generated for each earthquake case and their spectra compared to the target spectra. These comparisons, at the surface and at the foundation level, are shown in Figures 4-1 to 4-5 for the Reg. Guide 1.60 SSE. Power spectral density functions for the time histories are shown in Figures 4-6 to 4-7.

4.2 Building Model Frequencies

The first 30 fixed base frequencies and composite damping ratios for the Reactor Building dynamic model are given in Table 4-1. The percent mass participating in each direction is also shown. The frequencies in Hertz of the first significant modes for the main building portion of the model in each direction are shown below and compared to those calculated by EQE using the original Bechtel models (Reference 15):

Direction	New Model Frequency	Old E-W Model Frequency	Old N-S Model Frequency
N-S	5.04		5.61
E-W	6.36	5.79	
Vertical	14.66	14.96	13.78

Composite modal damping ratios were computed using the stiffness weighting function method of Reference 2.

4.3 Soil Impedances and Scattering Functions

The soil impedances and scattering functions were computed using the low strain soil layer properties provided in Reference 13. These are shown in Table 4-2. A weighted average, effective embedment of 31.5 feet was used. Impedances and scattering functions were computed for best estimate, upper bound (best estimate times 2.0) and lower bound (best estimate divided by

2.0) soil properties for the R.G. 1.60 SSE and PNPS FSAR (Housner) SSE cases. The best estimate impedances are shown in Figures 4-8 to 4-15 for R.G. 1.60 SSE. The scattering functions are shown in Figures 4-16 to 4-20. Because of smooth variations in the soil properties, the impedances and scattering functions for the upper bound and lower bound OBE cases could be scaled from the calculated impedances and scattering functions for the best estimate OBE cases.

4.4 In-Structure Response Spectra

The coupled soil-structure system was analyzed for seismic response. In-structure response time histories were calculated at the required node points for each direction of input for each soil case. Directional responses could be combined algebraicly because the input time histories were statistically independent. Response spectra were generated at the nodes, for each direction, for each soil case. The spectra were broadened. Regulatory Guide 1.122 specifies that the broadening ratio shall be determined by varying parameters but shall be at least 10%. A ratio of 15% may be used in lieu of varying parameters. In this analysis, the only parameters whose variance would significantly affect the building frequency are the soil properties. To be conservative, each soil case was individually broadened using a broadening factor of 15% for the best estimate soil case and 10% for the upper and lower bound soil cases. The spectra for the three soil cases were then enveloped. Finally, for the Reactor Building floors outside containment and the torus, spectra at all the points at the same elevation were enveloped.

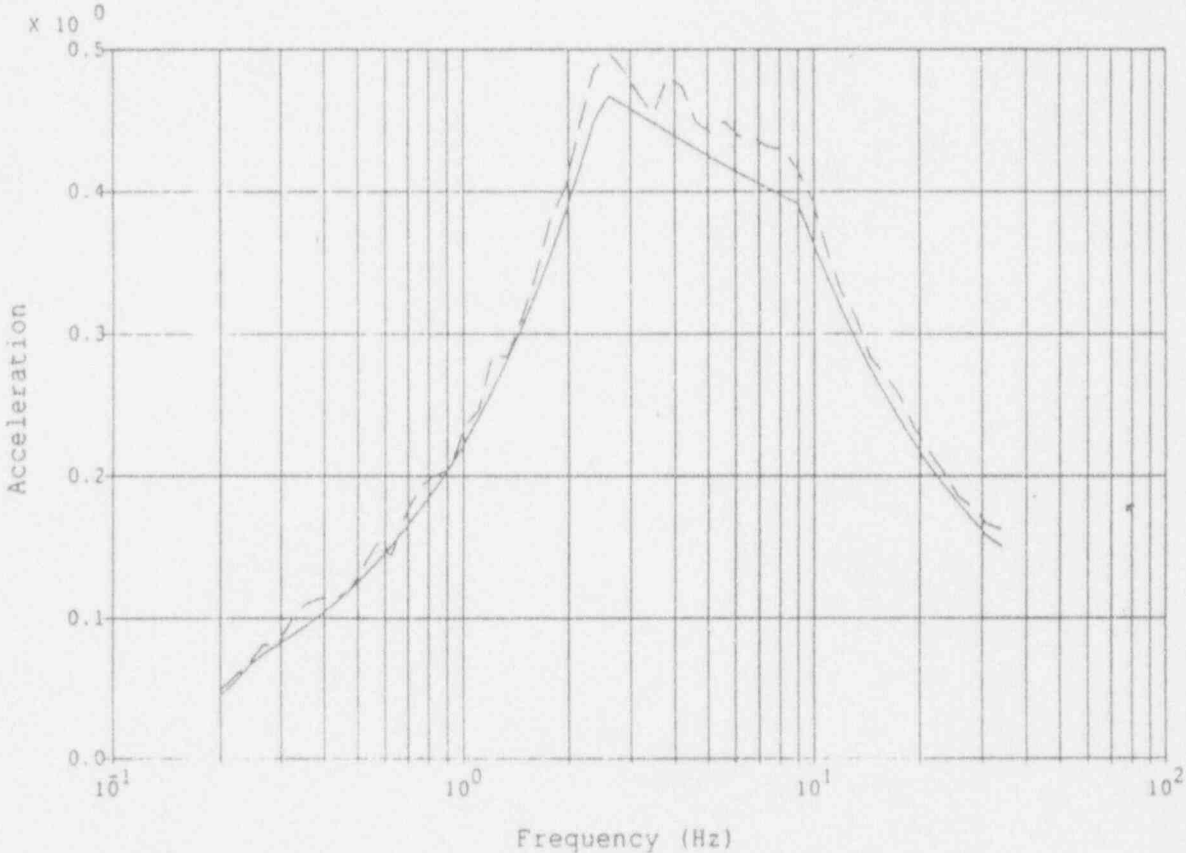
The final in-structure response spectra for R.G. 1.60 SSE input are contained in Attachment A to this report. The in-structure response spectra for other cases may be found in Reference 14. The analysis is documented in Reference 14.

TABLE 4-1

mode no	freq hz	dampg ratio	x (NS)	y (EW)	z (V)	xx	yy	zz
1	5.04	0.067	49.454	0.132	0.003	0.287	84.935	0.745
2	6.36	0.055	0.117	35.065	0.017	55.475	0.164	0.377
3	6.83	0.038	0.015	0.000	0.001	0.009	0.408	0.089
4	7.07	0.051	0.052	12.007	0.019	25.409	0.100	0.659
5	9.20	0.070	0.106	1.000	0.000	0.681	0.008	47.643
6	12.62	0.070	8.327	0.036	1.810	0.024	0.023	0.131
7	13.43	0.070	0.000	12.396	3.569	0.083	0.007	0.074
8	14.62	0.041	0.229	0.691	8.859	0.228	0.143	0.018
9	14.63	0.035	0.317	0.125	0.160	0.053	0.129	0.000
10	14.66	0.063	0.000	0.277	35.883	0.058	0.023	0.040
11	17.42	0.070	5.123	0.024	0.609	0.002	0.033	7.425
12	18.72	0.070	0.964	0.640	0.140	0.488	0.036	1.966
13	19.54	0.070	0.257	0.555	0.179	0.615	0.014	2.879
14	20.28	0.035	0.000	0.000	3.199	0.000	0.000	0.000
15	21.63	0.069	0.191	2.729	0.225	1.898	0.544	0.563
16	22.32	0.069	0.561	0.494	0.851	0.350	2.412	0.010
17	24.99	0.037	0.010	0.004	0.013	0.005	0.061	0.022
18	25.02	0.037	0.002	0.070	0.001	0.041	0.006	0.000
19	27.24	0.069	0.518	0.033	0.576	0.038	0.545	0.217
20	27.55	0.069	0.715	0.004	0.042	0.049	0.001	1.141
21	30.33	0.069	0.009	0.783	0.854	1.131	0.001	0.047
22	32.92	0.070	0.000	0.003	0.173	0.976	0.111	0.007
23	34.36	0.070	0.025	0.003	0.005	0.047	0.004	0.165
24	36.56	0.068	0.059	0.003	0.890	0.013	0.136	0.082
25	39.35	0.038	0.000	0.203	0.001	0.049	0.002	0.000
26	39.38	0.039	0.253	0.000	0.108	0.001	0.075	0.003
27	39.38	0.040	0.000	0.075	0.000	0.024	0.000	0.000
28	39.38	0.040	0.006	0.000	0.021	0.000	0.003	0.001
29	40.21	0.059	0.158	0.004	2.156	0.038	0.001	0.066
30	41.47	0.065	0.000	0.108	0.003	0.024	0.024	0.[illegible]
total pct mass			67.470	67.465	60.368	88.094	89.950	64.369

TABLE 4-2

Layer No.	Thick (ft)	Shear Wave Velocity (ft/sec)	Density (lb*sec^2/ft)	Damping Ratio (%)	Poisson's Ratio
1	10	535	3.92	0.02	0.33
2	10	745	3.92	0.02	0.33
3	10	860	4.26	0.02	0.4
4	10	925	4.26	0.02	0.4
5	5	963	4.26	0.02	0.4
6	5	1215	4.01	0.02	0.4
7	10	1255	4.01	0.02	0.4
8	10	1310	4.01	0.02	0.4
9	10	1365	4.01	0.02	0.4
10	10	1415	4.01	0.02	0.4
11	10	1465	4.01	0.02	0.4
Rock	-	3000	5.22	0.02	0.4



Legend:

RG 1.60 ~~Housner Design~~
Spectrum

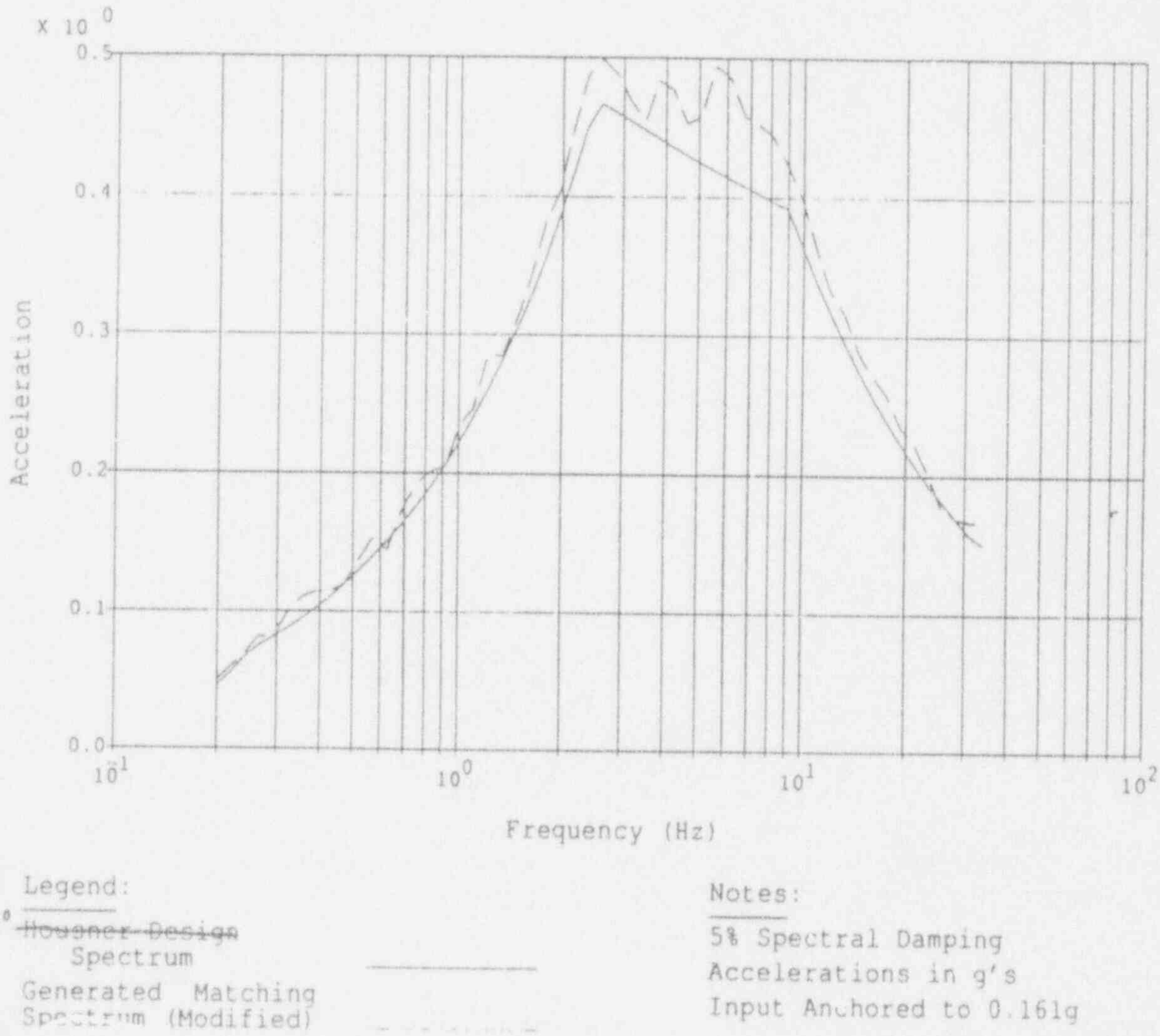
Generated Matching
Spectrum

Notes:

5% Spectral Damping
Accelerations in g's
Input Anchored to 0.15g

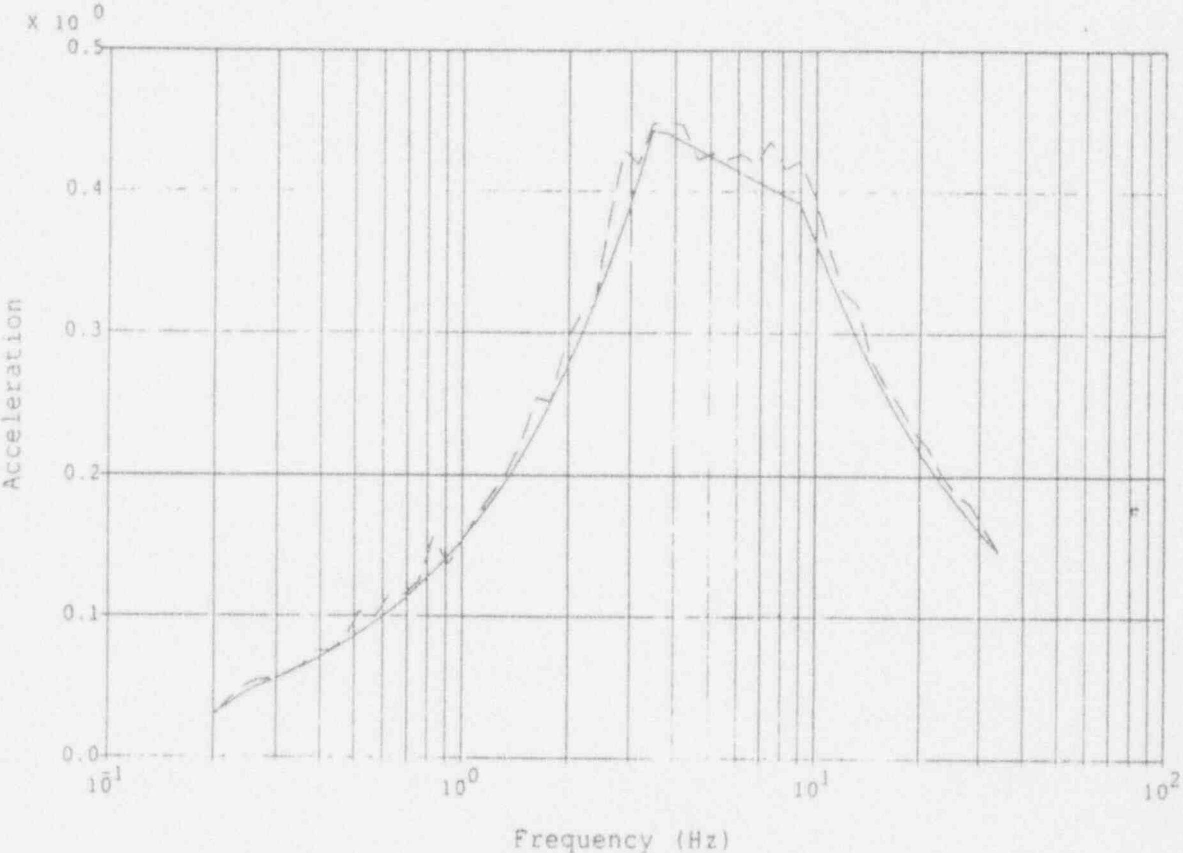
BECO: Pilgrim Nuclear Power Station, Reactor Building, Soil Analysis
Comparison of Generated Motion Matching RG 1.60 Design Spectrum, Comp 1

Figure 4-1



BECO: Pilgrim Nuclear Power Station, Reactor Building, Soil Analysis
Comparison of Generated Motion Matching RG 1.60 Design Spectrum, Comp 2

Figure 4-2



Legend:

R.G. 1.60 ~~Housner Design~~ Spectrum

Generated Matching Spectrum — — —

Notes:

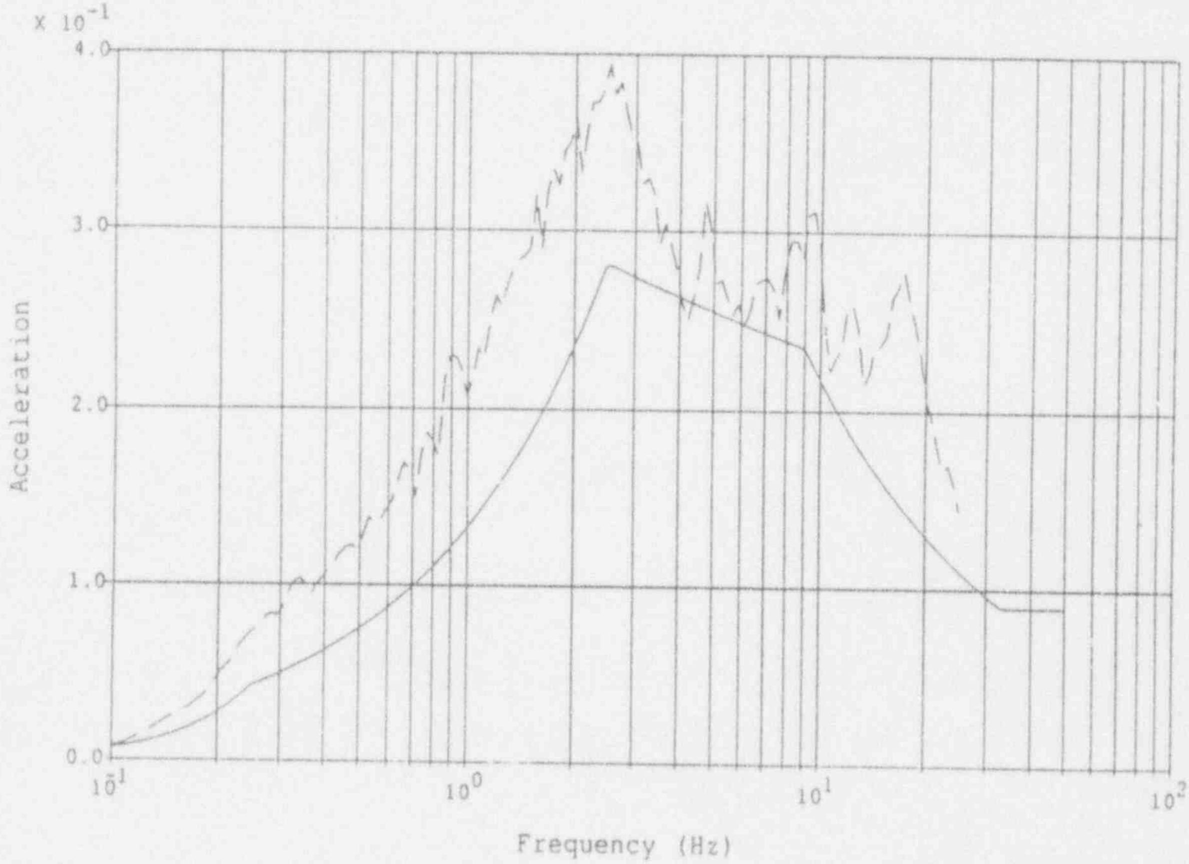
5% Spectral Damping

Accelerations in g's

Input Anchored to 0.10g

BECO: Pilgrim Nuclear Power Station, Reactor Building, Soil Analysis
Comparison of Generated Motion Matching RG 1.60 Design Spectrum, Comp 3

Figure 4-3



Legend:

60% of RG 1.60 Input Design Spectrum

Env of LB,BE & UB at b.o.fnd,-23',lay.#10

Notes:

Sand Degradation Curves

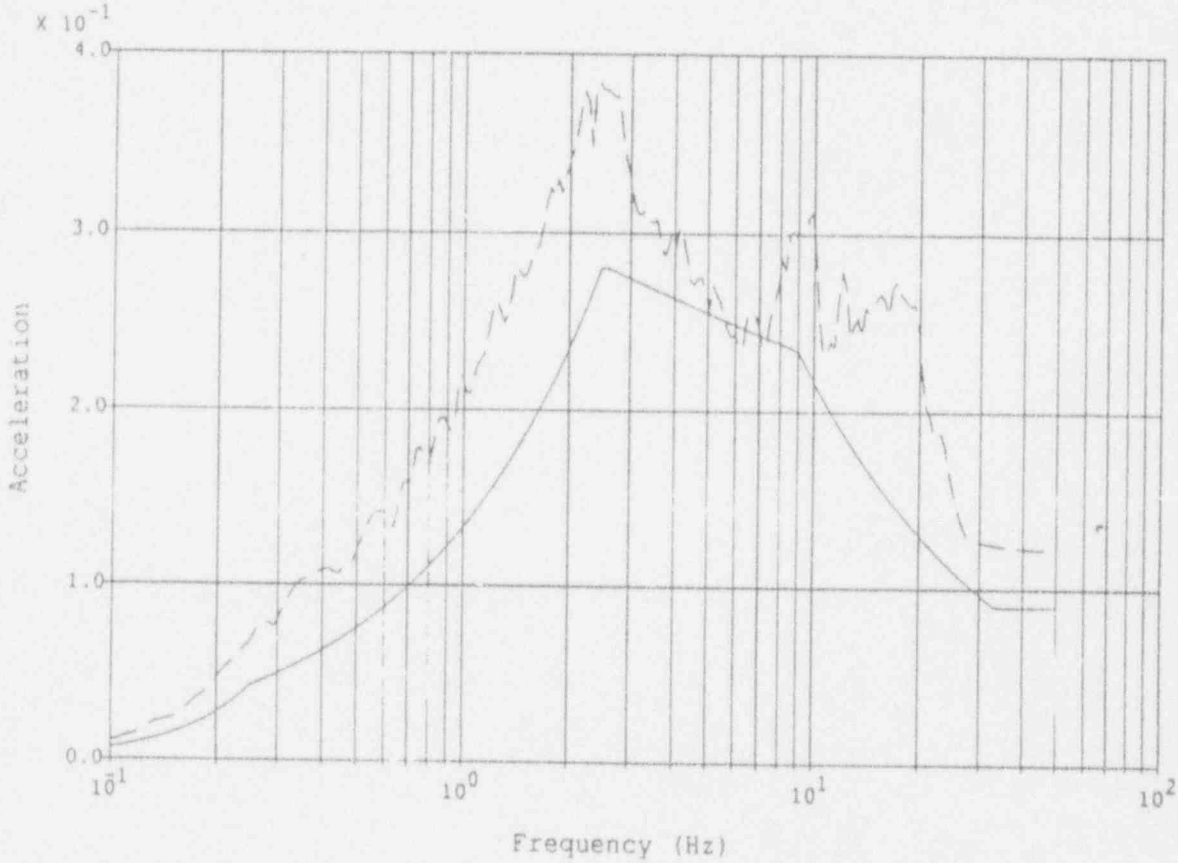
5% Spectral Damping

Accelerations in g's

BECO: Pilgrim Nuclear Power Station, Reactor Building, Soil Analysis
Envelope of Deconvolved Motion at Foundation vs RG1.60 Input, Comp 1

Figure 4-4

EQE



Legend:

60% of RG 1.60 Input Design Spectrum ————

Env of LB, BE & UB at b.o.fnd, -23', lay.#10 — — — —

Notes:

Modified Input Motion
Sand Degradation Curves
5% Spectral Damping
Accelerations in g's

BECO: Pilgrim Nuclear Power Station, Reactor Building, Soil Analysis
Envelope of Deconvolved Motion at Foundation vs RG1.60 Input, Comp 2

Figure 4-5

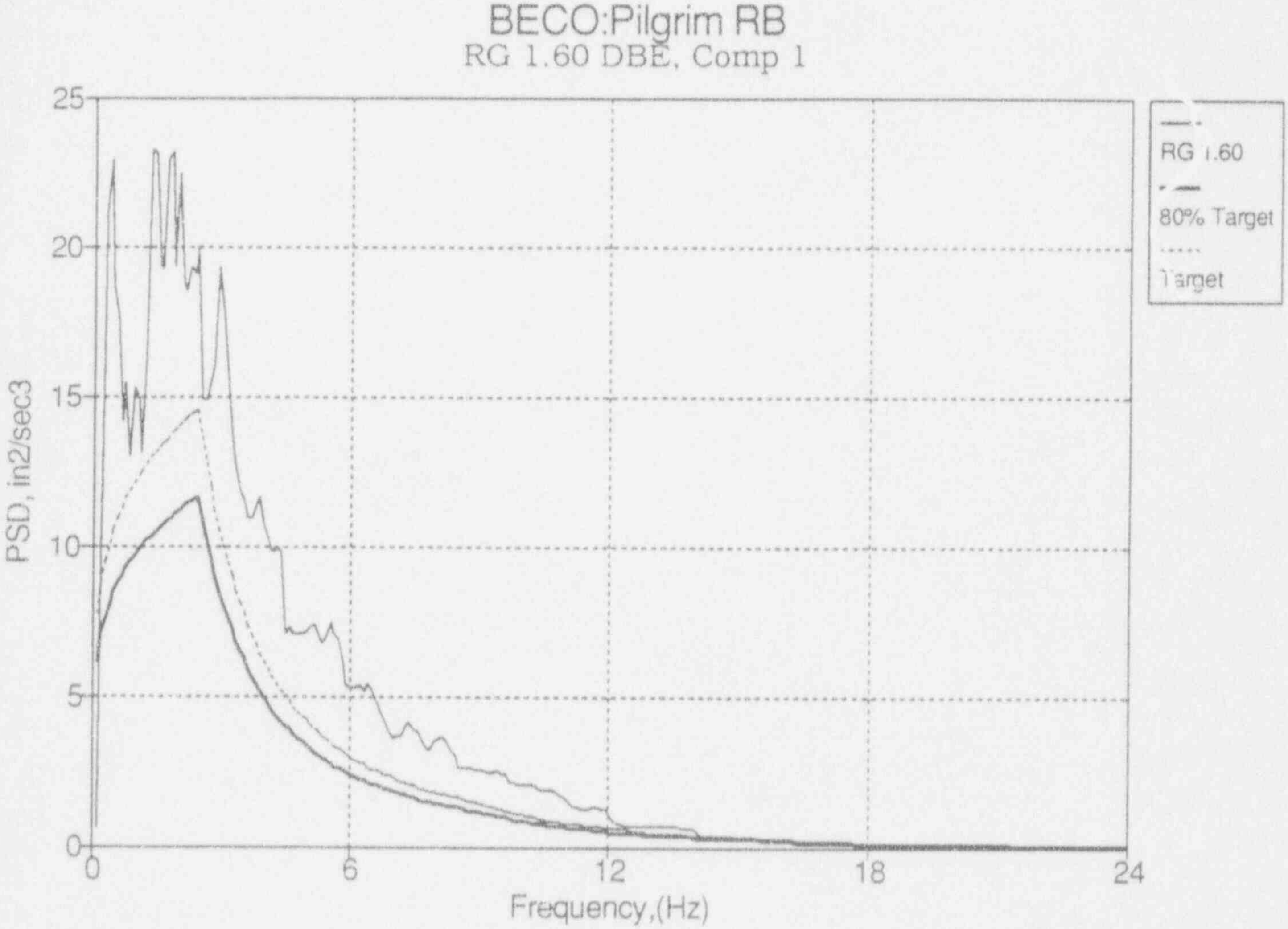

BECO:Pilgrim RB
RG 1.60 DBE, Comp 1
PSD, in2/sec3
Frequency,(Hz)
0
5
10
15
20
25
0
6
12
18
24
RG 1.60
80% Target
Target

Figure 4-6

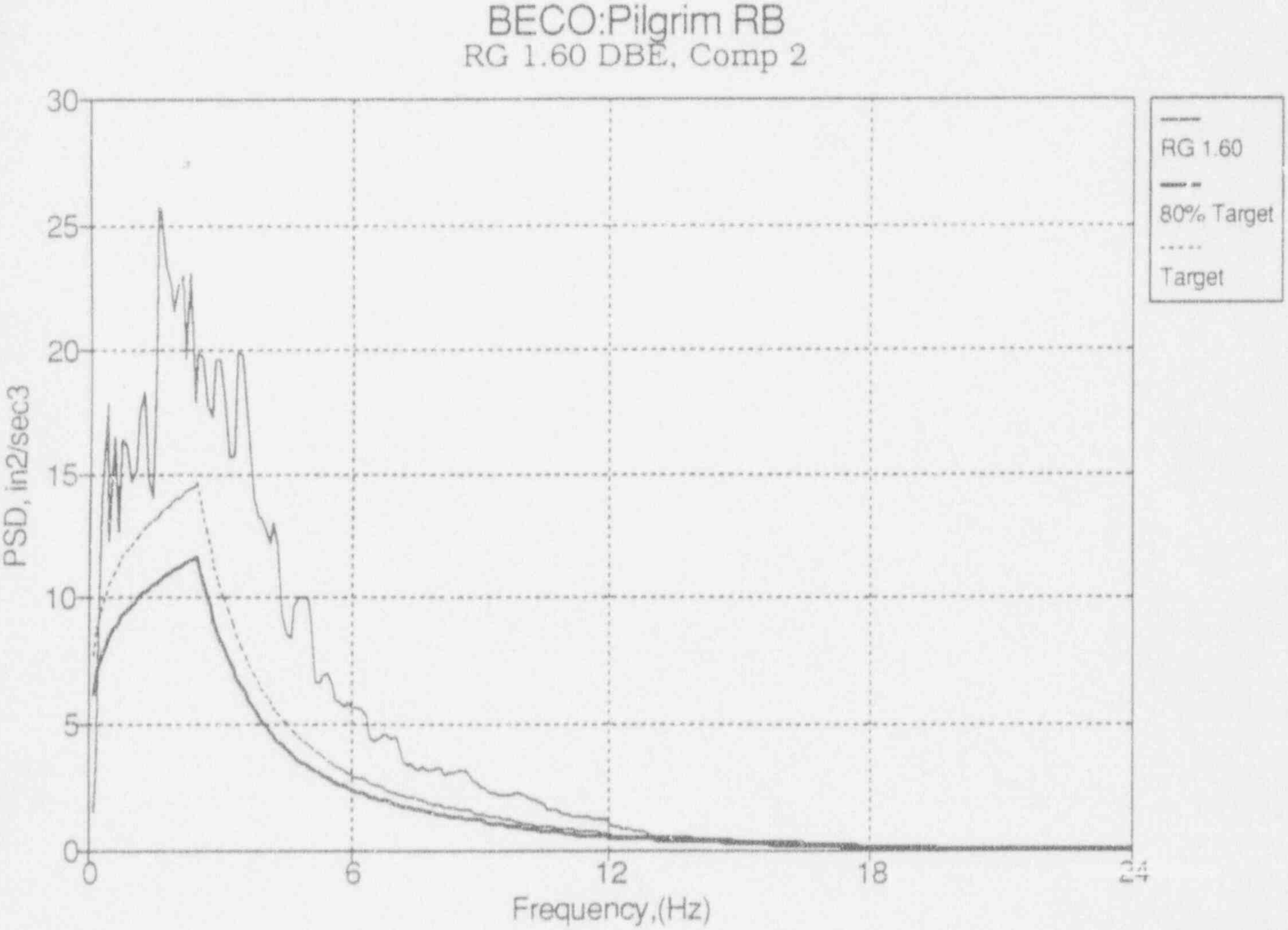

BECO:Pilgrim RB
RG 1.60 DBE, Comp 2
PSD, in2/sec3
30
25
20
15
10
5
0
0
6
12
18
24
Frequency,(Hz)
RG 1.60
80% Target
Target

Figure 4-7

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (1, 1)   values are physical units

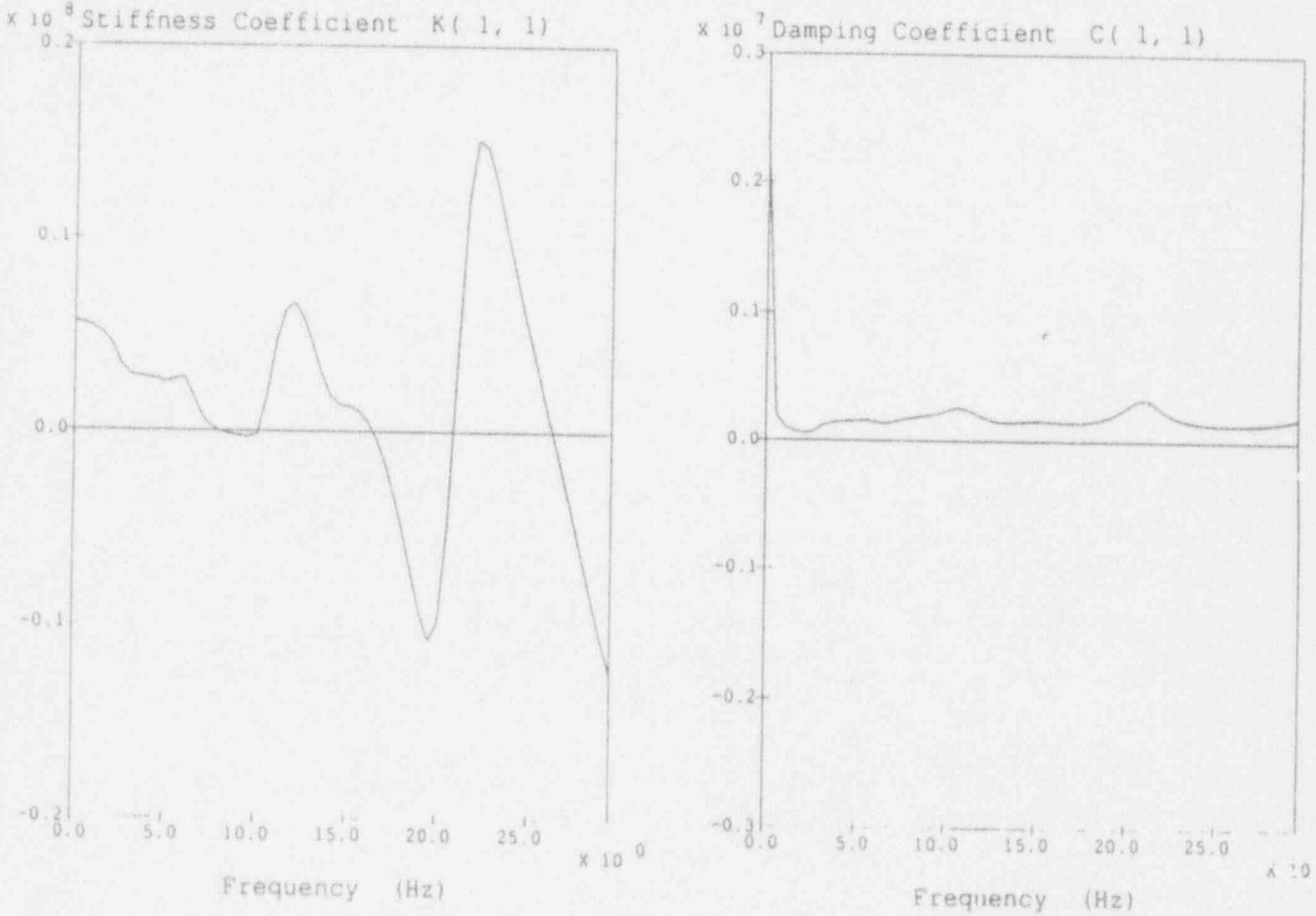


Figure 4-8

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.0580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (1, 5) values are physical units

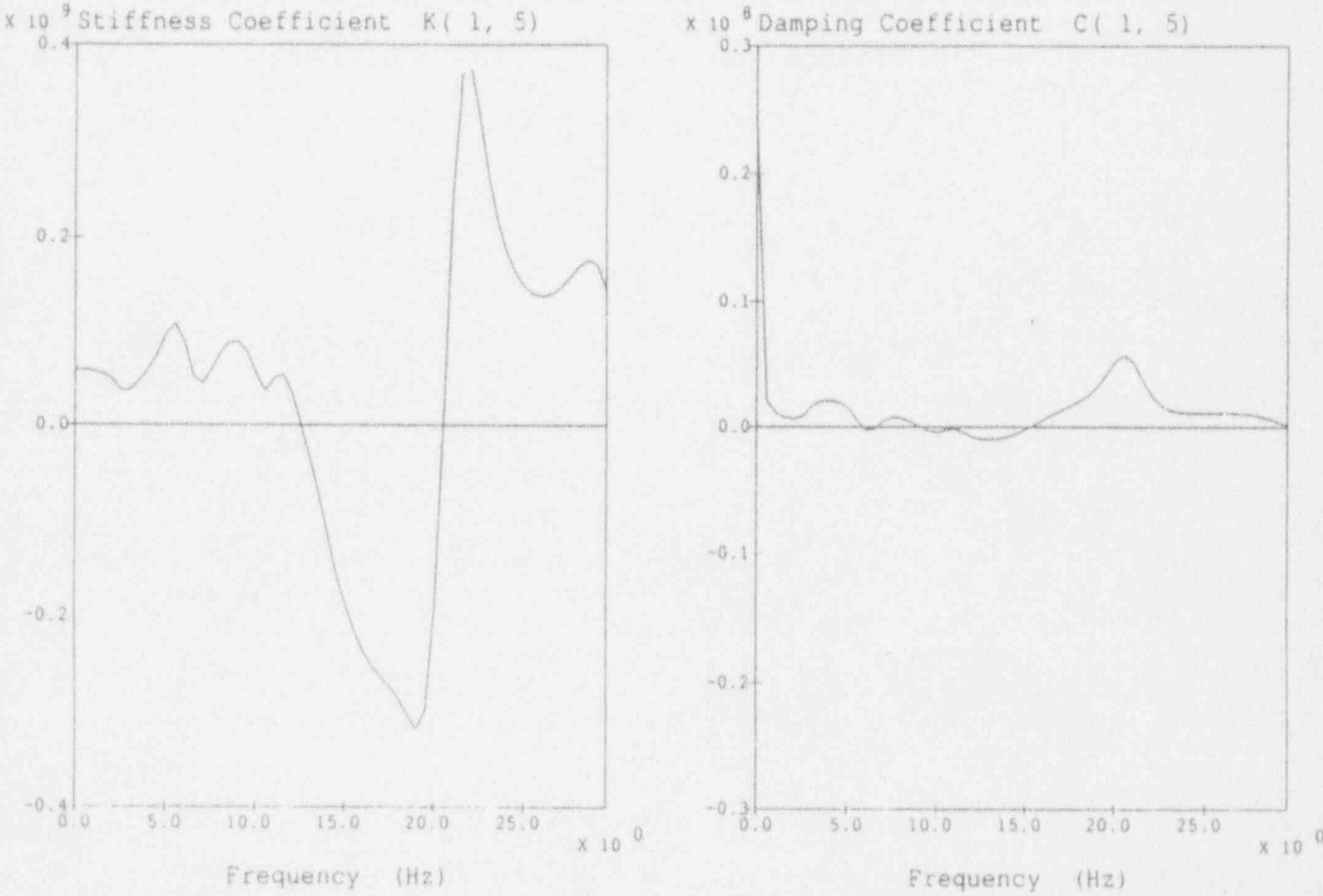


Figure 4-9

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
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Impedance Component (2, 2) values are physical units

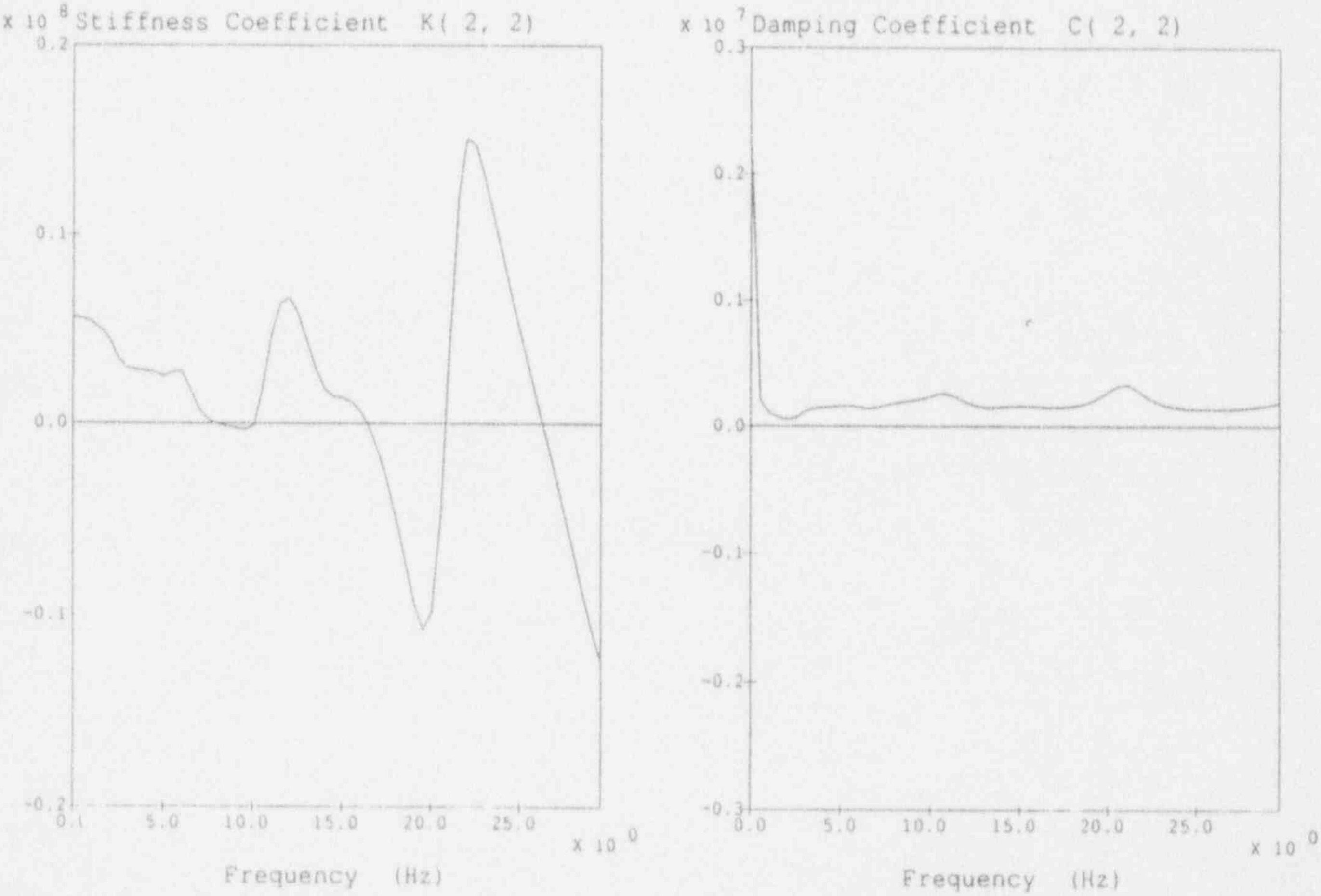

Figure 4-10

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (2, 4) values are physical units

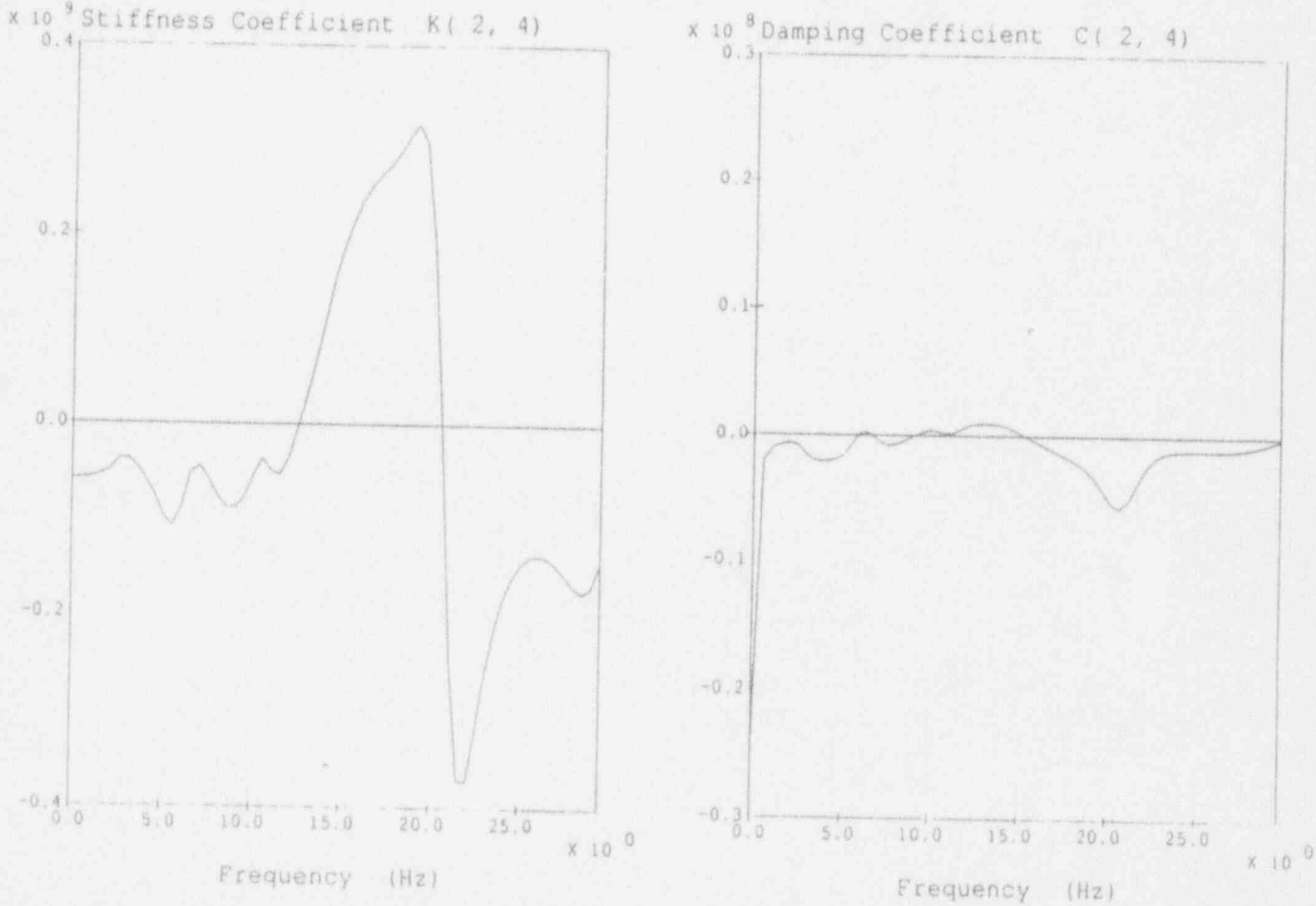

FIGURE 4-11

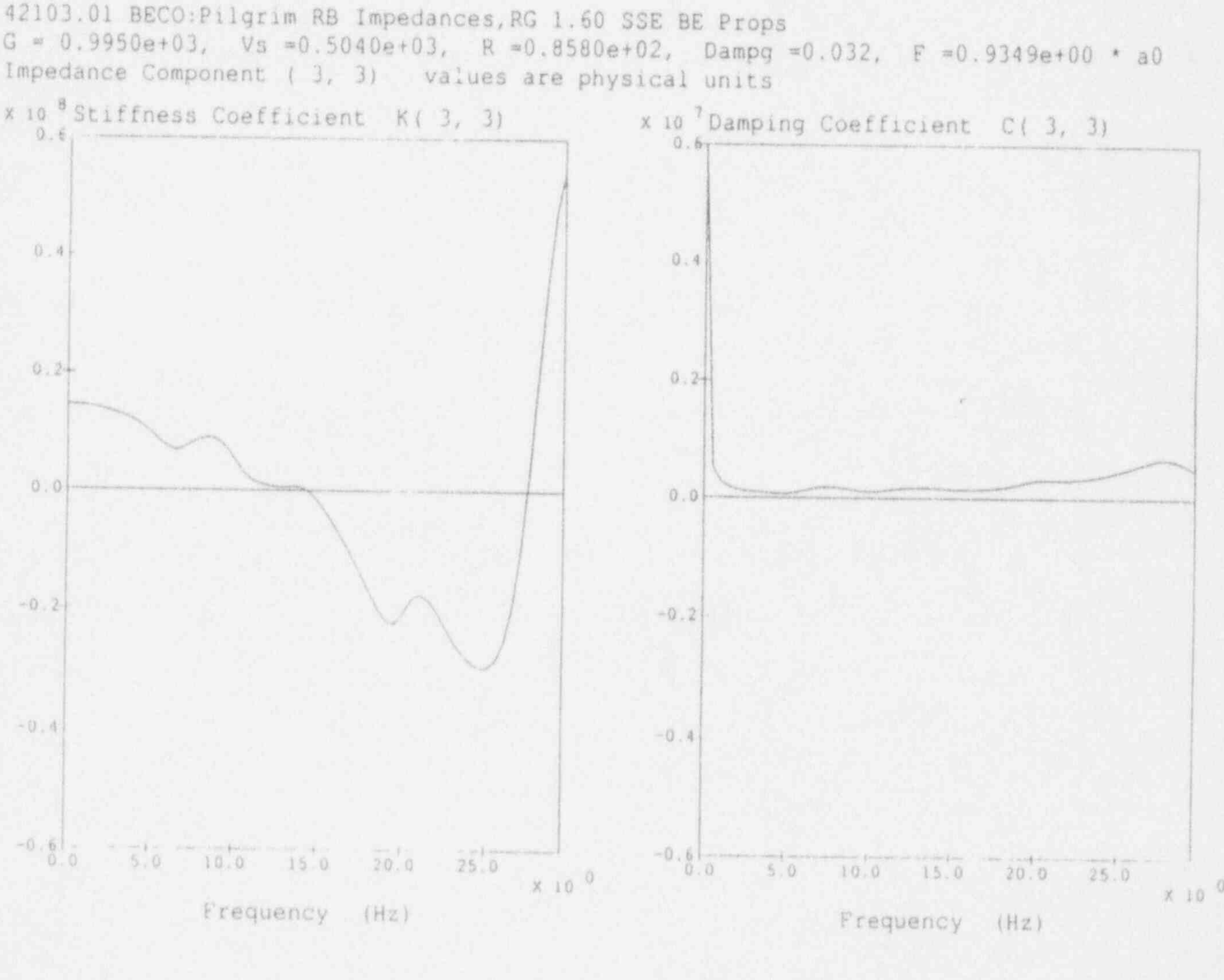
42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (3, 3) values are physical units
x 10 8 Stiffness Coefficient K(3, 3)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.0 5.0 10.0 15.0 20.0 25.0
x 10 0
Frequency (Hz)
x 10 7 Damping Coefficient C(3, 3)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.0 5.0 10.0 15.0 20.0 25.0
x 10 0
Frequency (Hz)

FIGURE 4-12

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (4, 4) values are physical units

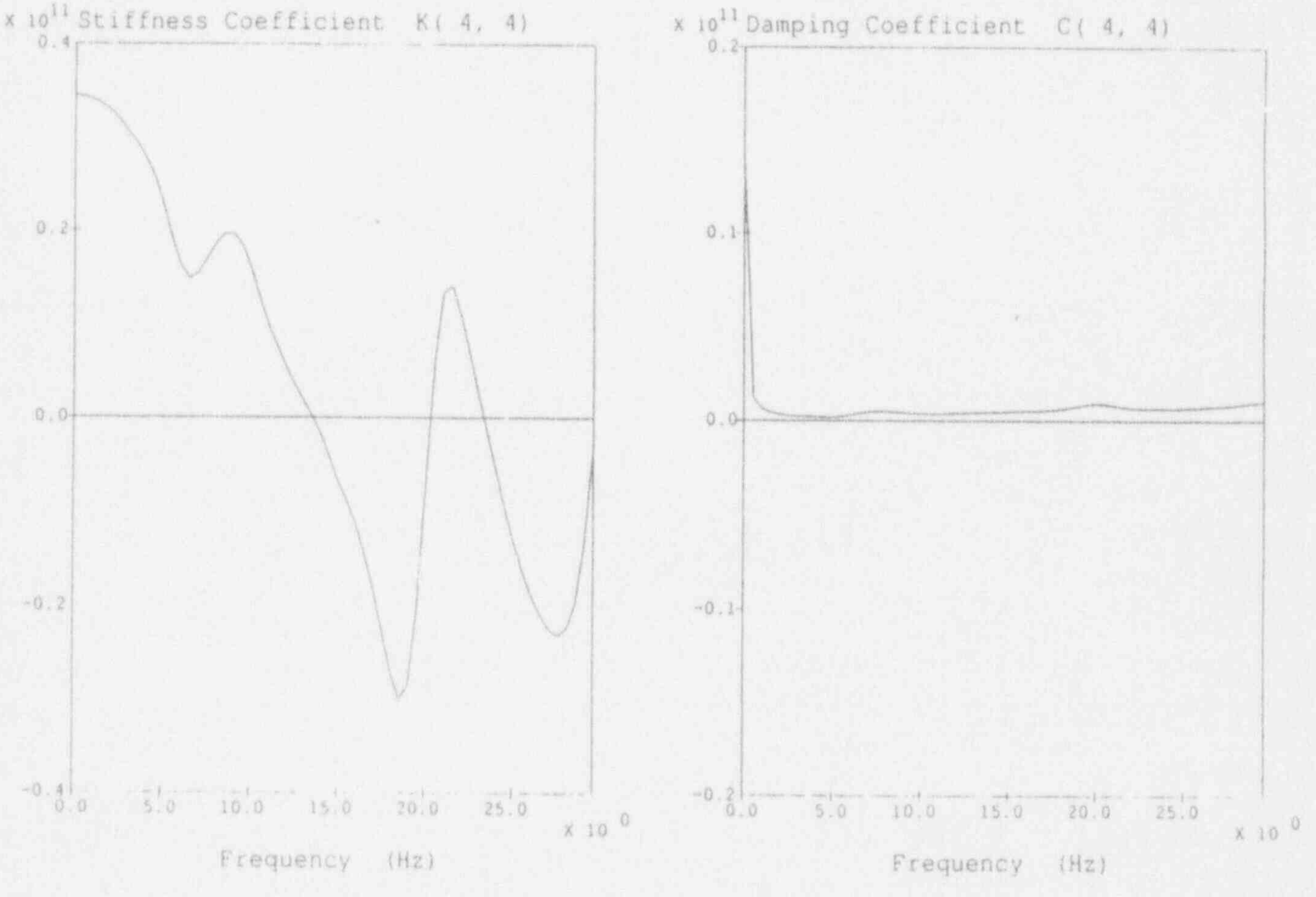

FIGURE 4-13

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (5, 5) values are physical units

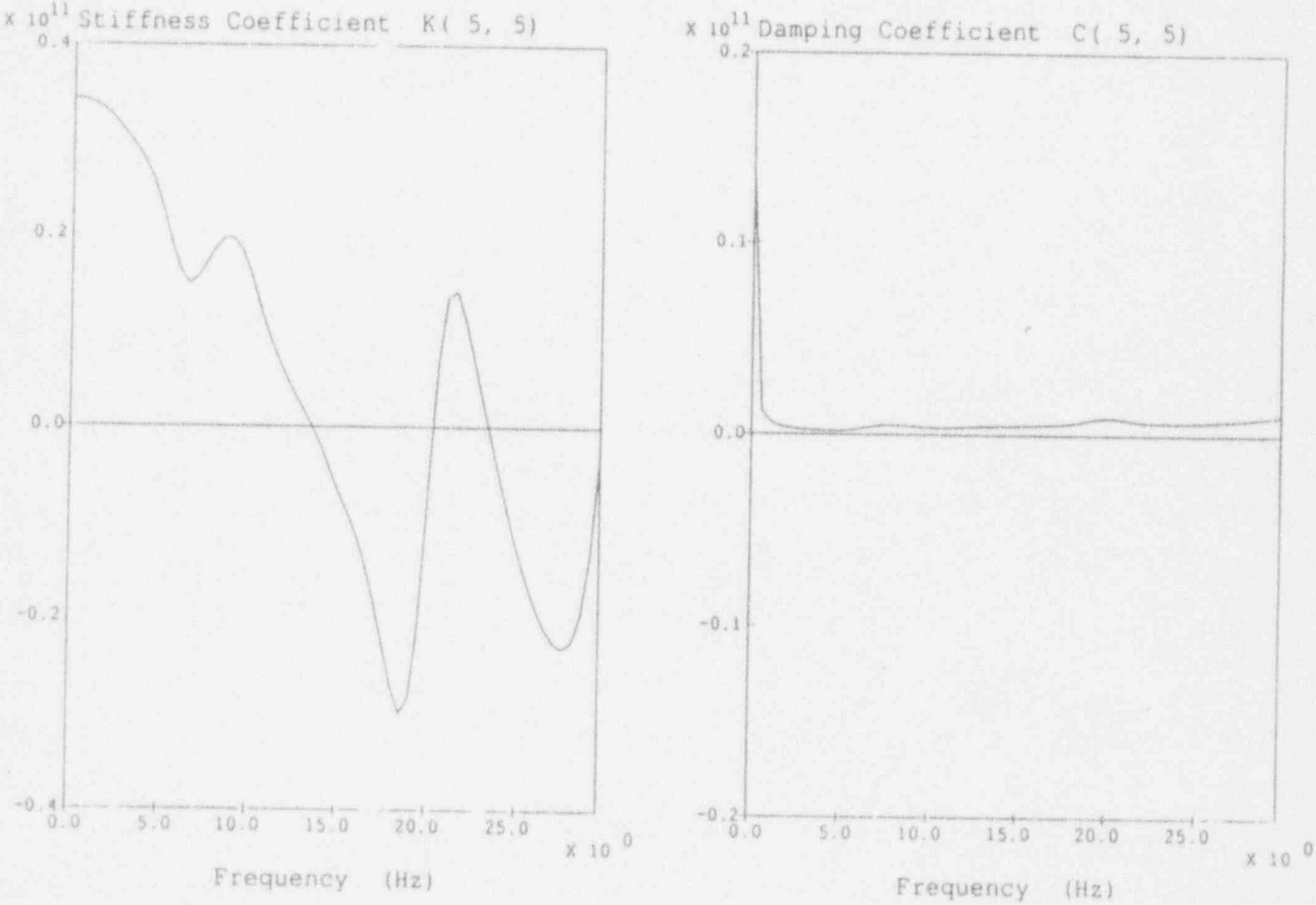

FIGURE 4-14

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F =0.9349e+00 * a0
Impedance Component (6, 6) values are physical units

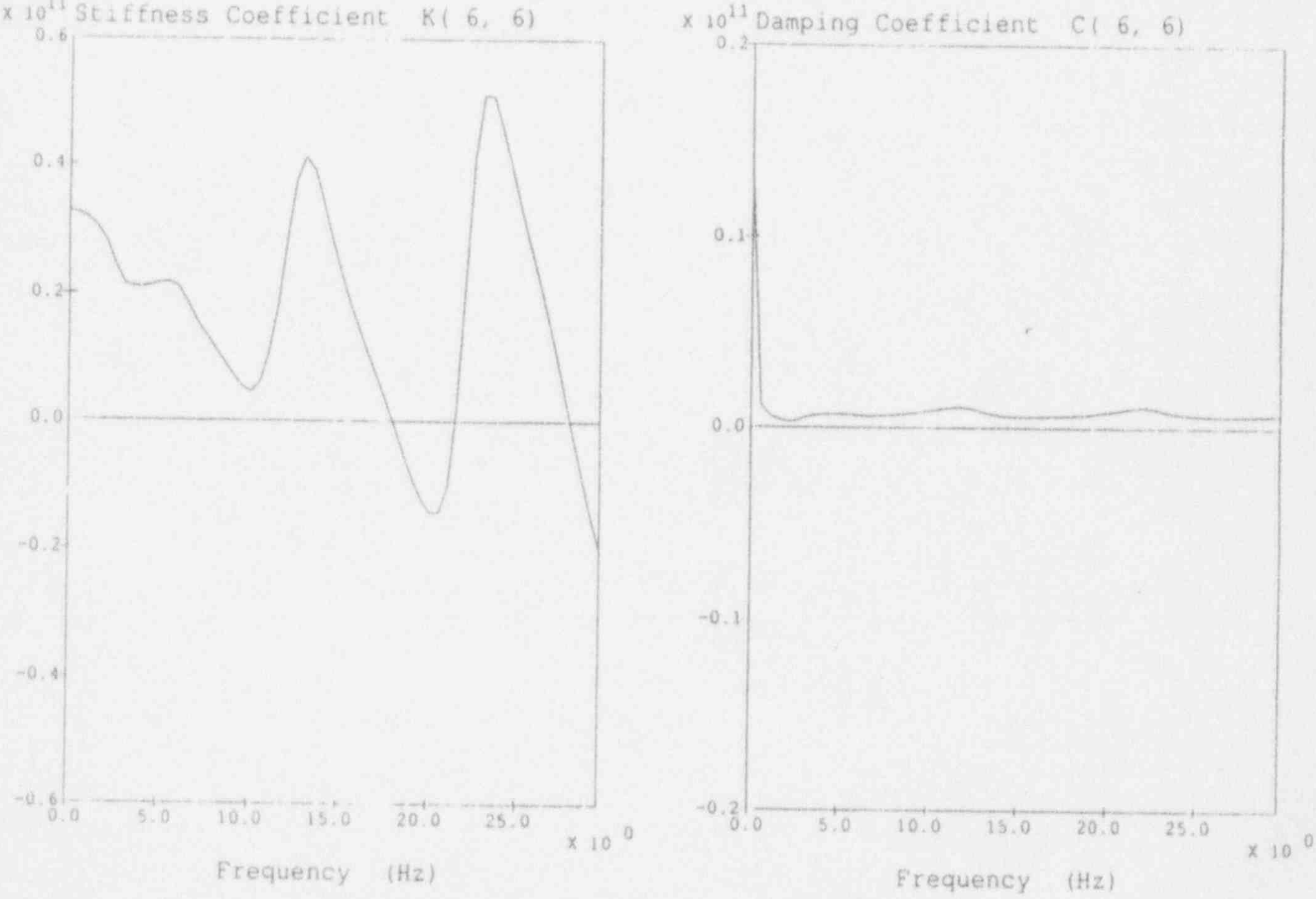

Figure 4-15

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F = 0.9349e+00 * a0
Incident Wave Case 1 Component 1 values are physical units

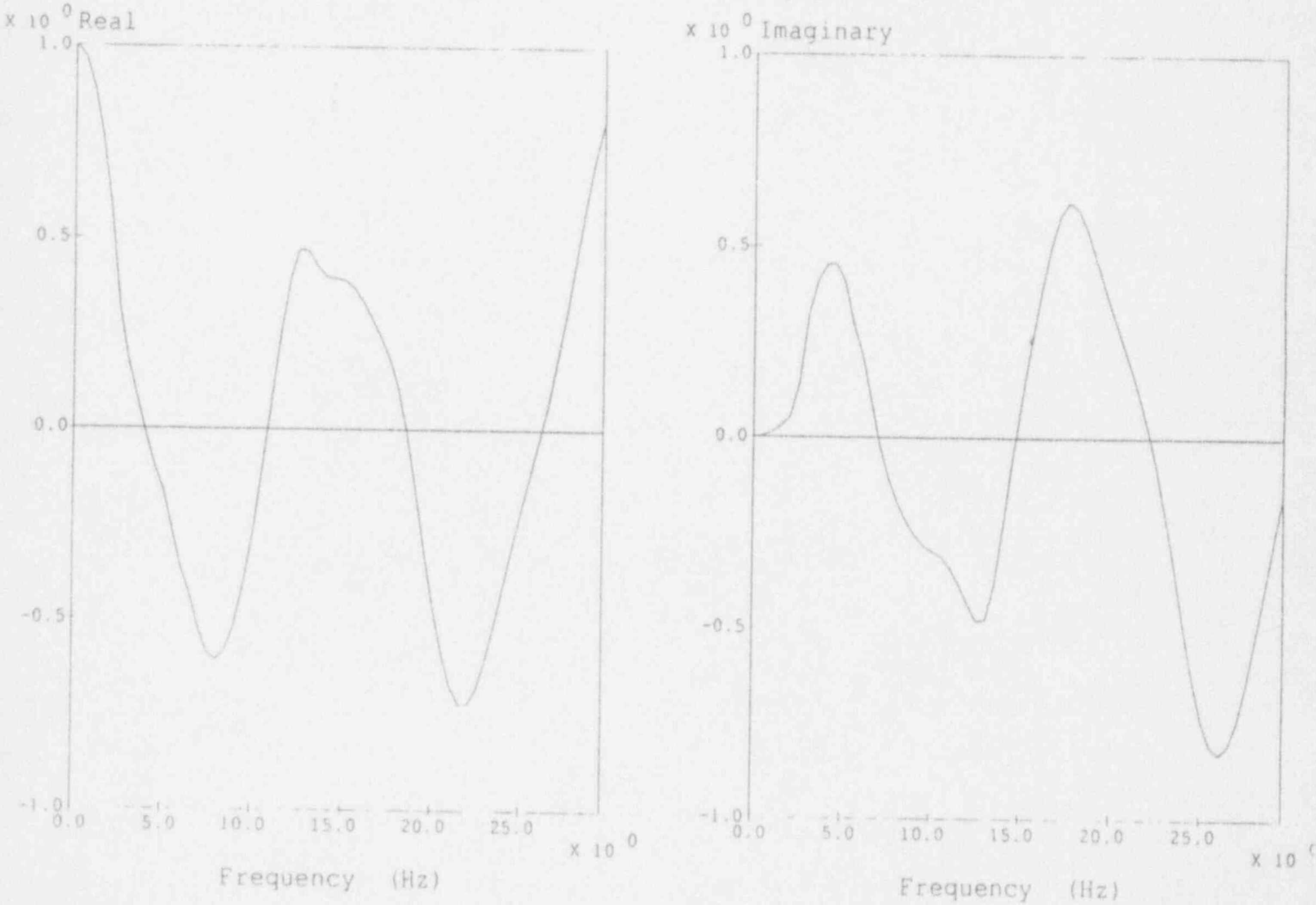

Figure 4-16

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
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Incident Wave Case 1 Component 5 values are physical units

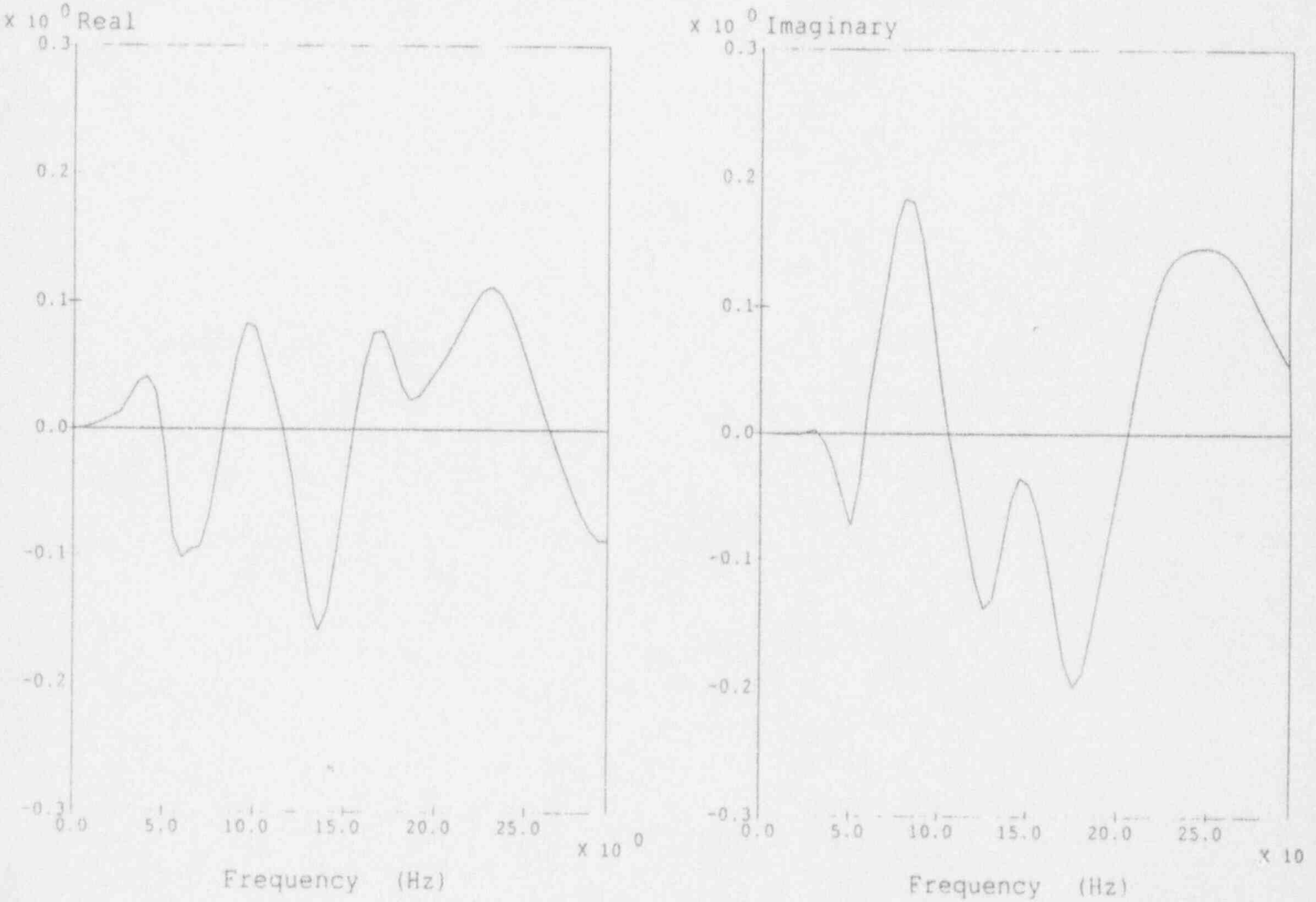

Figure 4-17

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F = 0.9349e+00 * a0
Incident Wave Case 2 Component 2 values are physical units

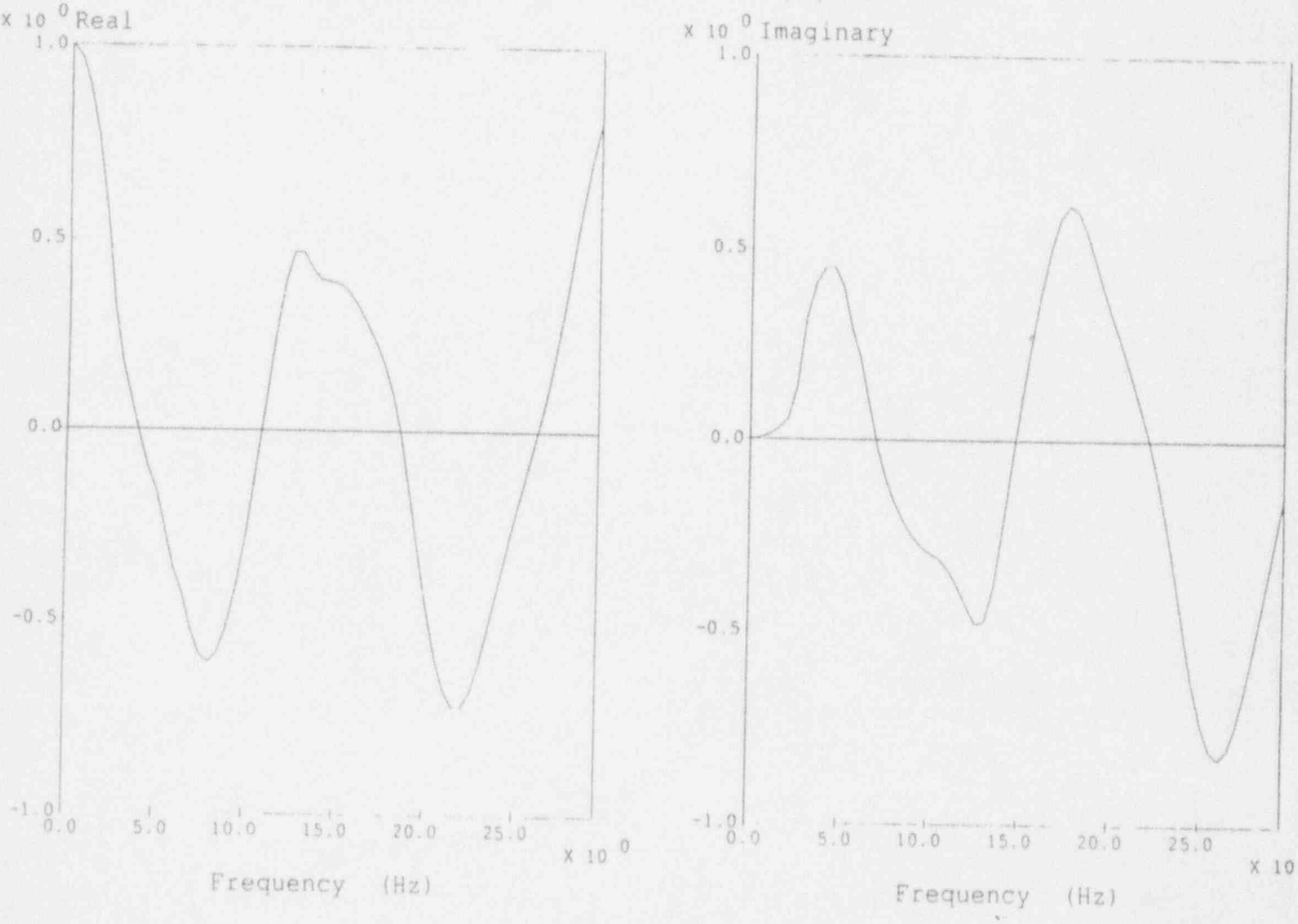

Figure 4-18

42103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
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Incident Wave Case 2 Component 4 values are physical units

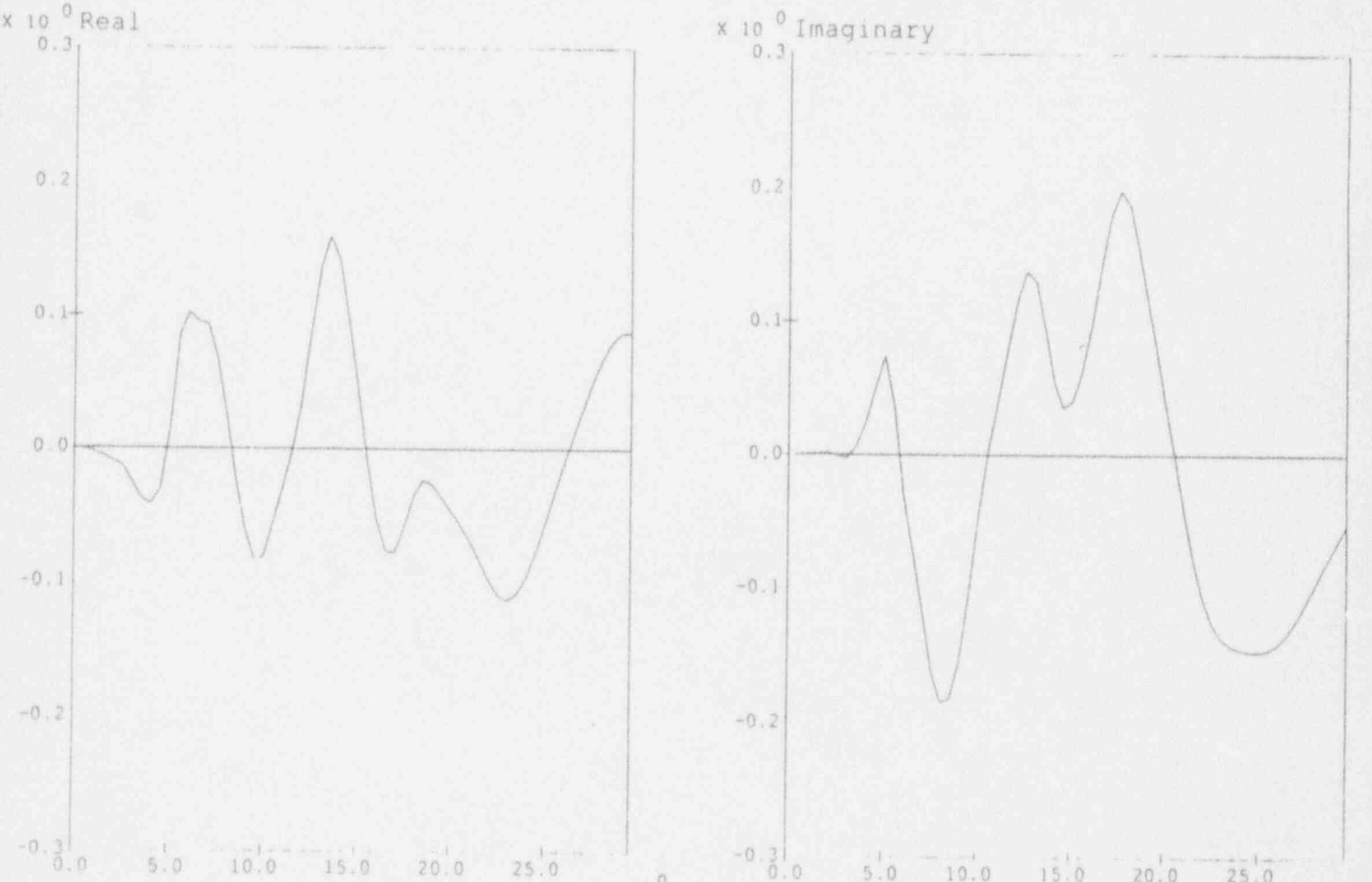

Figure 4-19

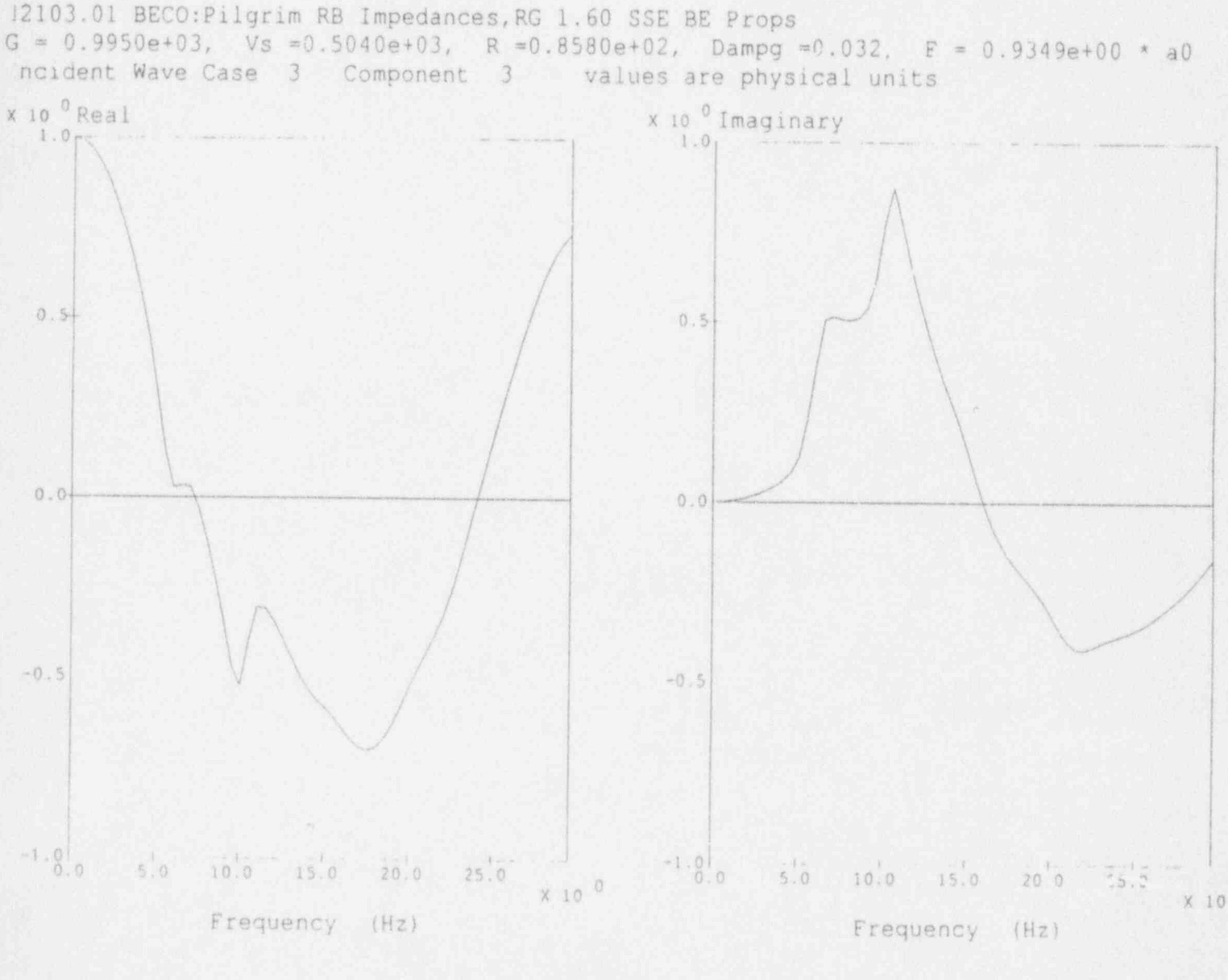
]2103.01 BECO:Pilgrim RB Impedances,RG 1.60 SSE BE Props
G = 0.9950e+03, Vs =0.5040e+03, R =0.8580e+02, Dampg =0.032, F = 0.9349e+00 * a0
ncident Wave Case 3 Component 3 values are physical units
x 10 0 Real
1.0
0.5
0.0
-0.5
-1.0
0.0
5.0
10.0
15.0
20.0
25.0
x 10 0
Frequency (Hz)
x 10 0 Imaginary
1.0
0.5
0.0
-0.5
-1.0
0.0
5.0
10.0
15.0
20.0
x 10 0
Frequency (Hz)

Figure 4-20

5. REFERENCES

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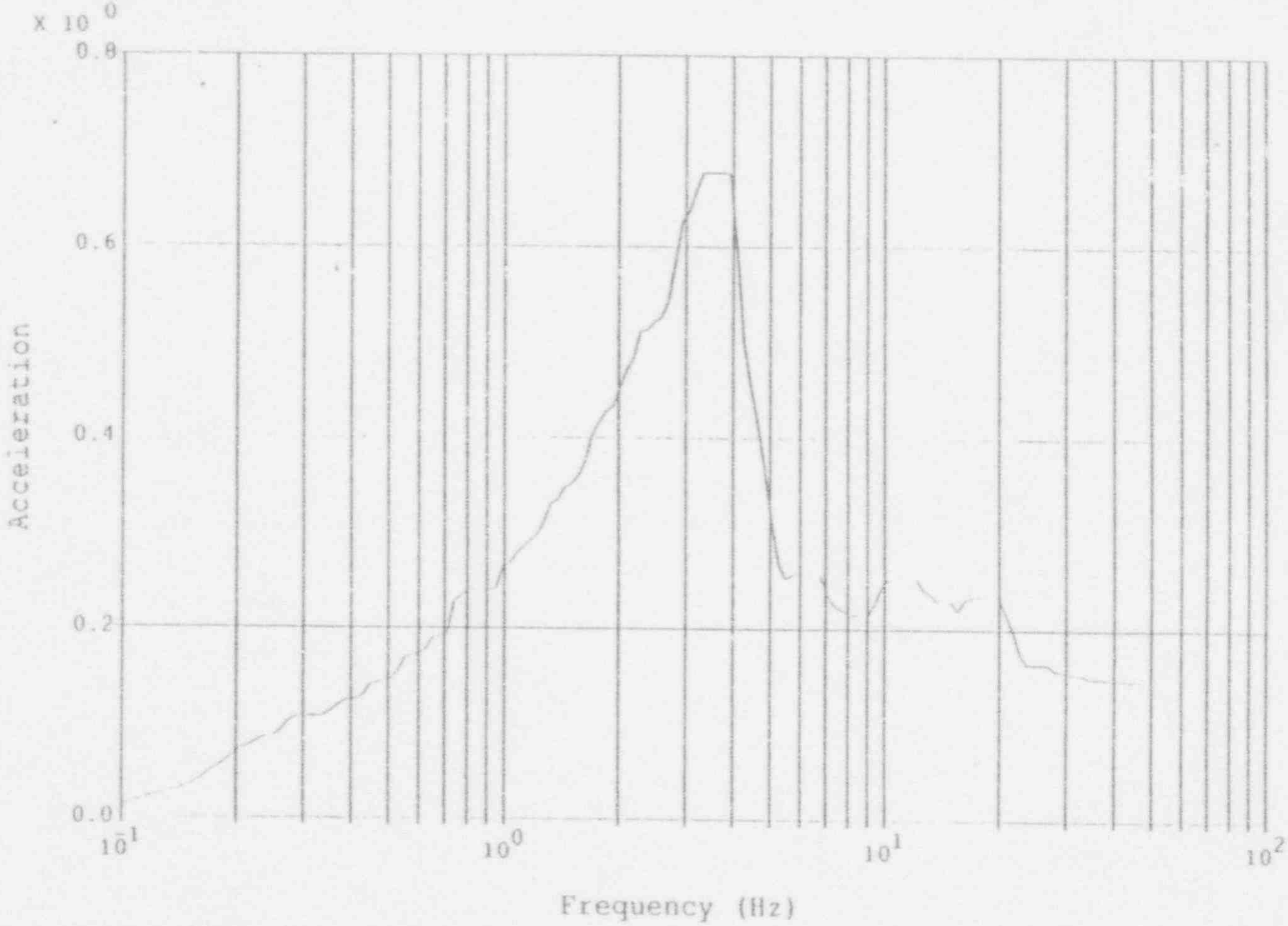
ATTACHMENT A

REGULATORY GUIDE 1.60 SSE

IN-STRUCTURE RESPONSE SPECTA

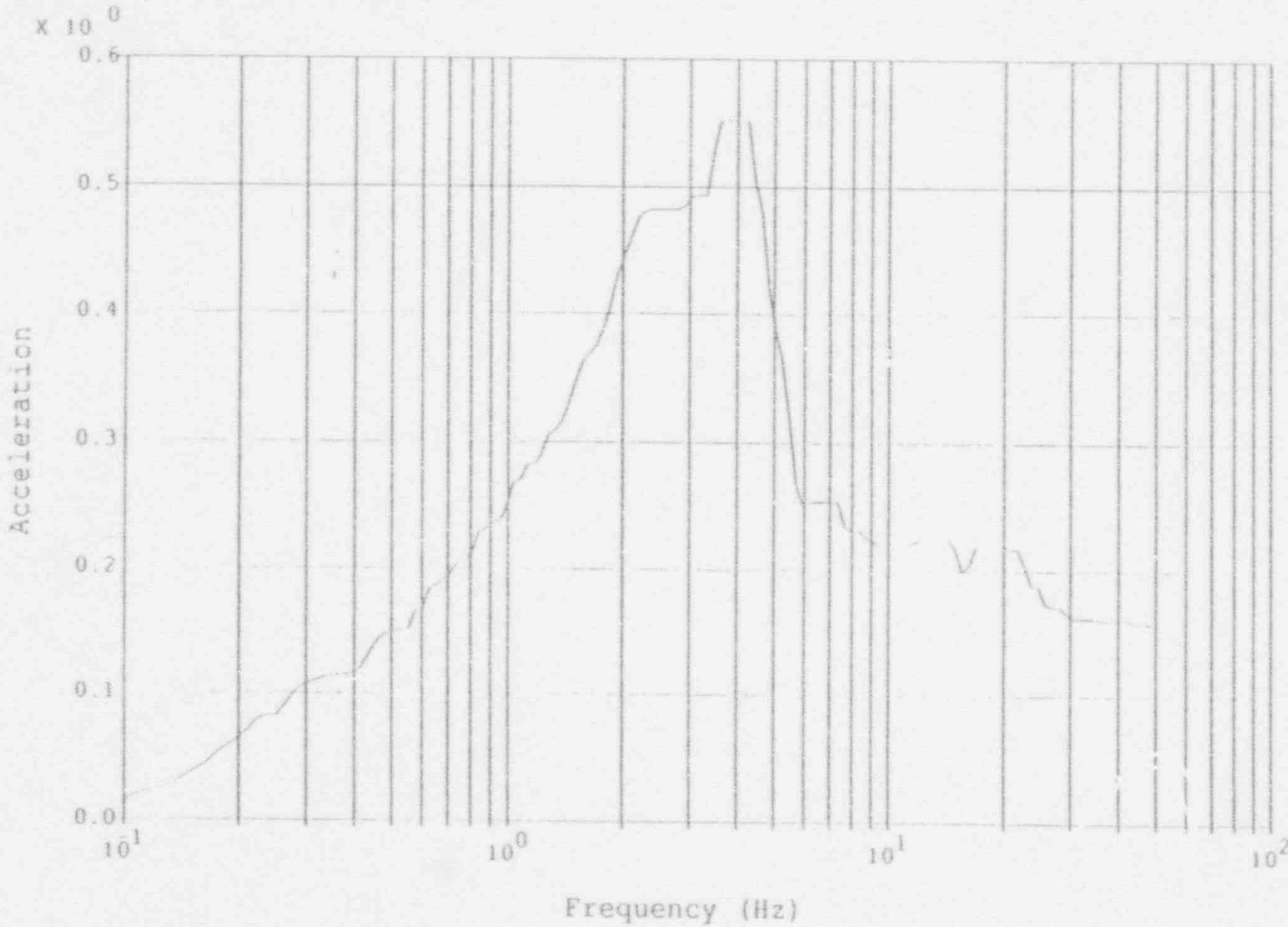


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 23.0', Translation in the NS Direction

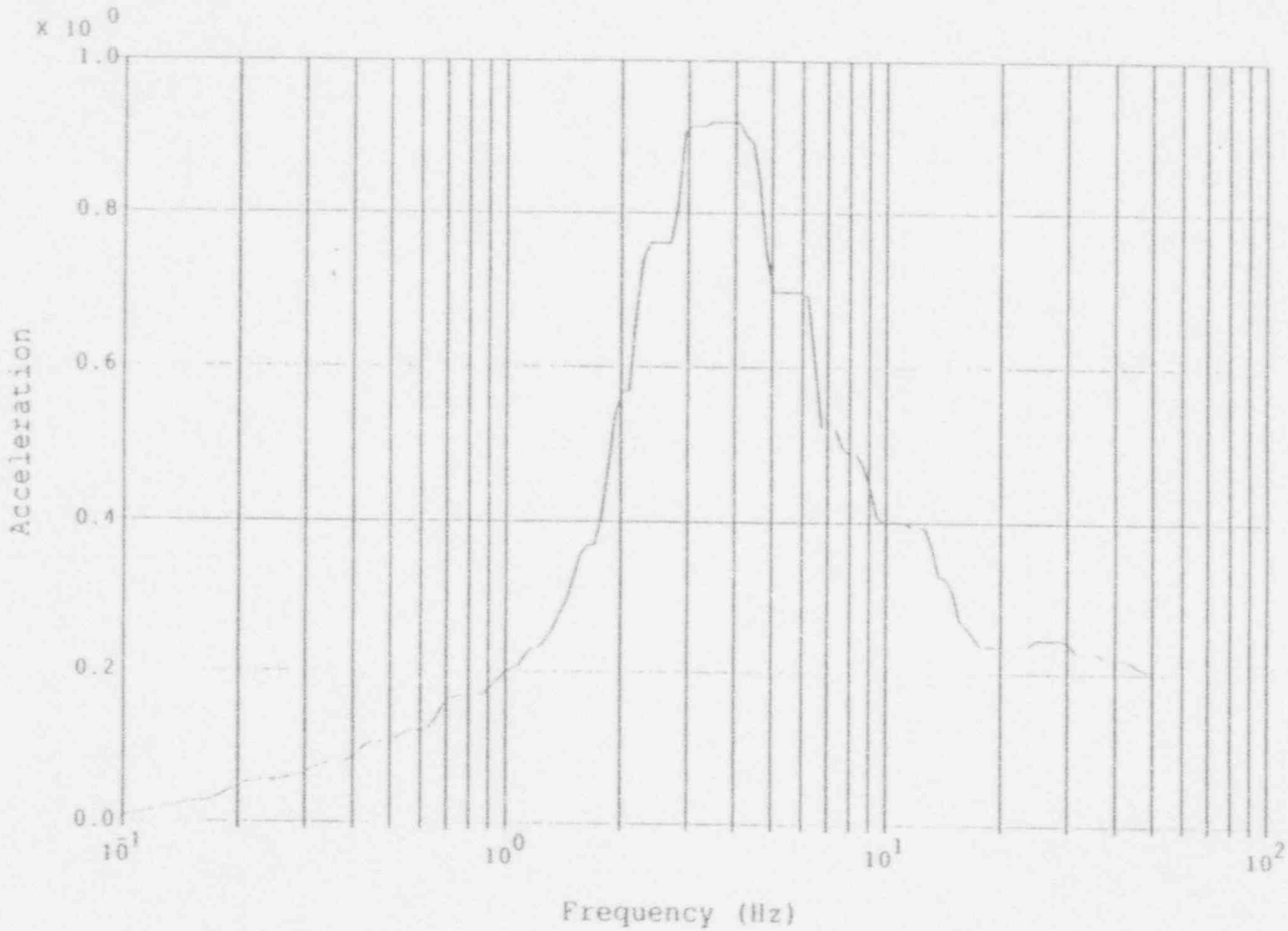
ASPLI SUN V1.2 rb2x.plt 15:05:27 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

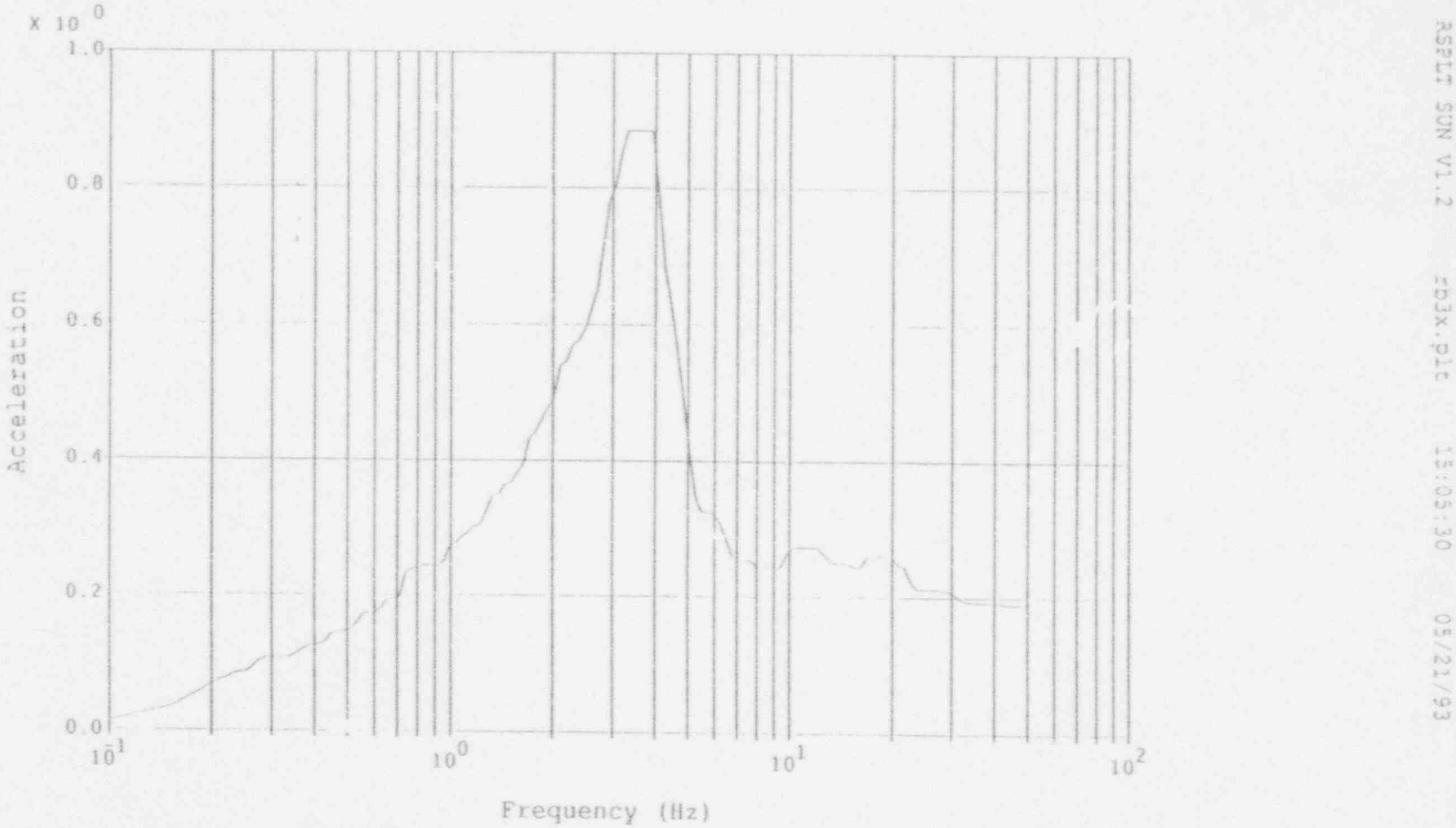
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 23.0', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 23.0', Translation in the Vertical Direction



Notes:

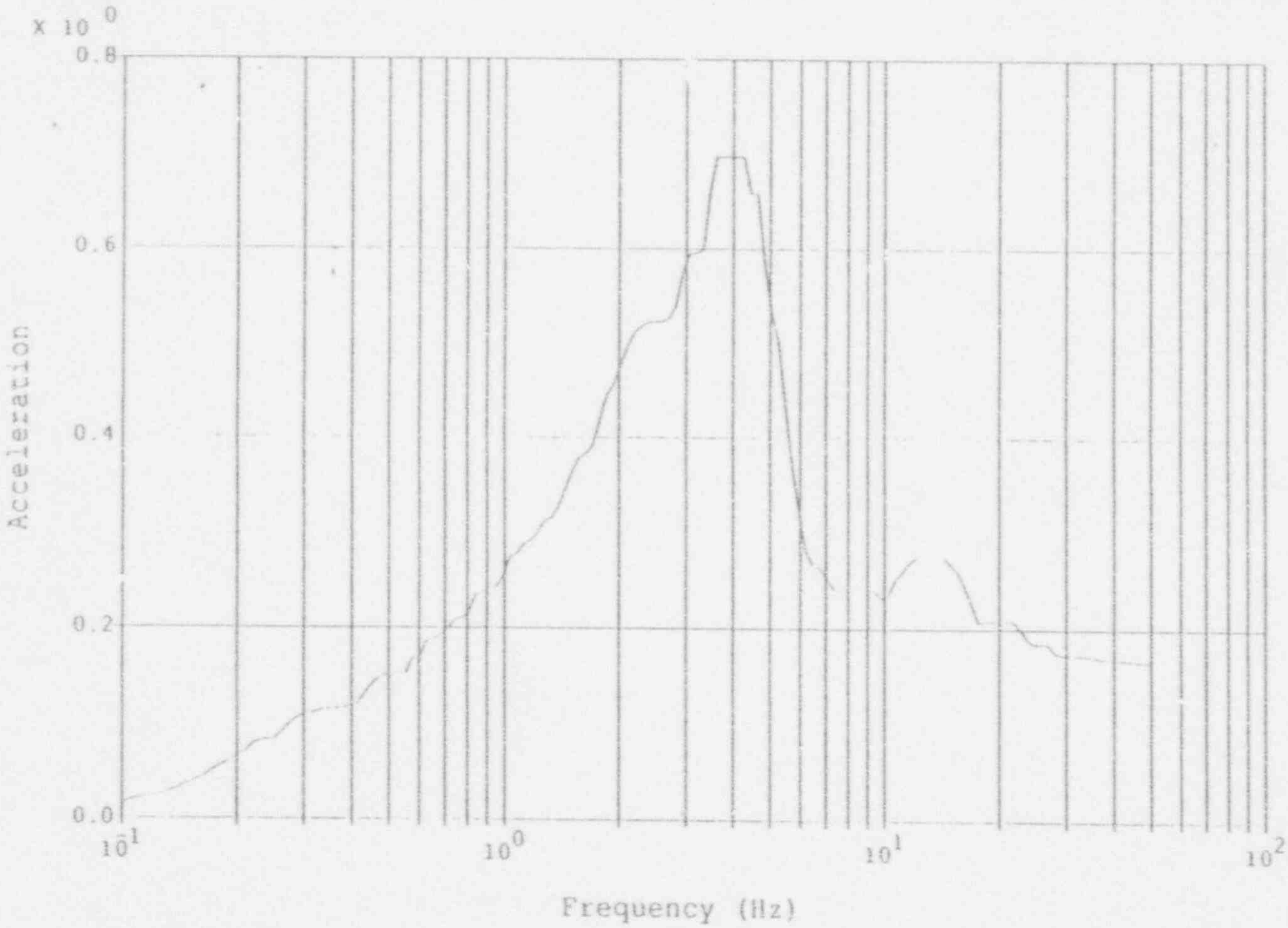
N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 51.0', Translation in the NS Direction

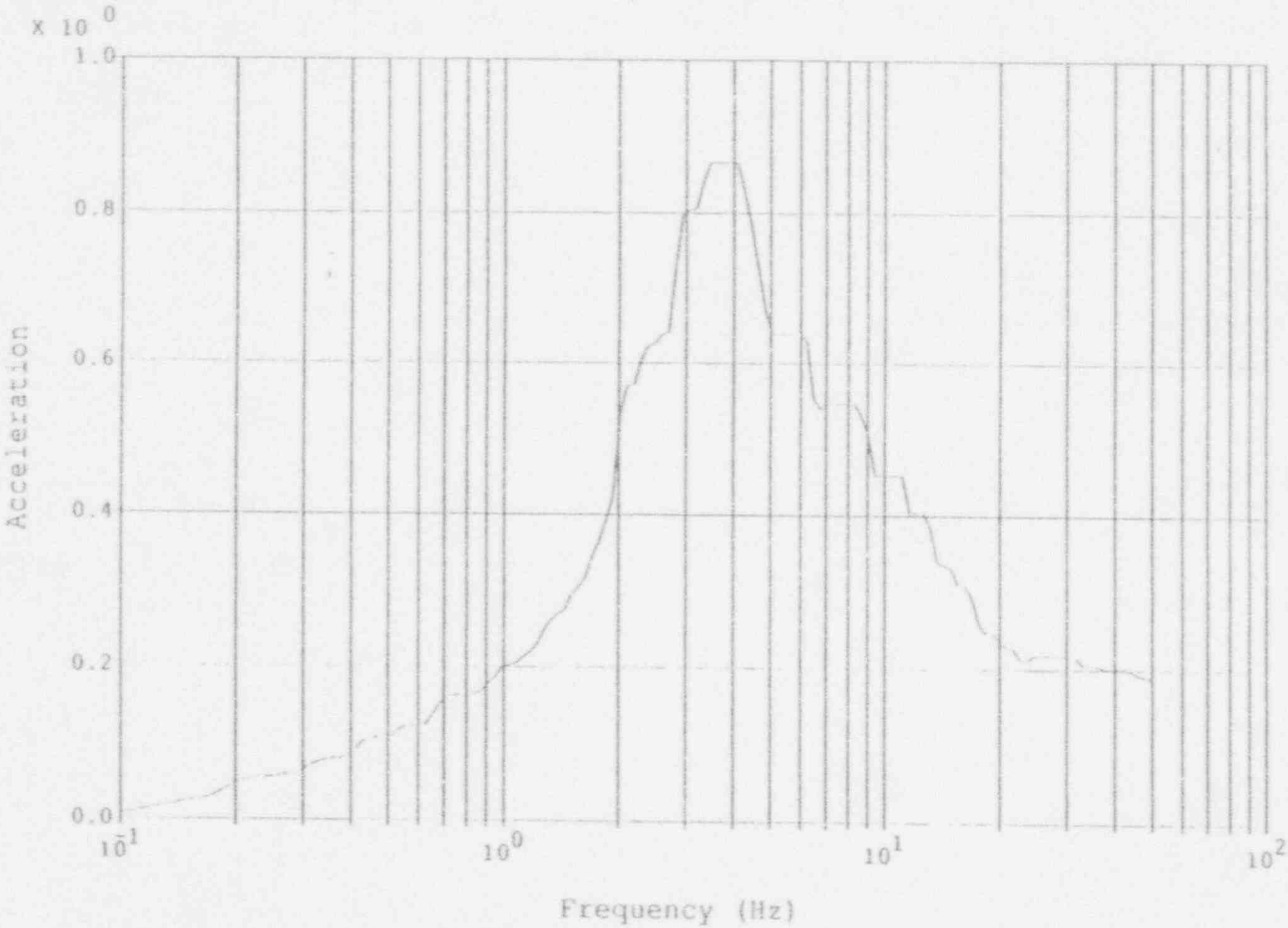


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 51.0', Translation in the EW Direction

RSPLT SUN V1.2 Eb3y.plt 15:05:32 05/21/93

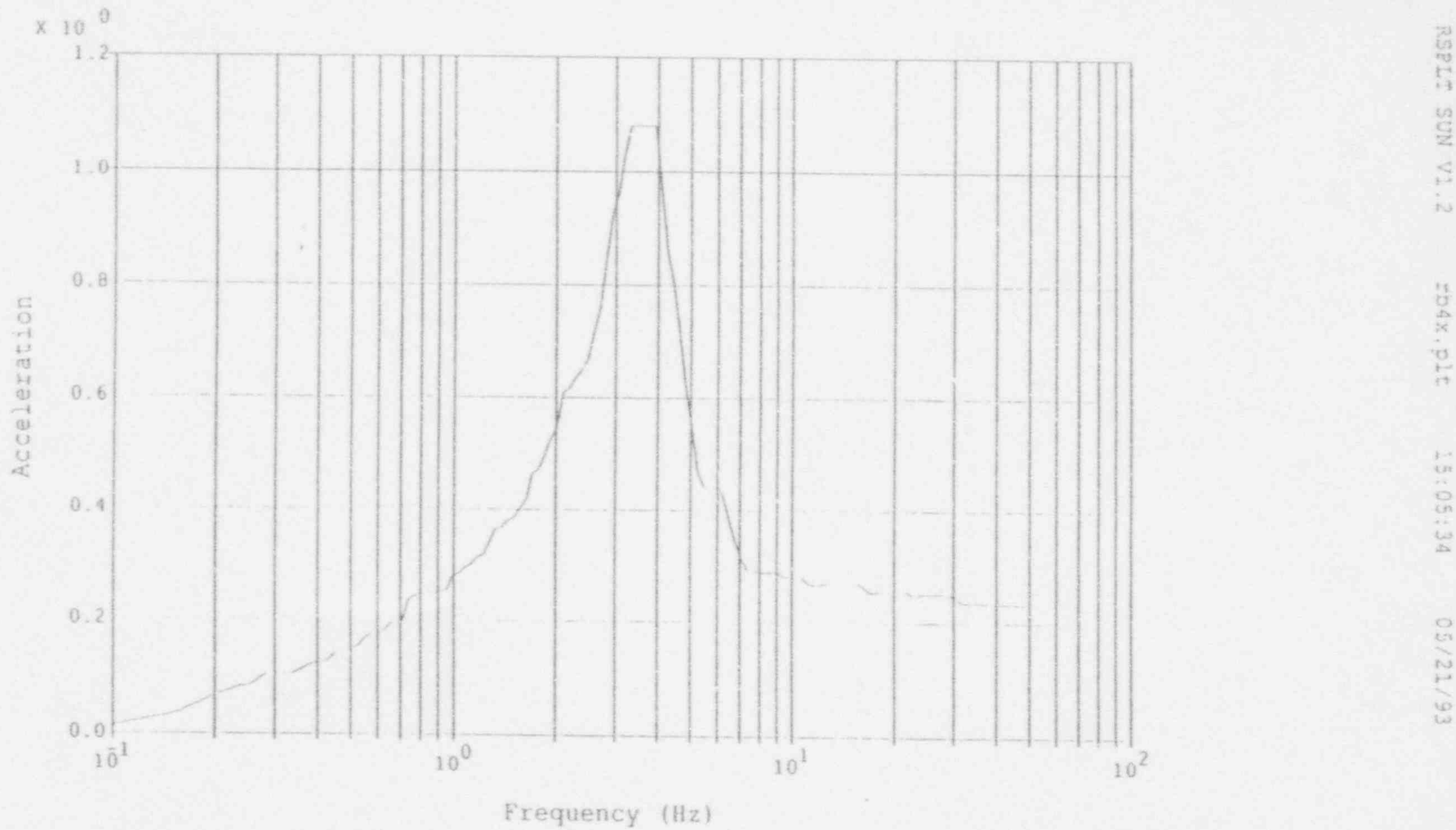


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 51.0', Translation in the Vertical Direction

ESPLIT SUN V1.2 eb3z.plt 15:05:33 05/21/93



Notes:

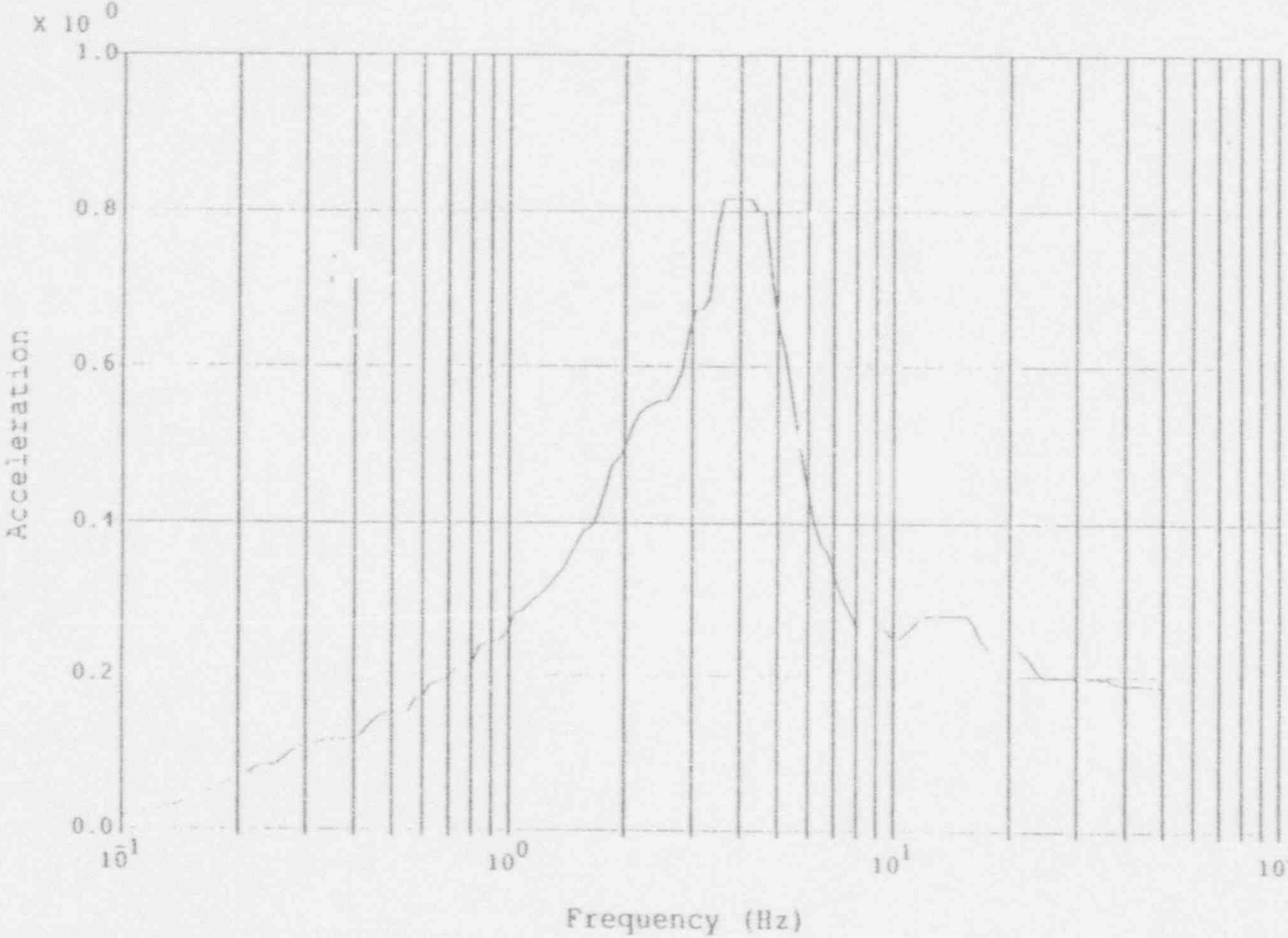
N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 74.25', Translation in the NS Direction

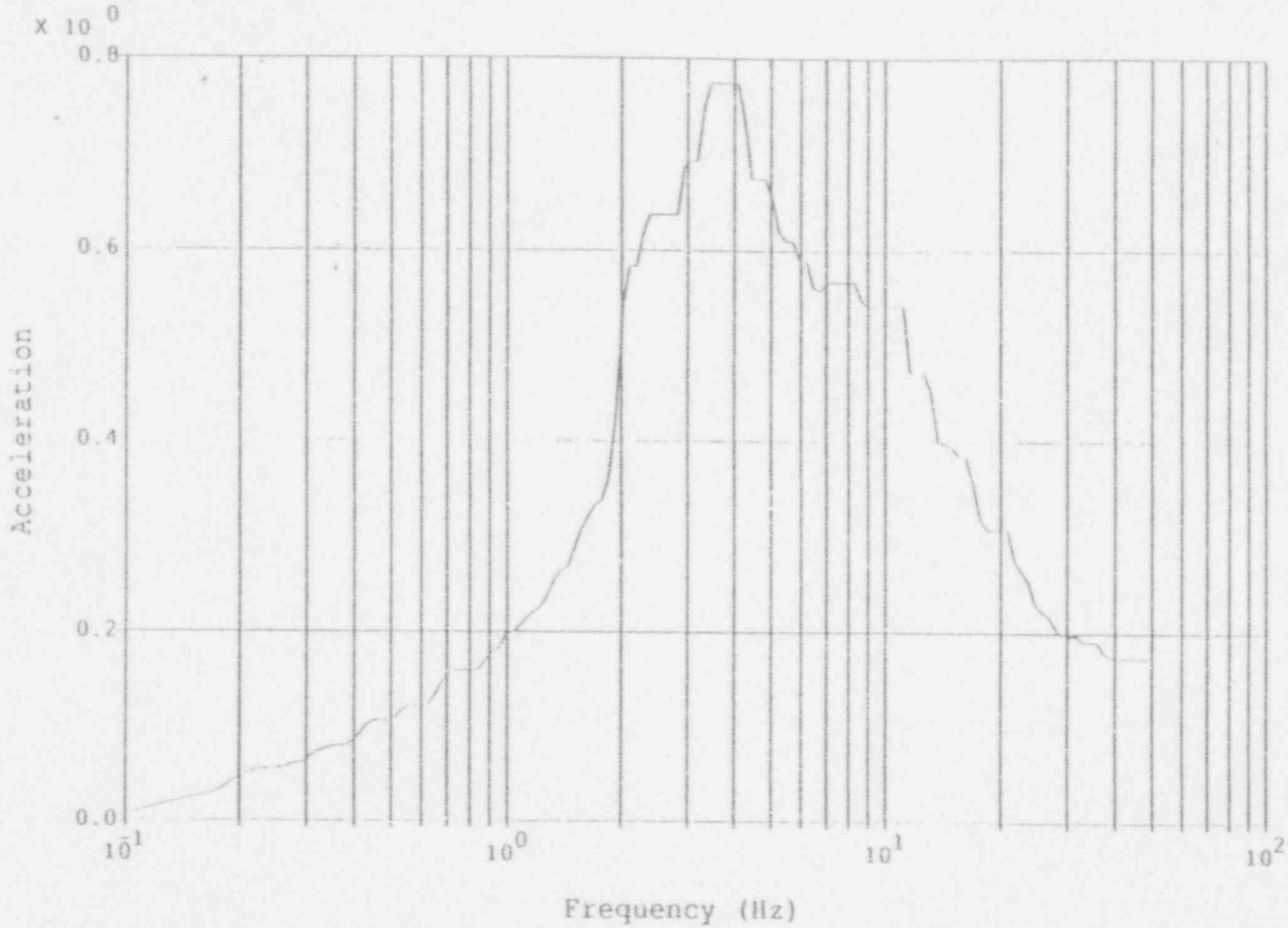


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 74.25', Translation in the EW Direction

RSPLT SUN V1.2 rb4y.plt 15:05:35 05/21/93

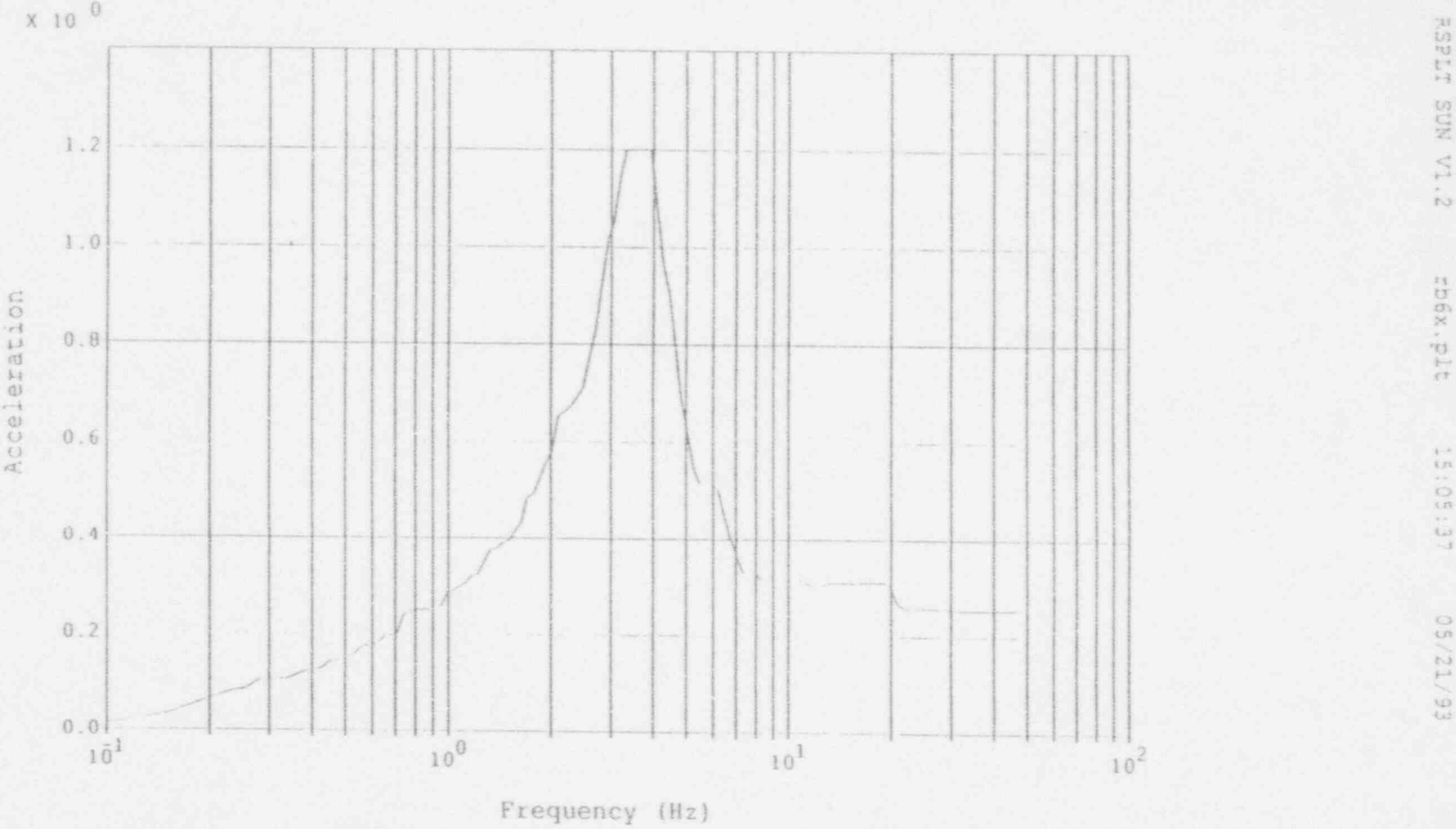


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 74.25', Translation in the Vertical Direction

RSPLT SUN V1.2 rb4z.plt 15:05:36 05/21/93



Notes:

N-411 Damped Spectrum

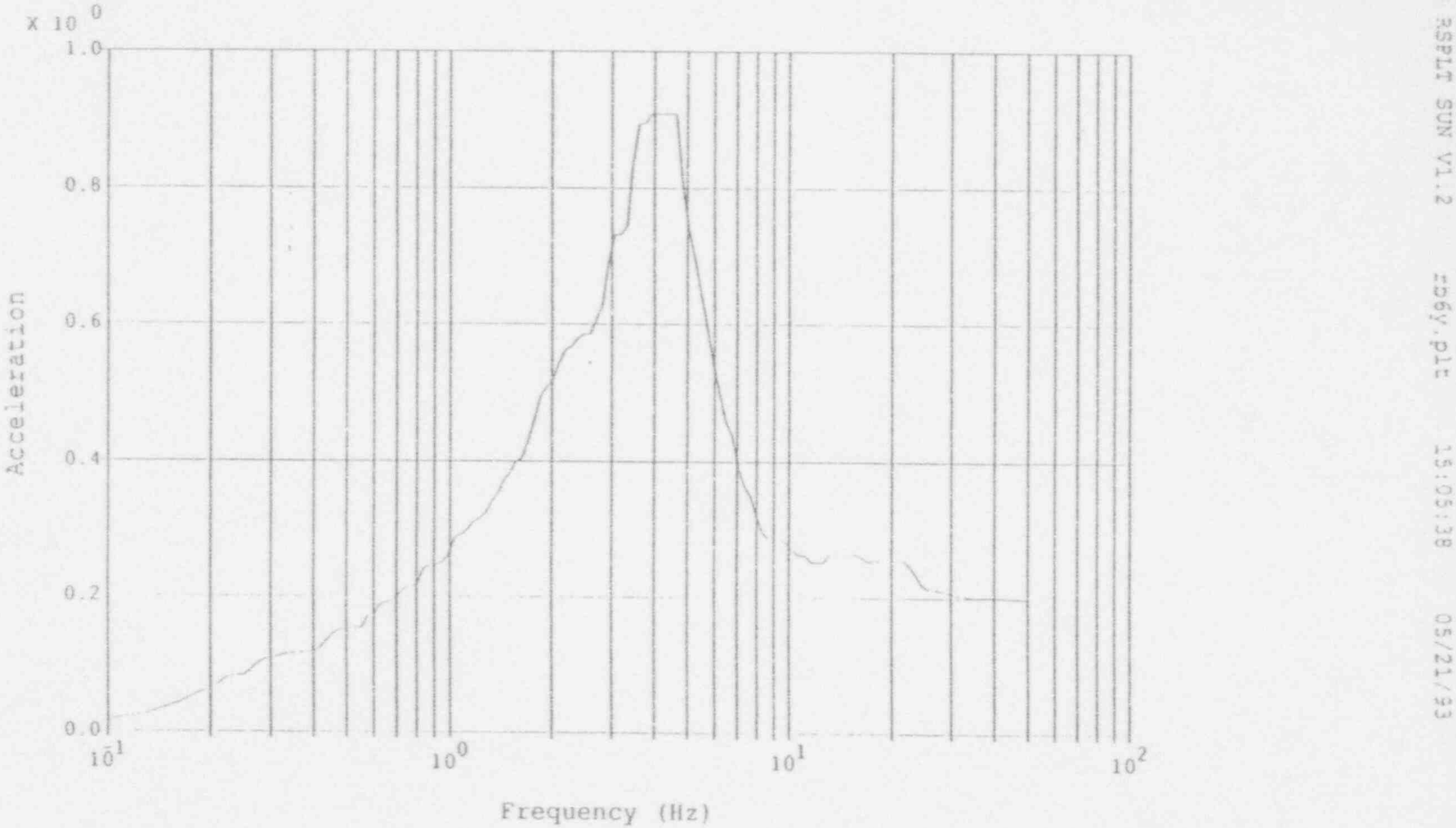
Accelerations in g's

1 SSE Level = 0.15g

Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE

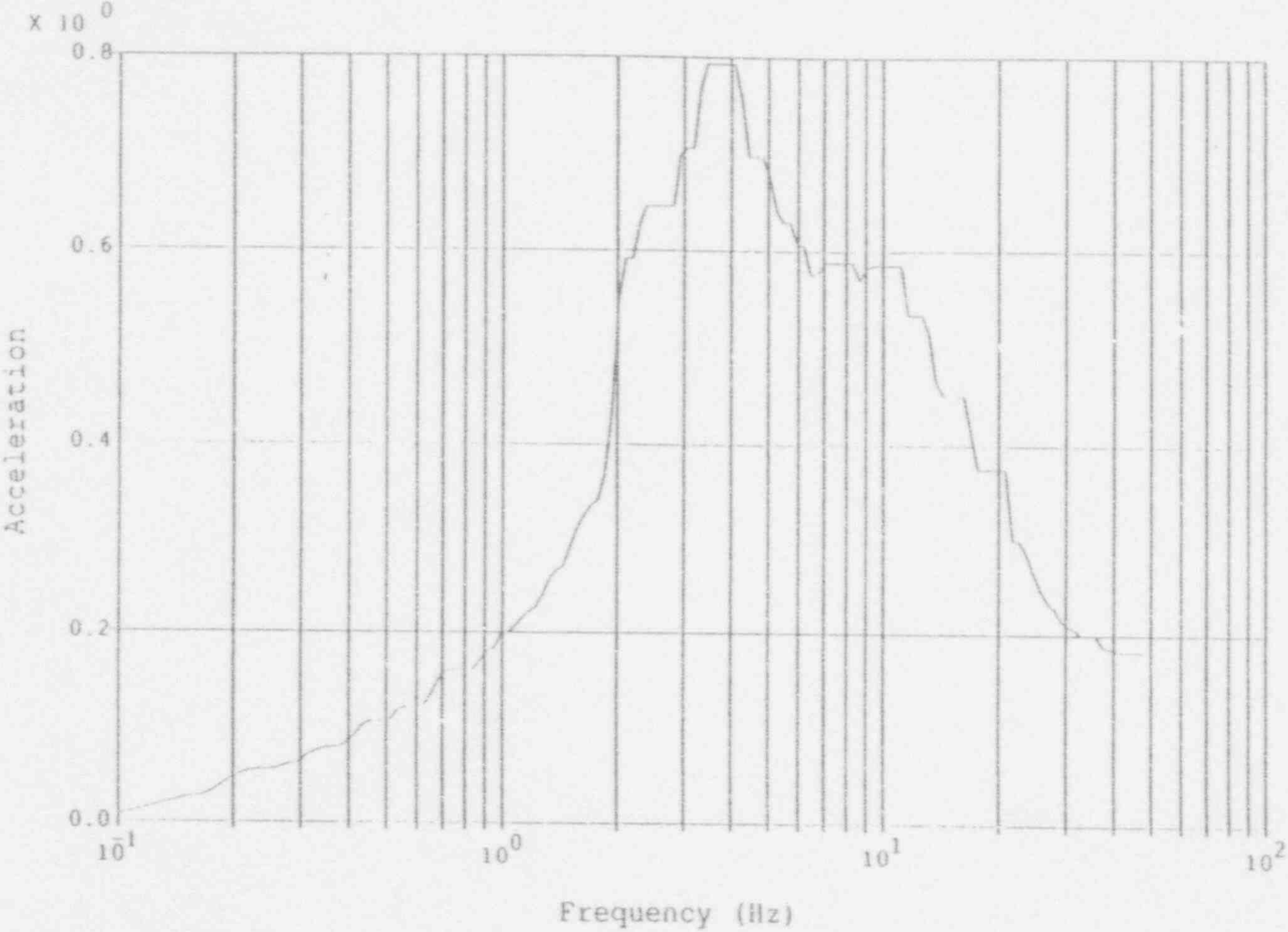
Reactor Building, El. 91.25', Translation in the NS Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 91.25', Translation in the EW Direction

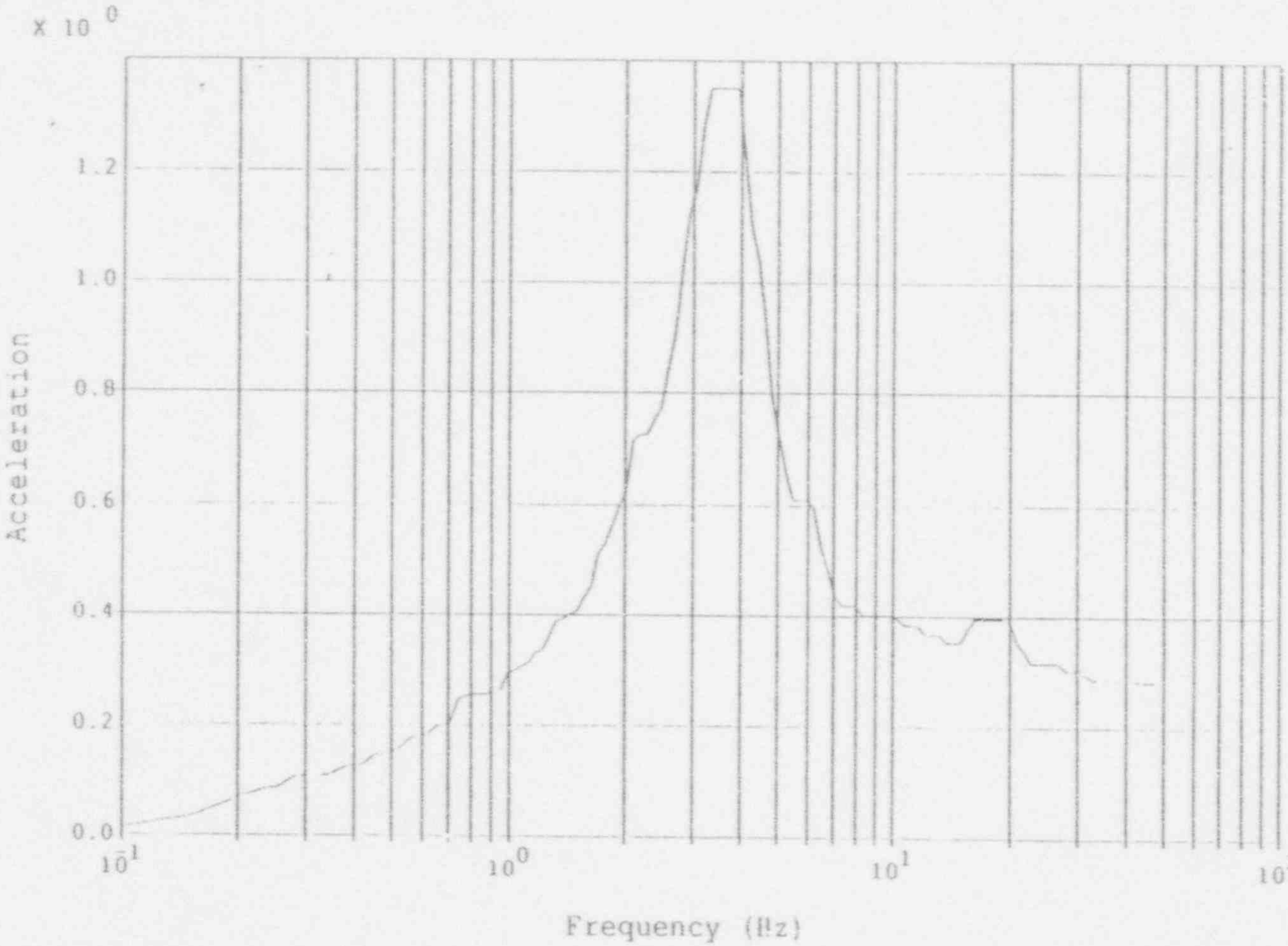


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 91.25', Translation in the Vertical Direction

RSPLT SUN V1.2 rb62.plt 15:05:39 05/21/93

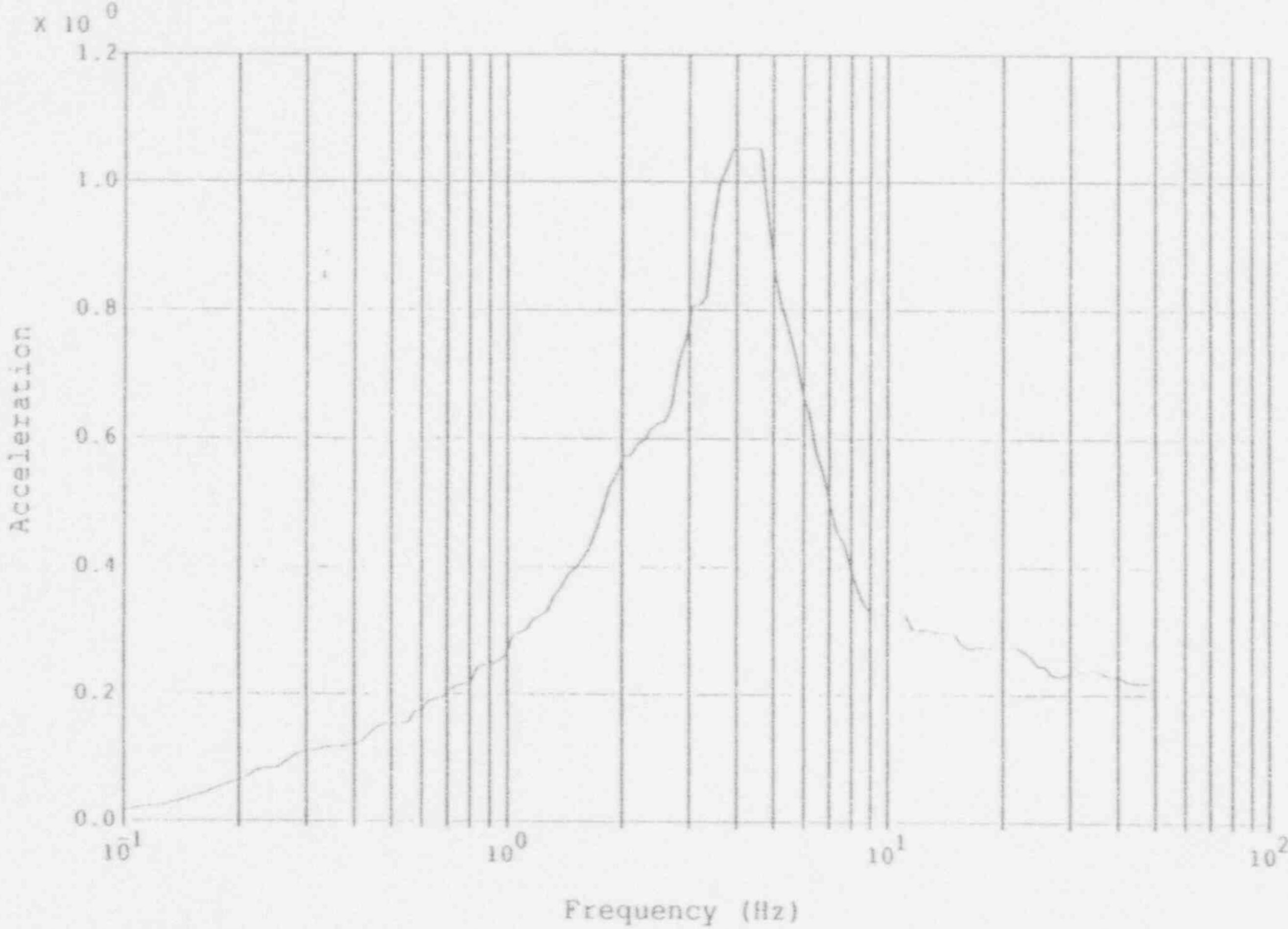


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 117.0', Translation in the NS Direction

RSPLT SUN V1.2 rb7x.plt 15:05:40 05/21/93

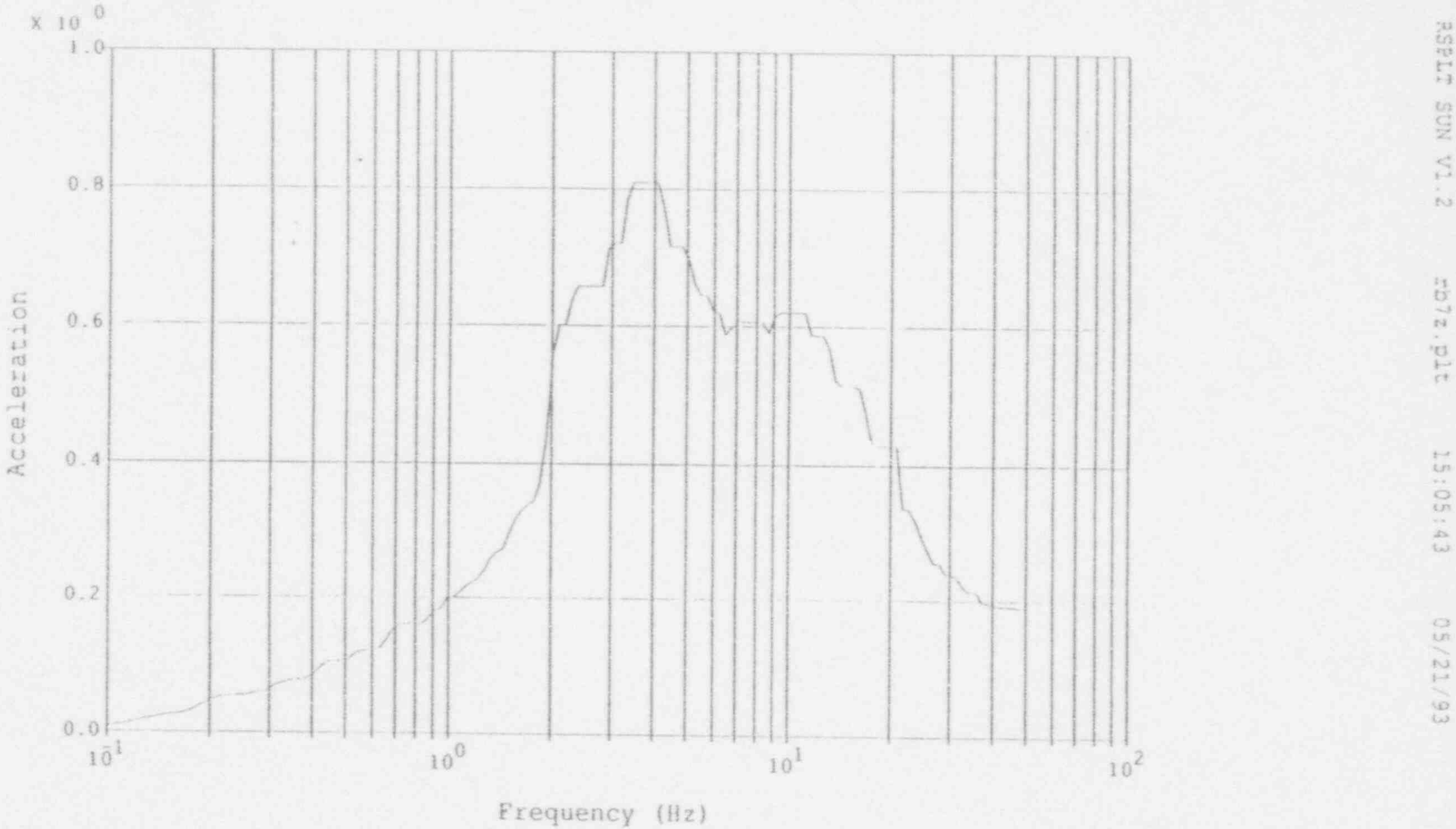


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 117.0', Translation in the EW Direction

RSPLT SUN V1.2 rp7y.plt 15:05:42 05/21/93



Notes:

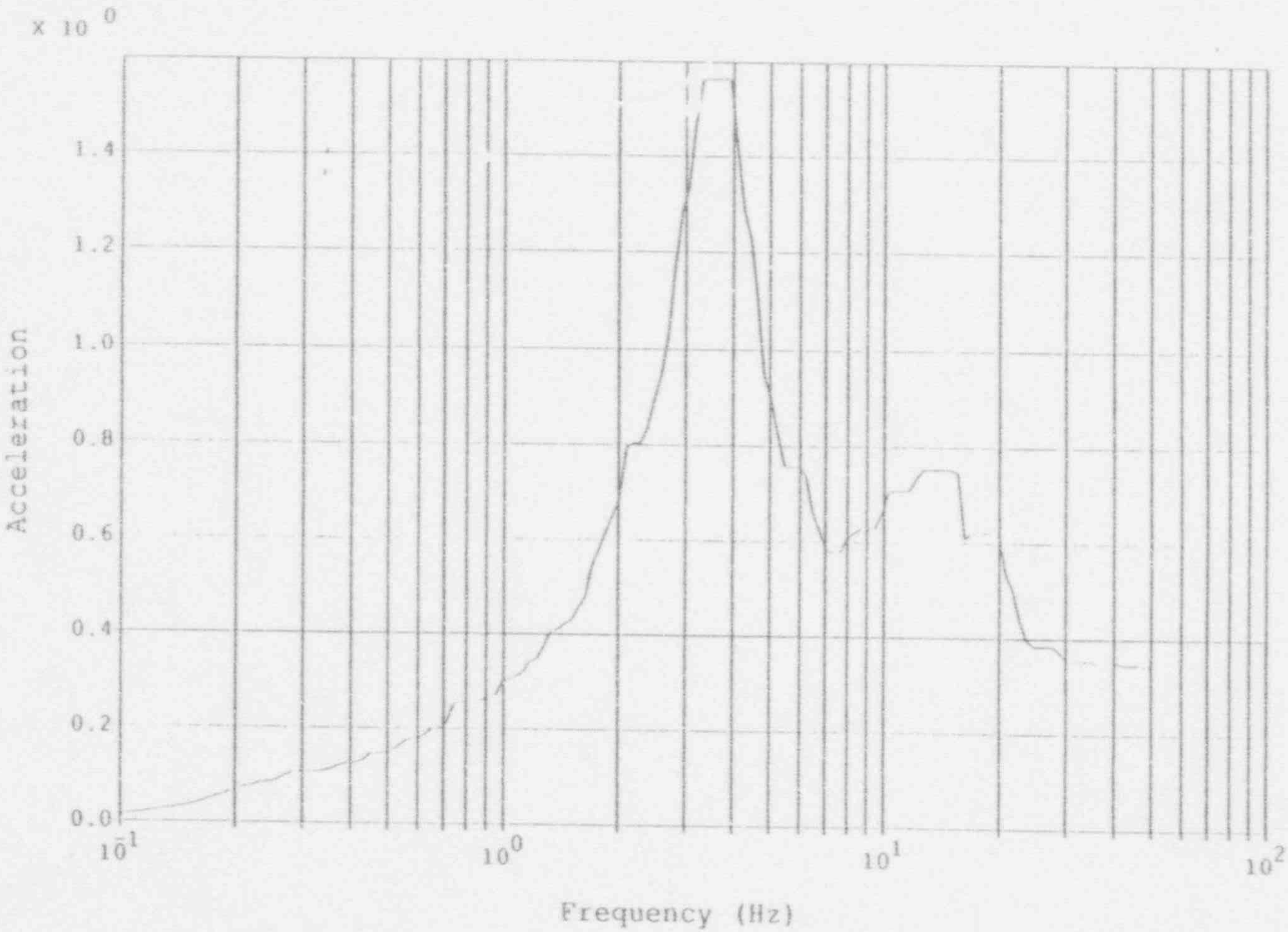
N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.10g

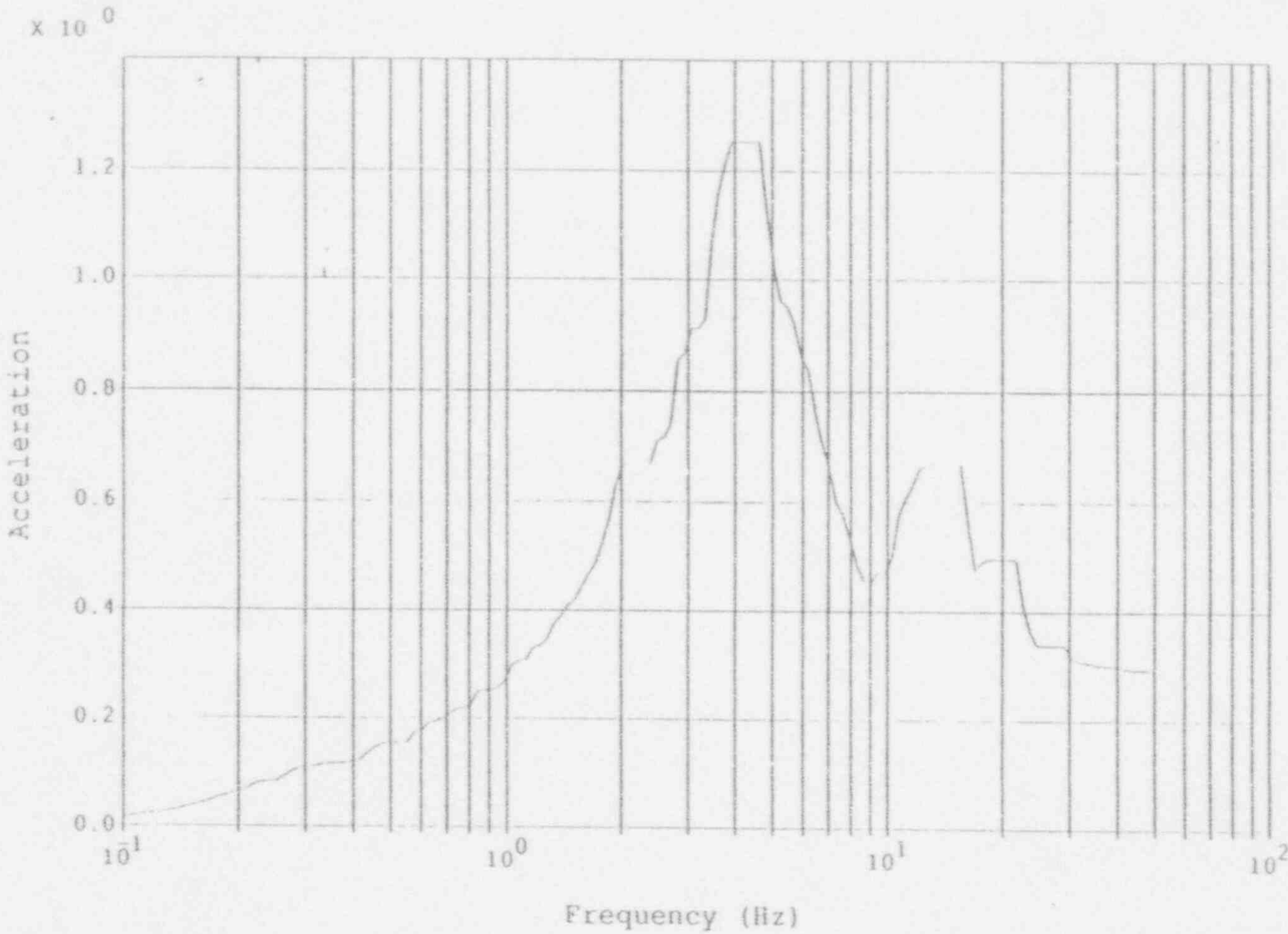
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 117.0', Translation in the Vertical Direction



Notes:

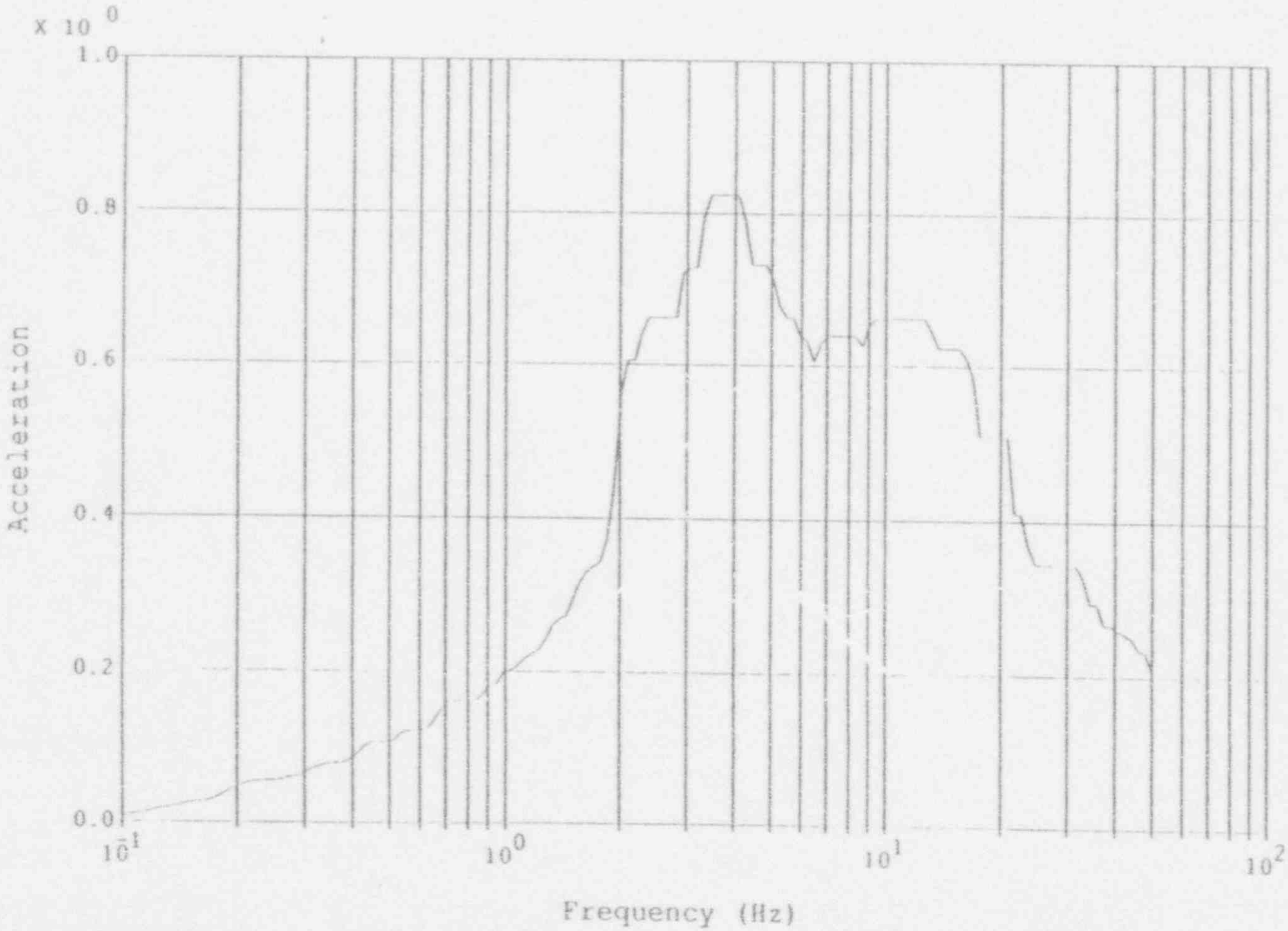
N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

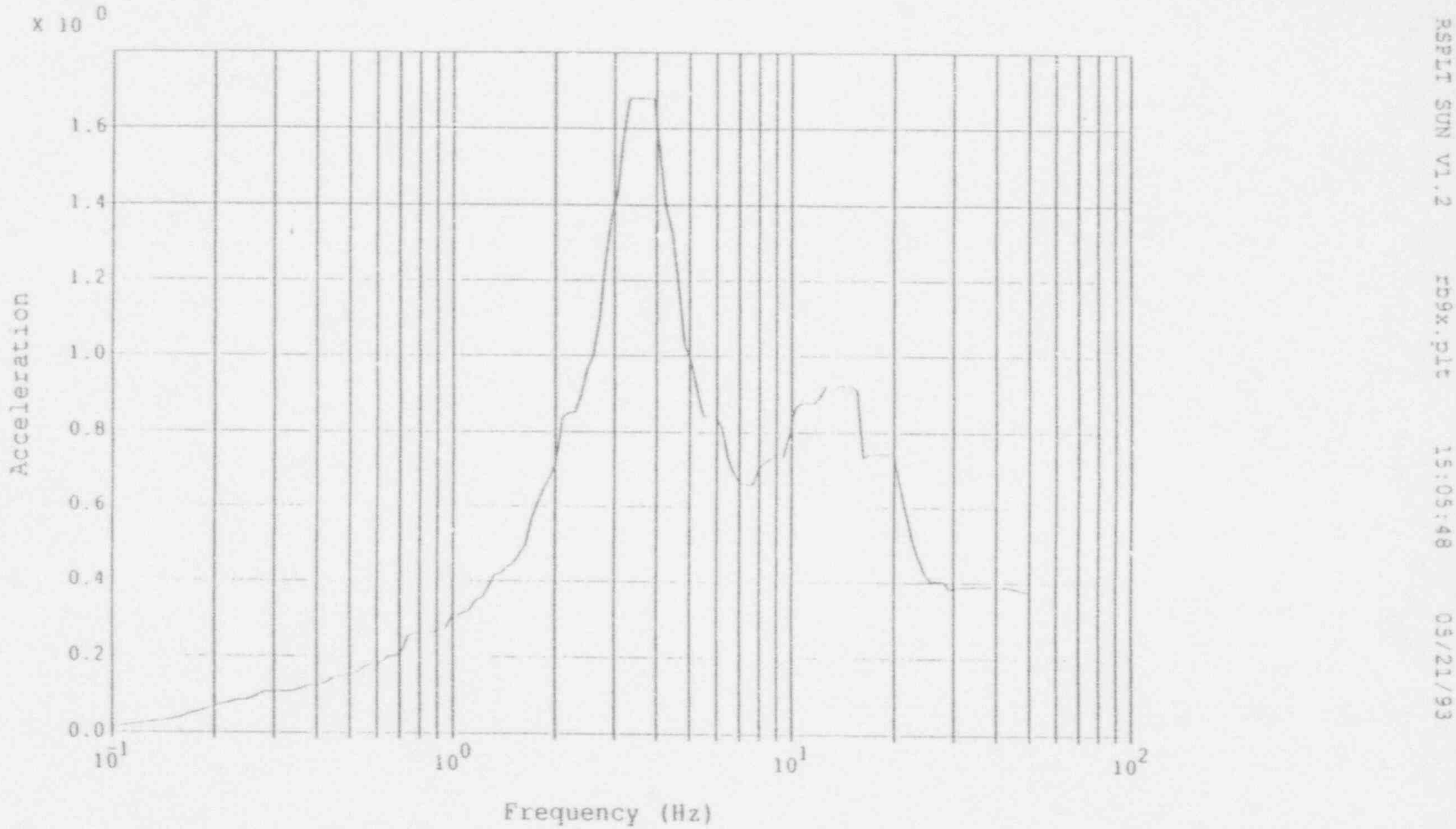
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 145.0', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

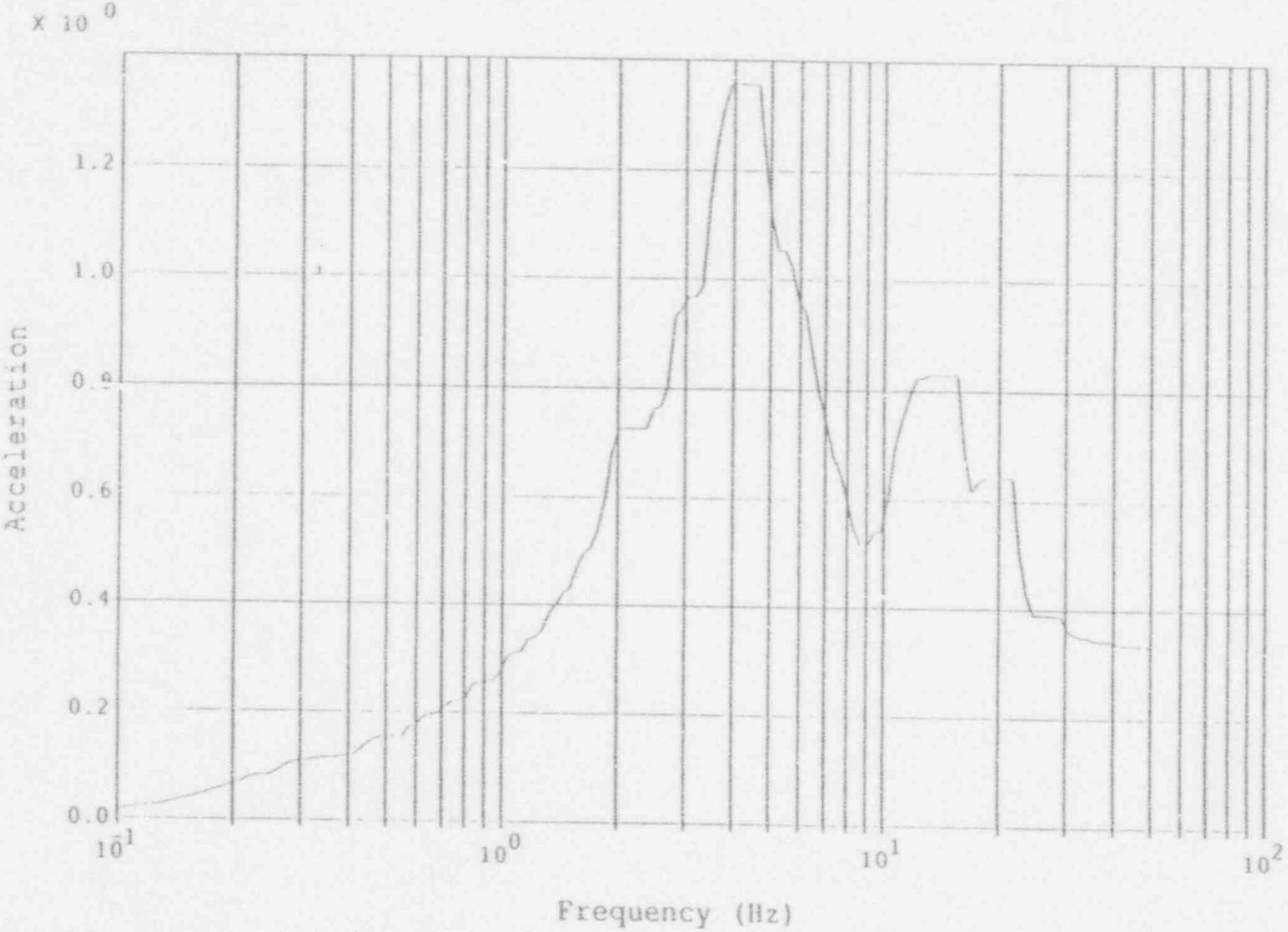
RSPLT SUN V1.2 zb8z.plt 15:05:47 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 164.5', Translation in the NS Direction

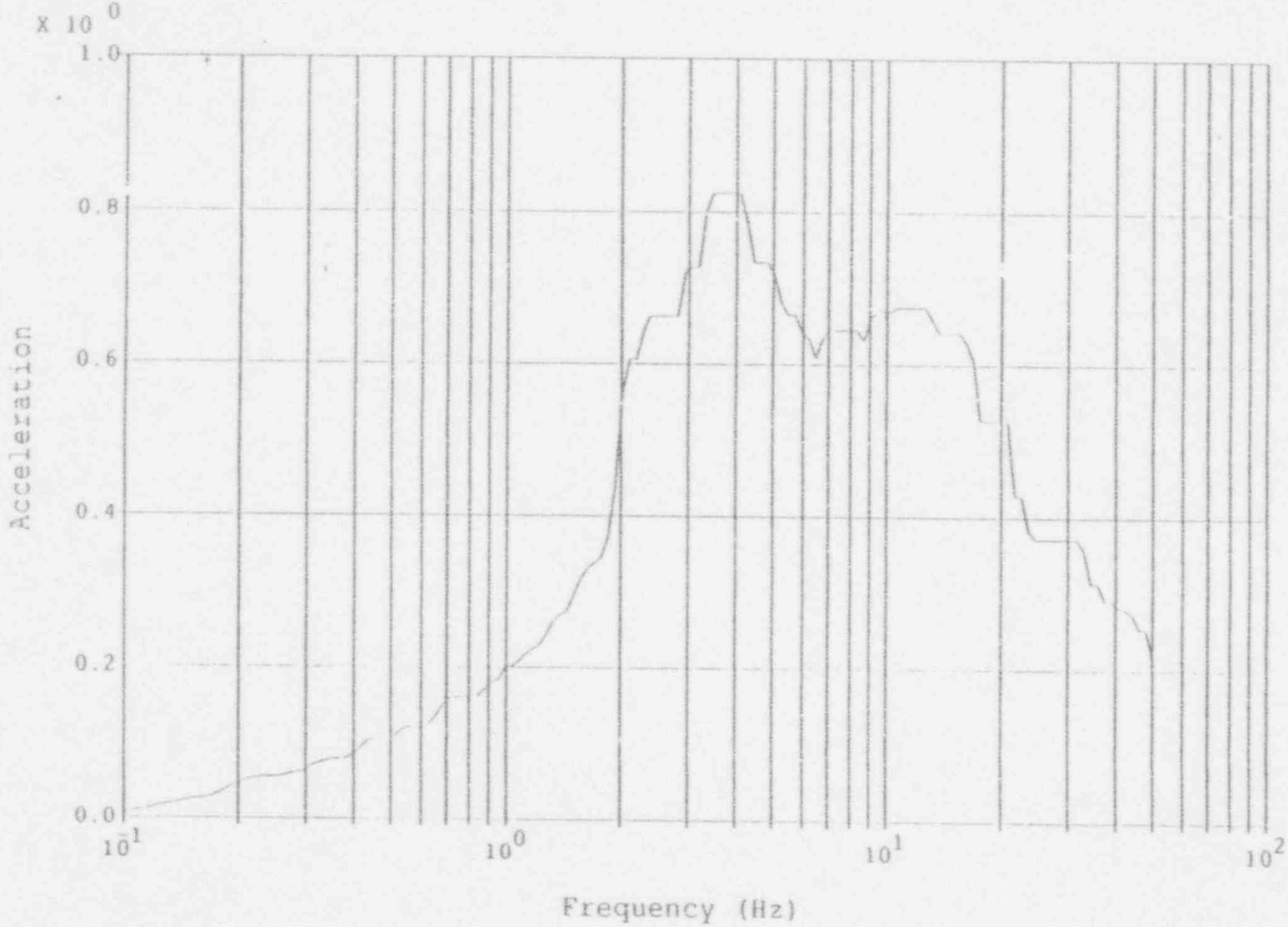


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 164.5', Translation in the EW Direction

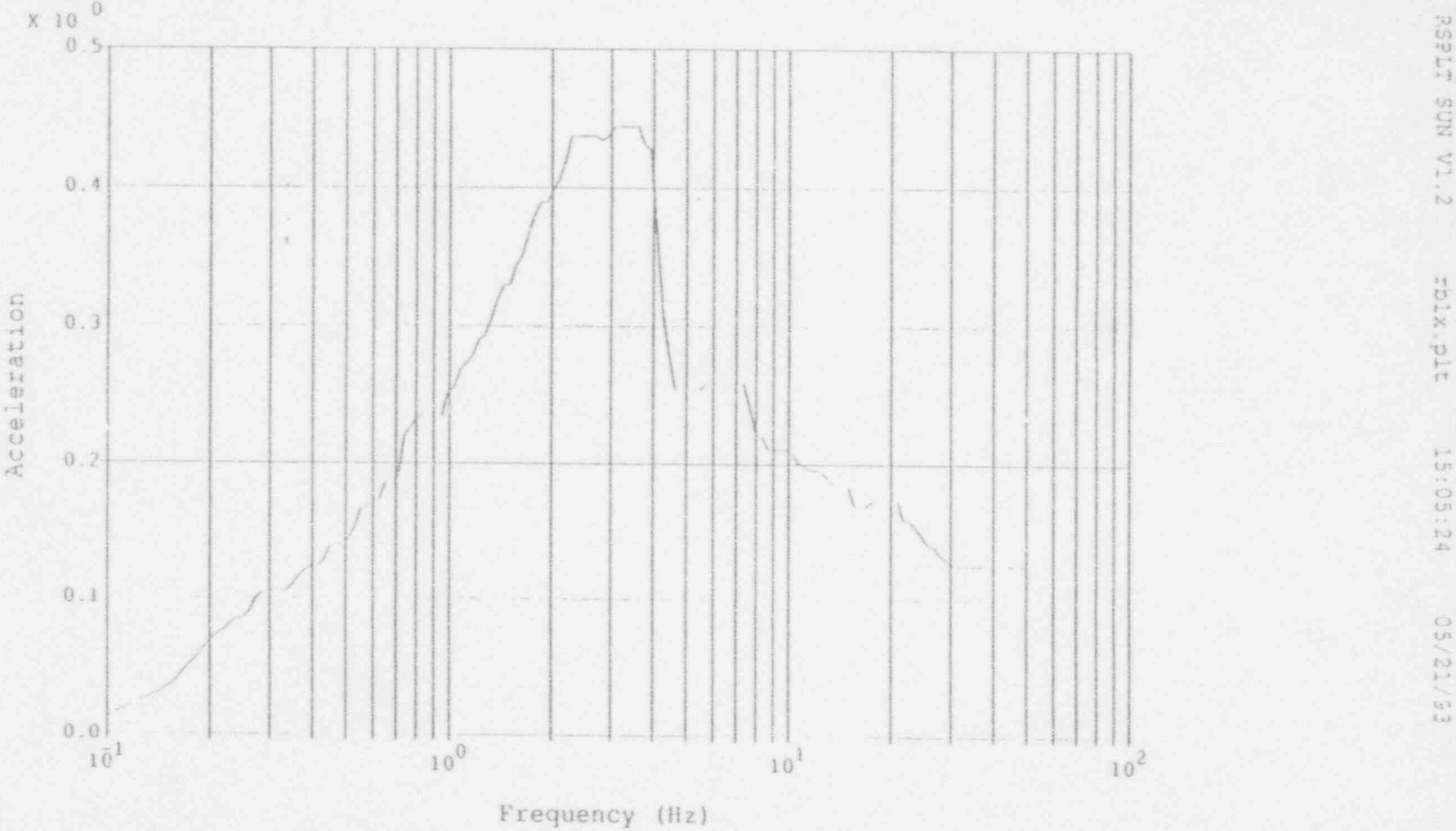
RSPLT SUN V1.2 zz9y.plt 15:05:49 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g
Five Locations Enveloped

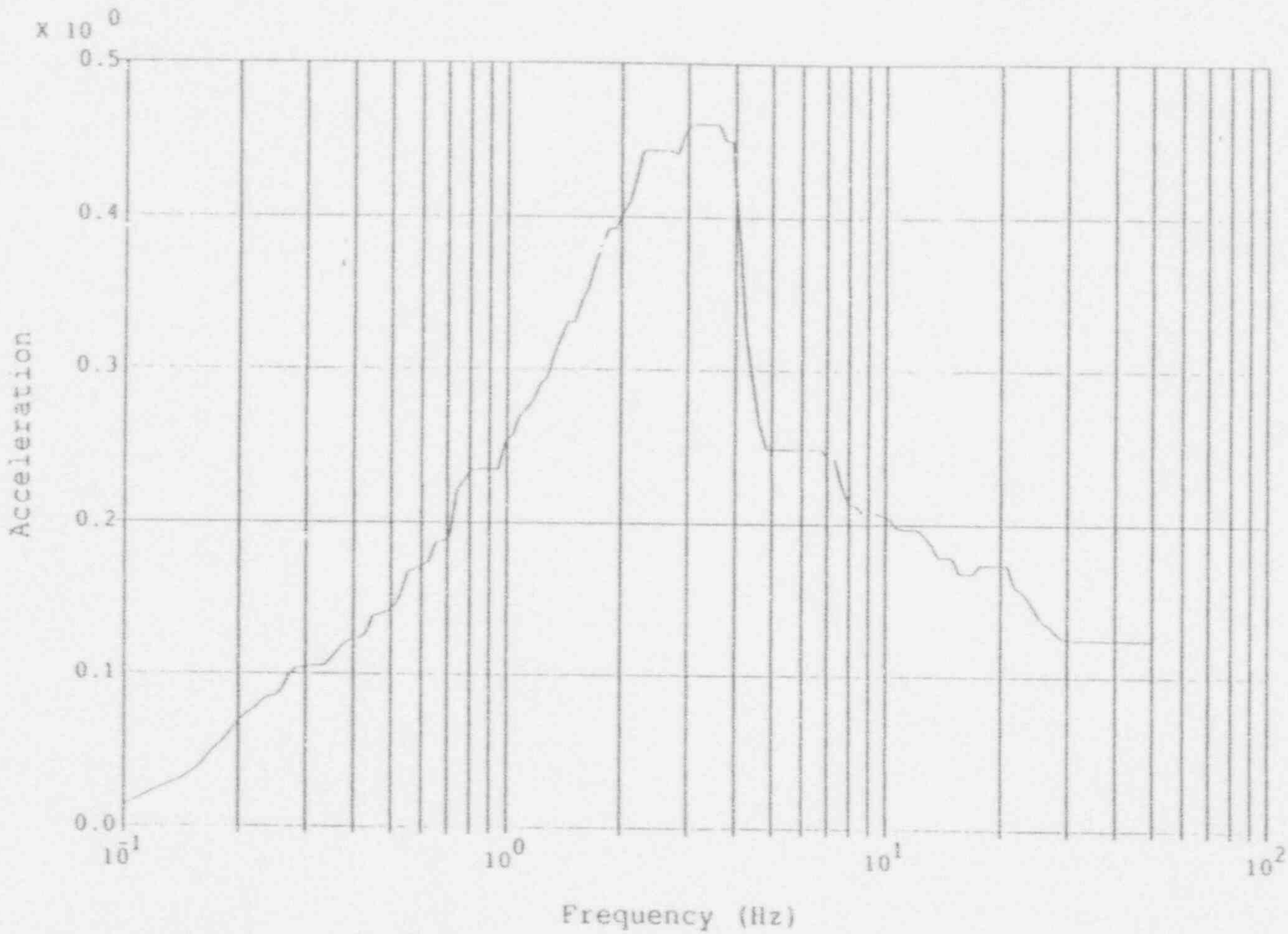
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building, El. 164.5', Translation in the Vertical Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Building Basemat, El.-17.5', Translation in the NS Direction

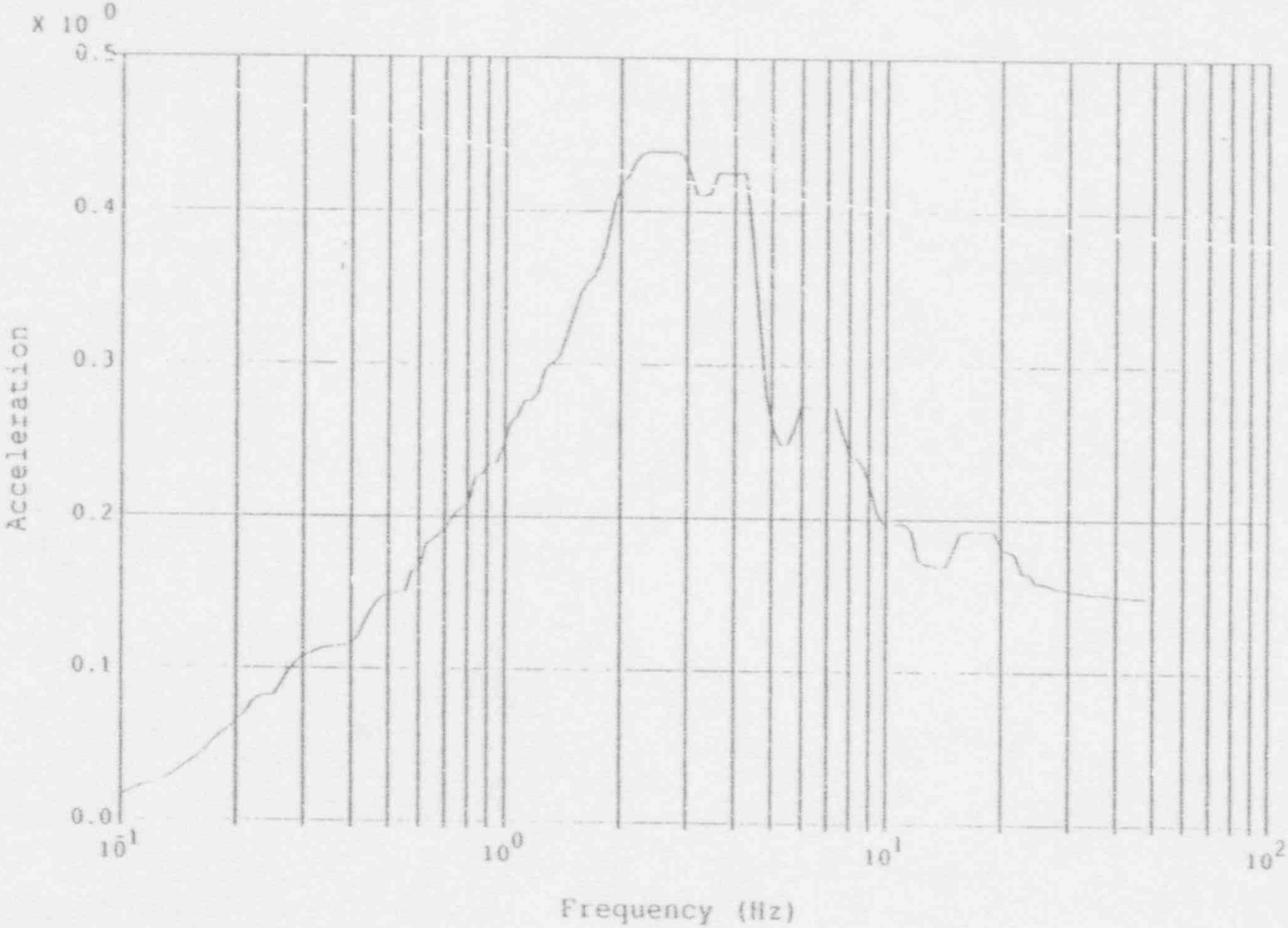


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Torus, El.-0.25', Translation in the NS Direction

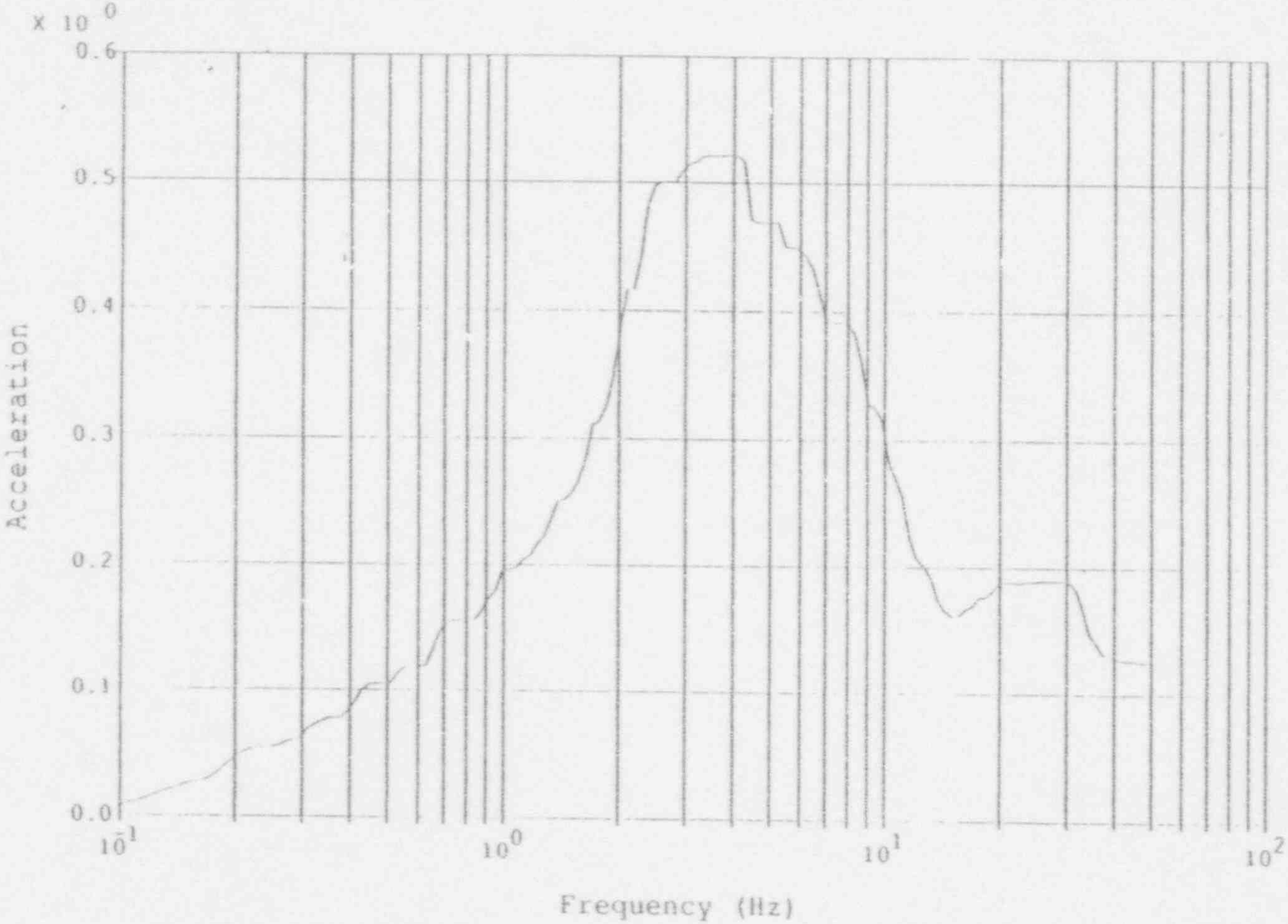
RSPLT SUN V1.2 torx.plt 15:05:51 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Torus, El.-0.25', Translation in the EW Direction

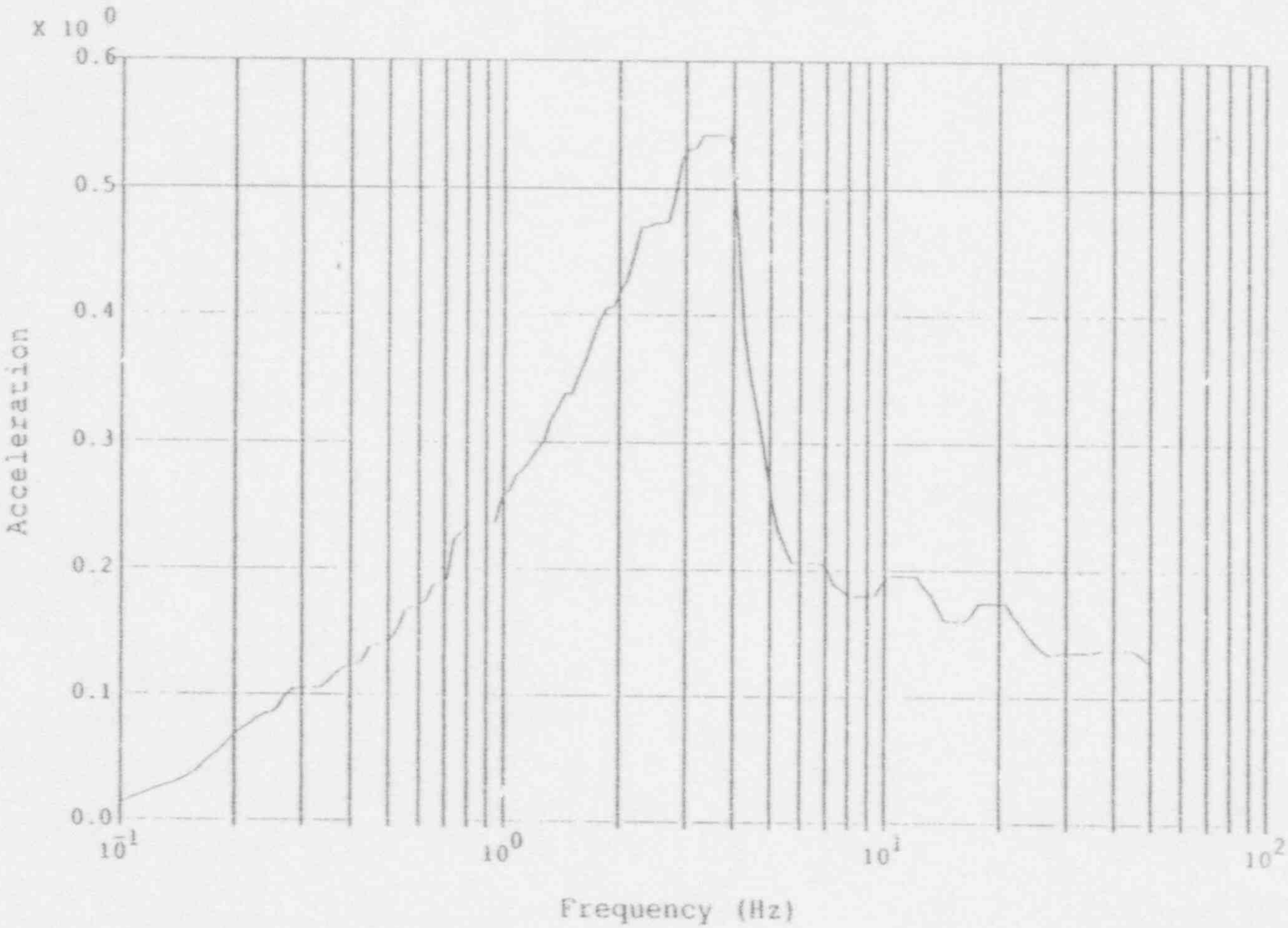


Notes:

N-411 Damped Spectrum
Accelerations in g's
½ SSE Level = 0.10g
Five Locations Enveloped

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Torus, El.-0.25', Translation in the Vertical Direction

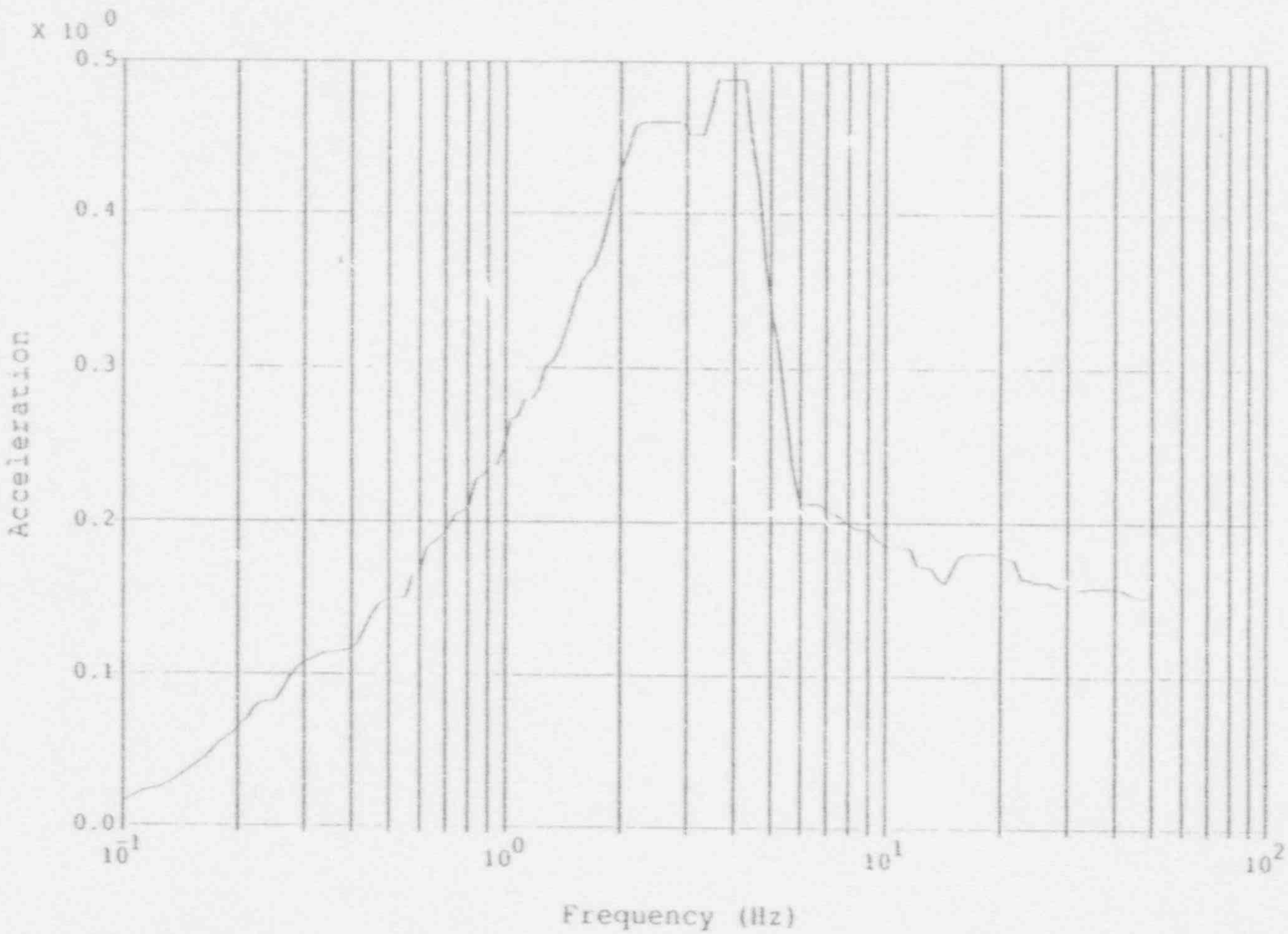
RSPLT SUN V1.2 torz.plt 15:05:54 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Drywell, El. 27.17', Translation in the NS Direction



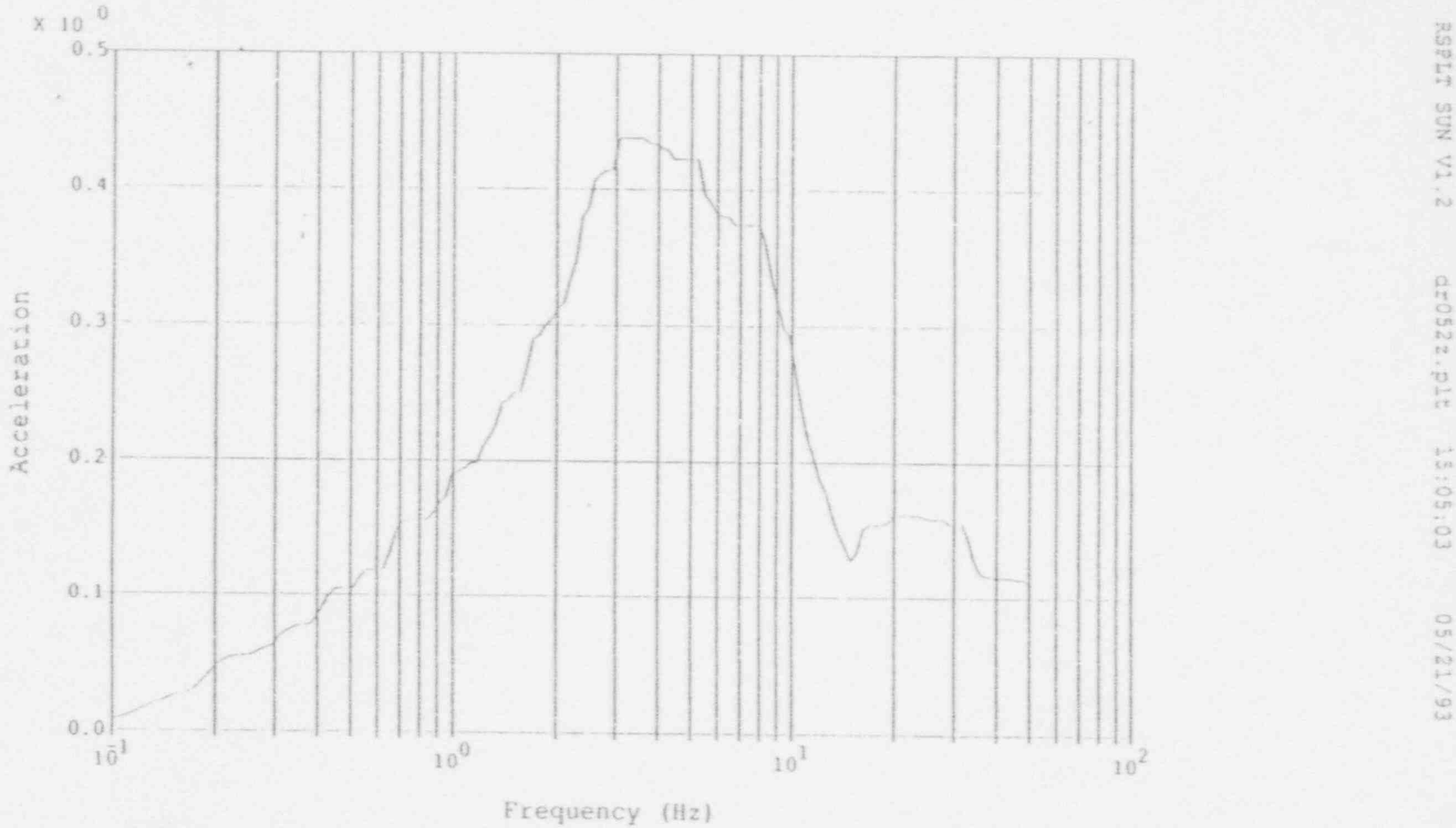
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Drywell, El. 27.17', Translation in the EW Direction



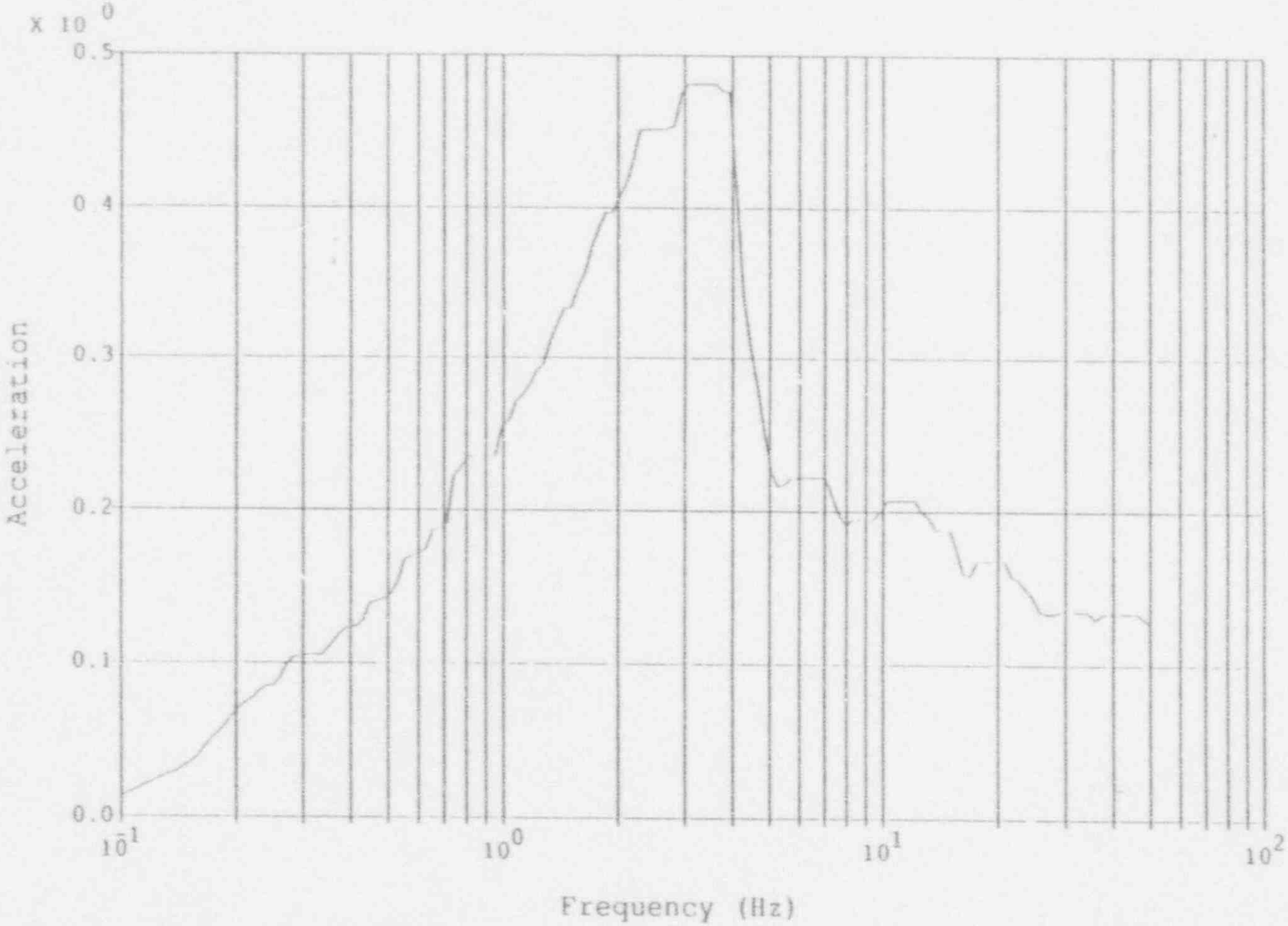
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Drywell, El. 27.17', Translation in the Vertical Direction



Notes:

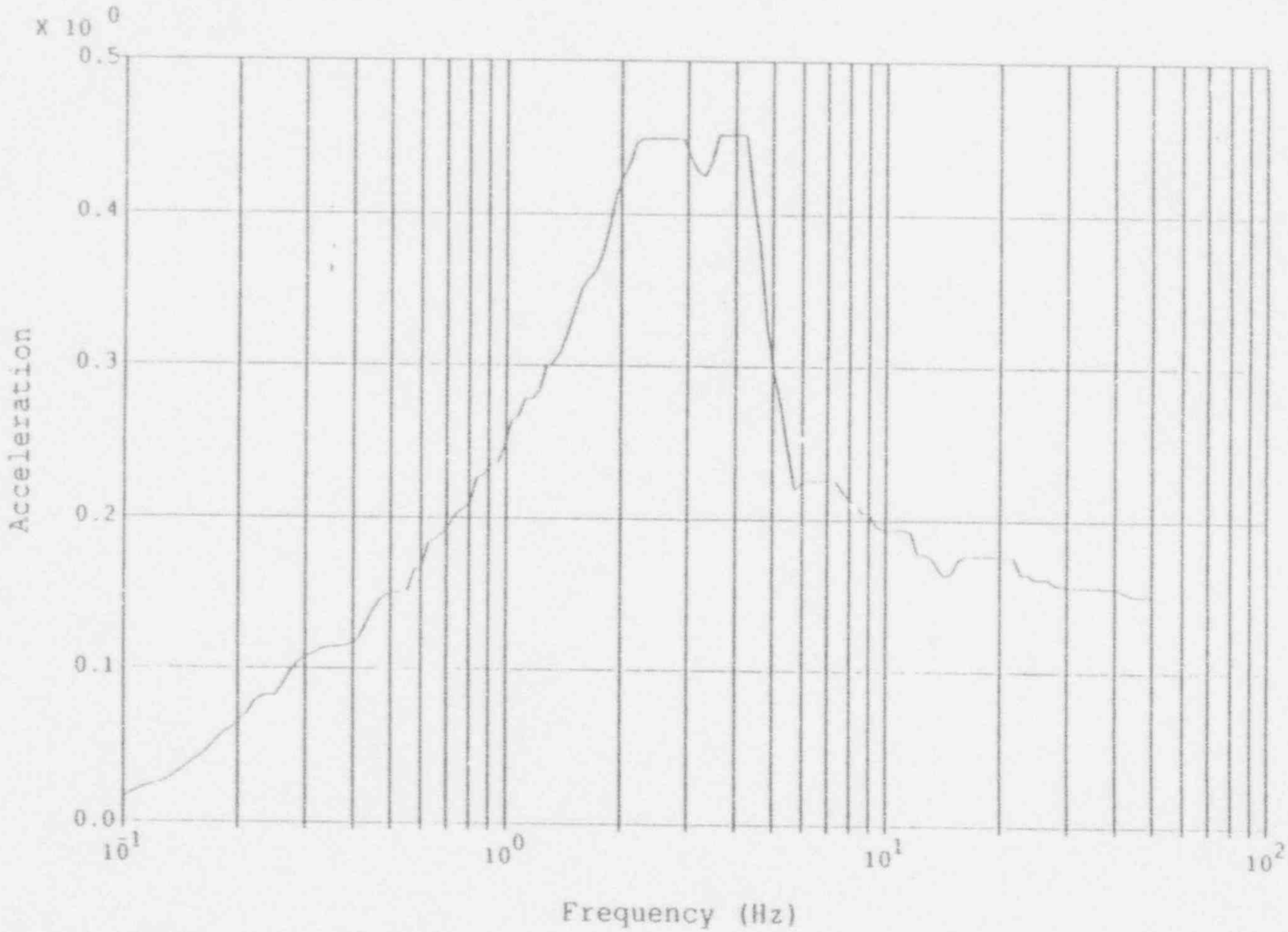
N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 15.40', Translation in the NS Direction

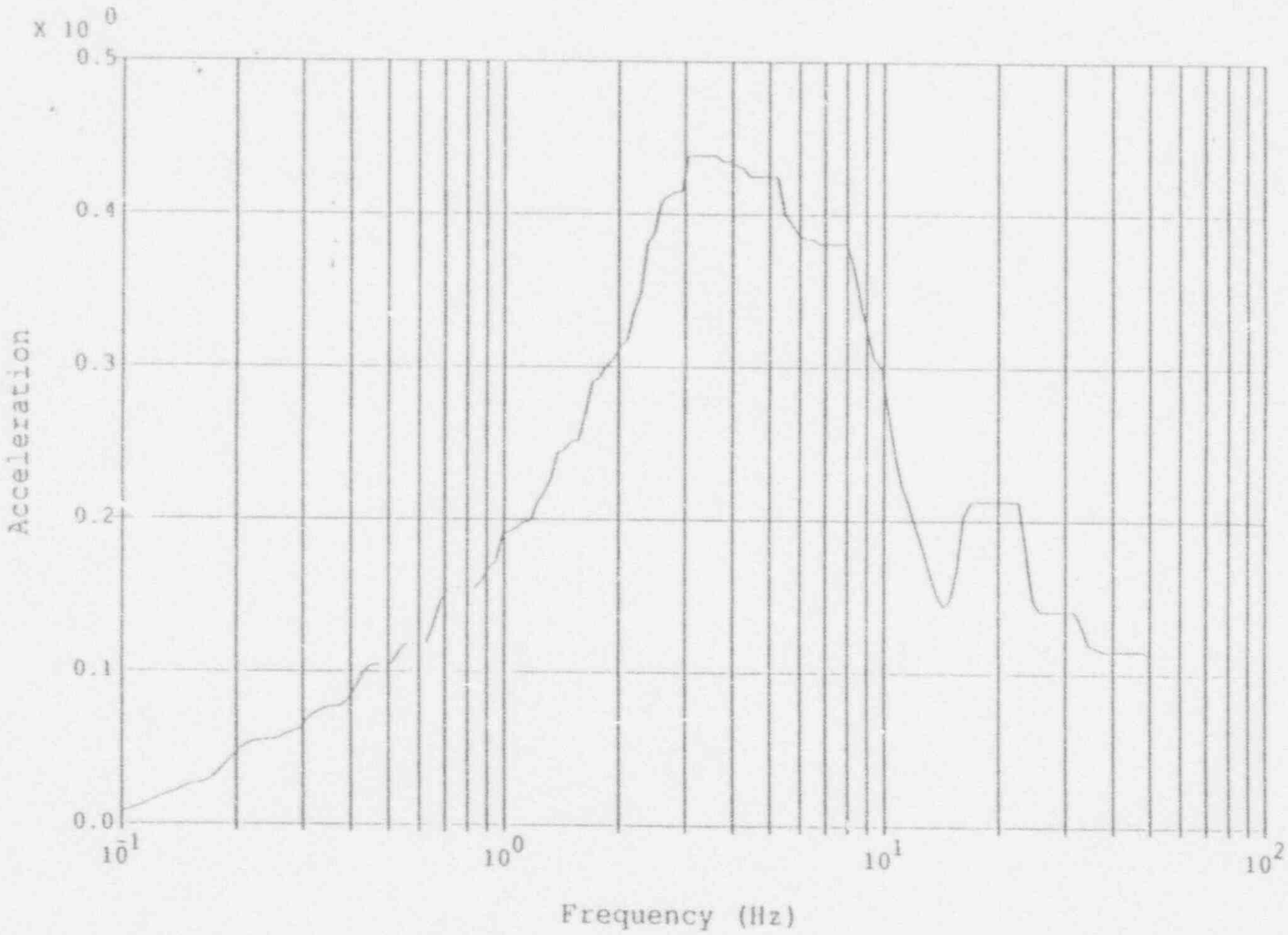
RSPLT SUN V1.2 pe010x.plt 15:05:10 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 15.40', Translation in the EW Direction



RSPLT SUN V1.2 pe010z.plt 15:05:12 05/21/93

Notes:

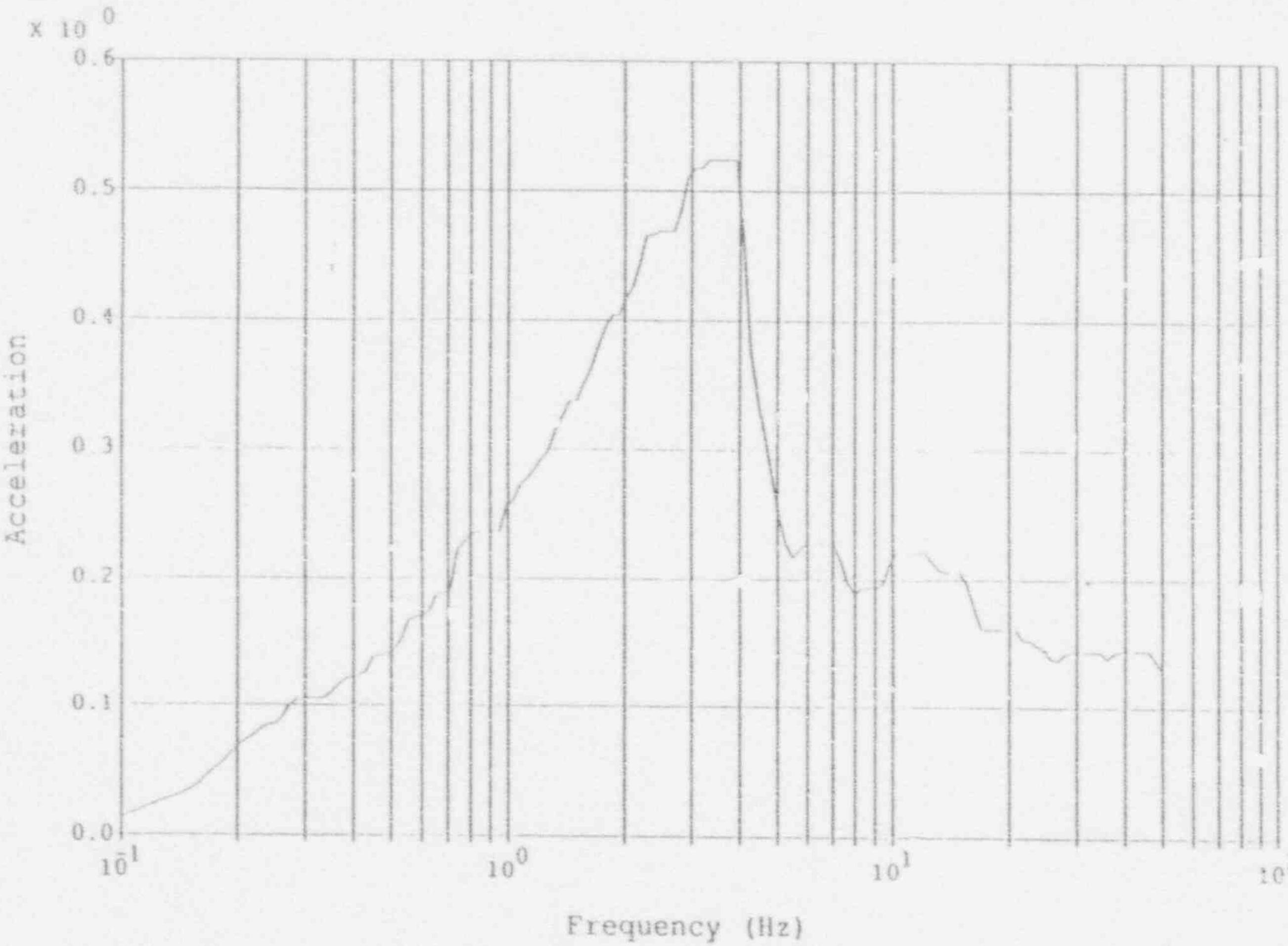
N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE

Pedestal, El. 15.40', Translation in the Vertical Direction

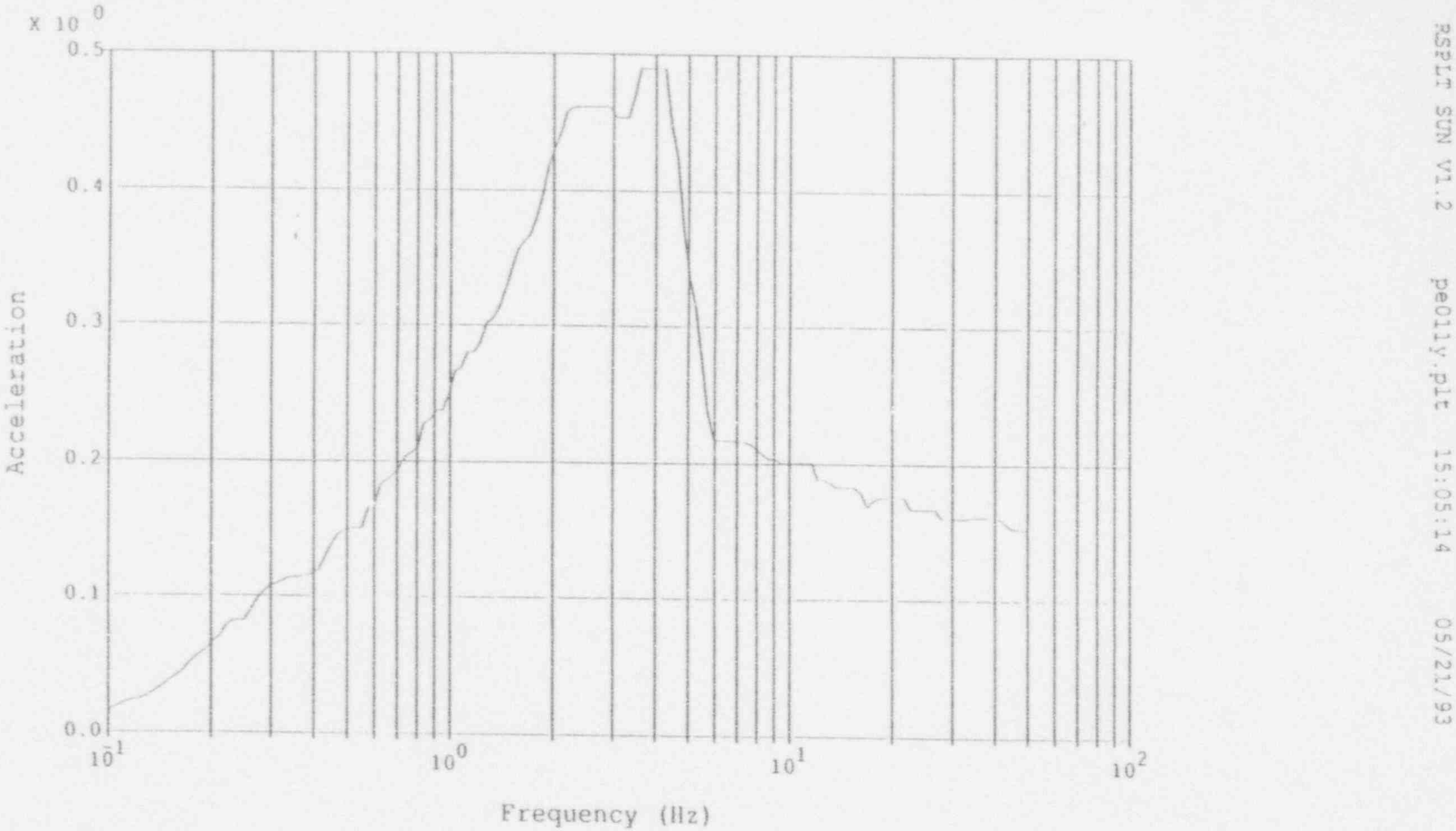


RSPLT SUN V1.2 pe011x.plt 15:05:13 05/21/93

Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 21.70', Translation in the NS Direction



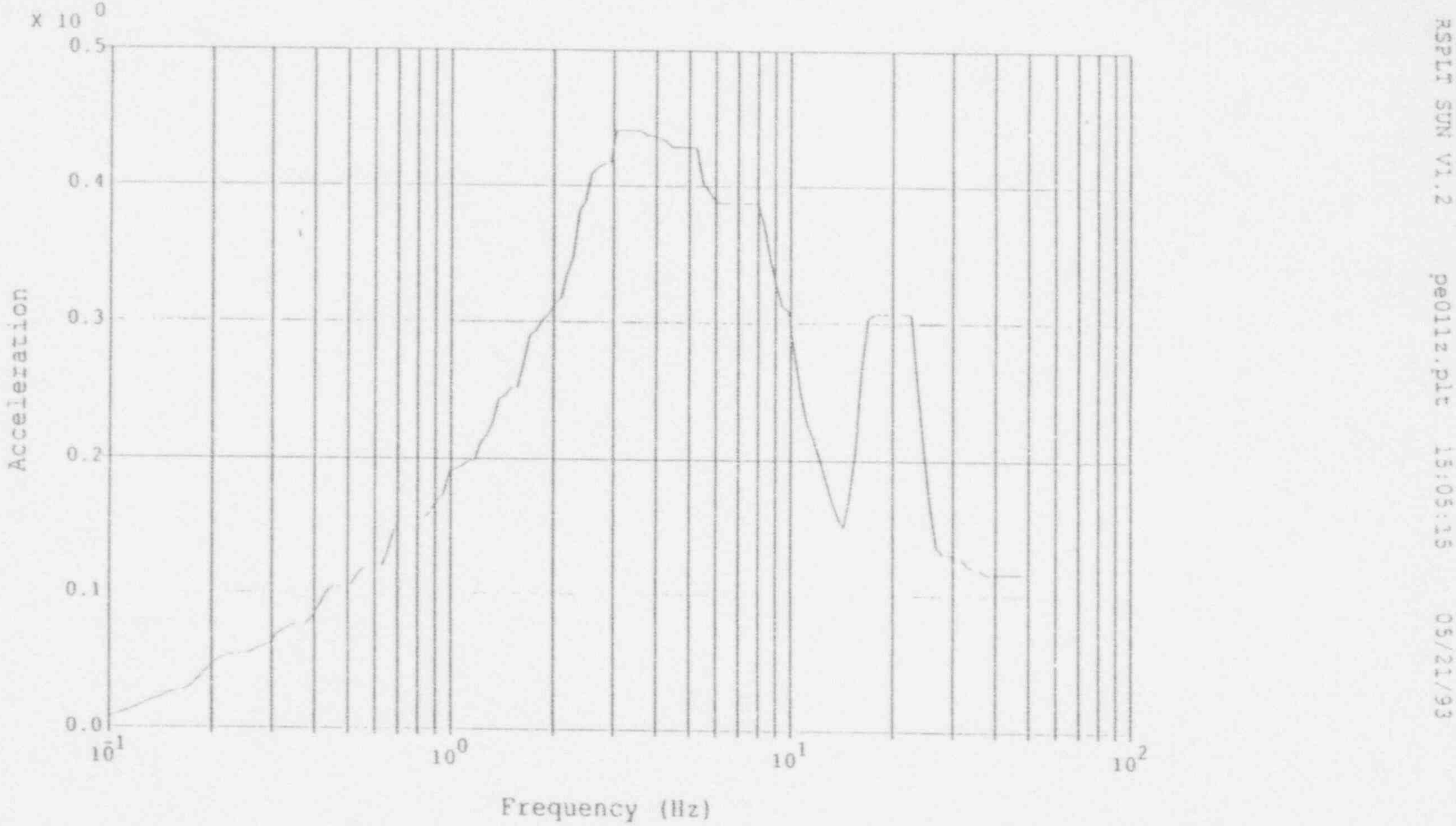
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 21.70', Translation in the EW Direction



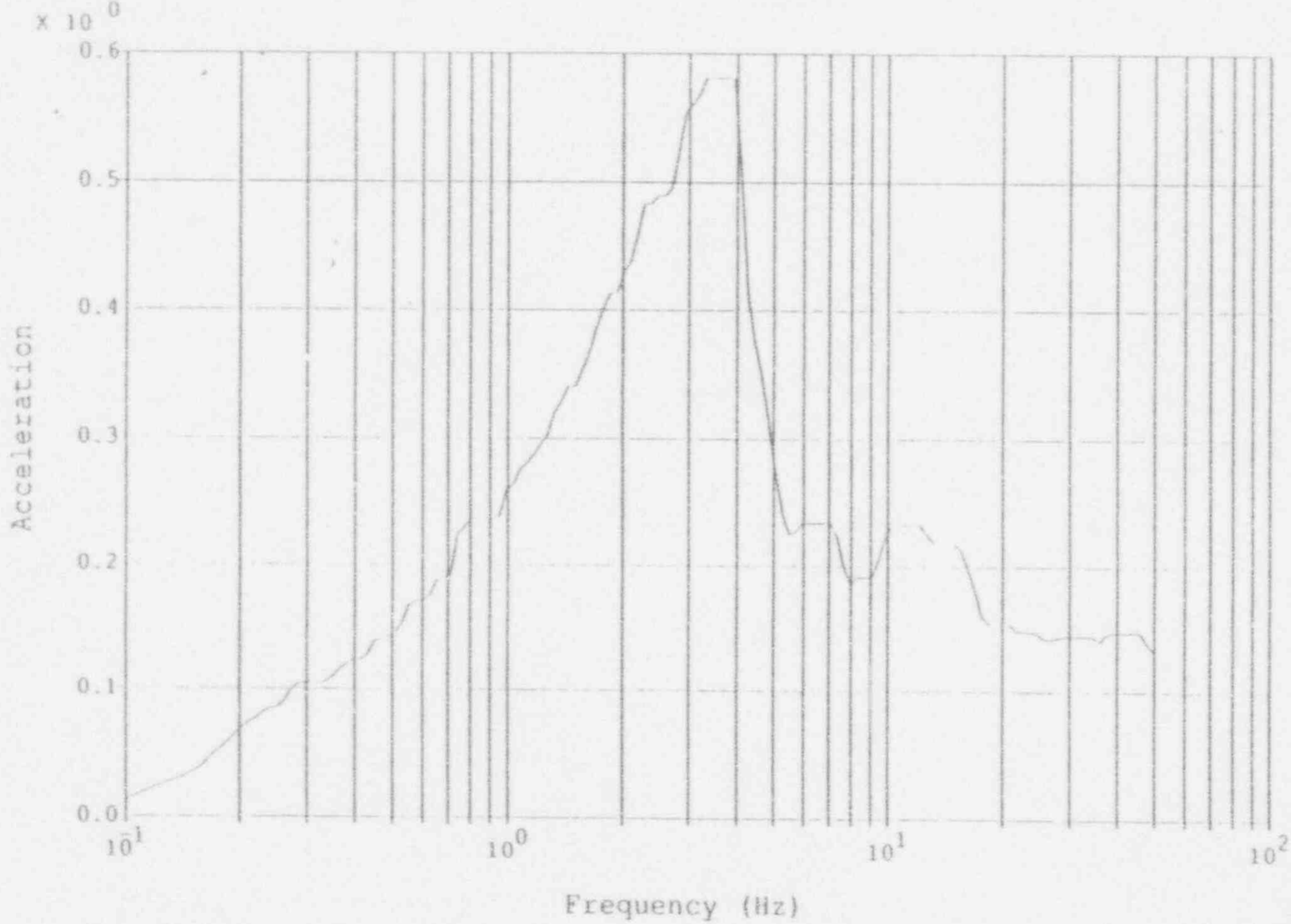
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 21.70', Translation in the Vertical Direction



RSPLT SUN V1.2 pe012x.plt 15:05:16 05/21/93

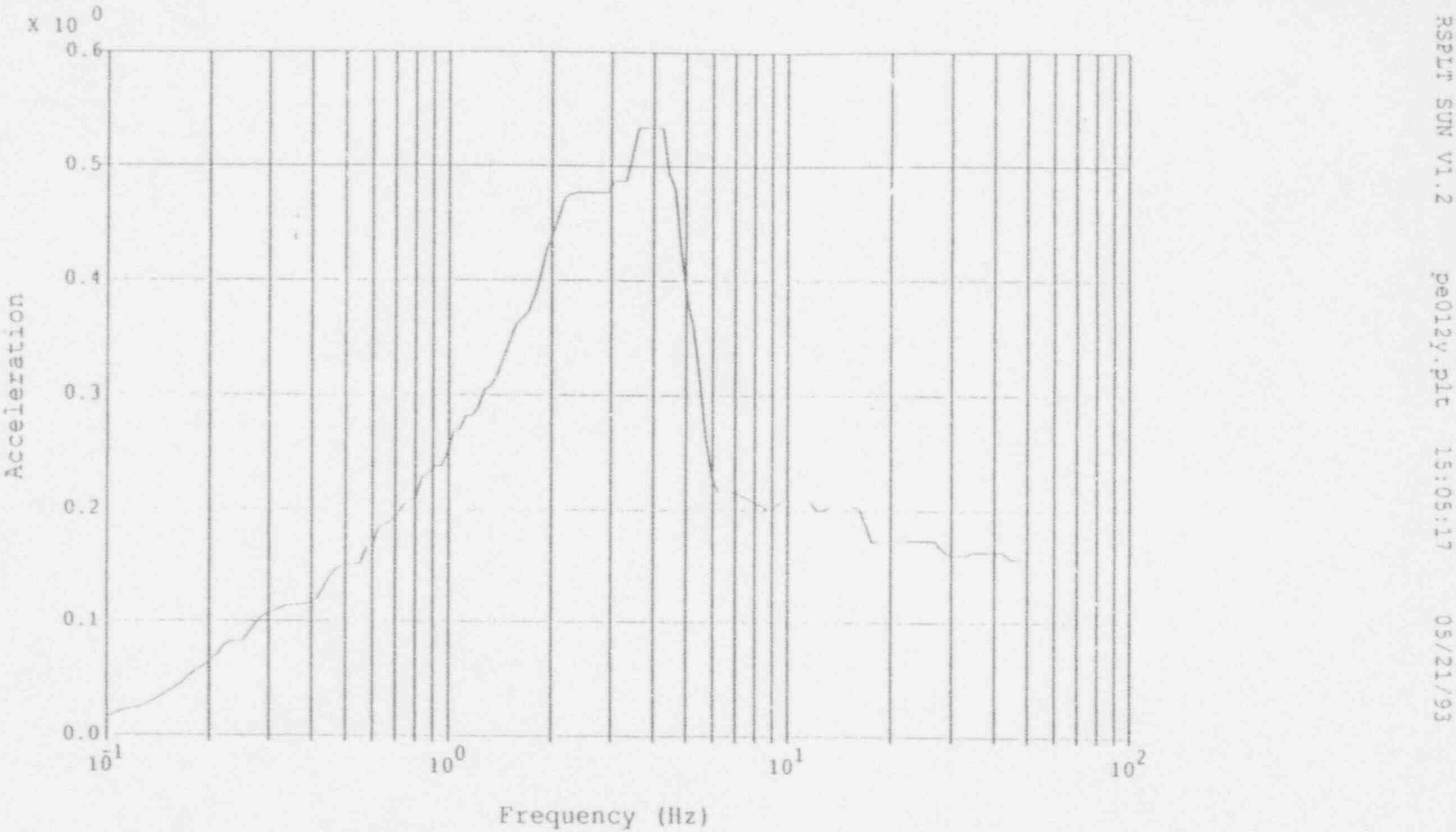
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 28.00', Translation in the NS Direction



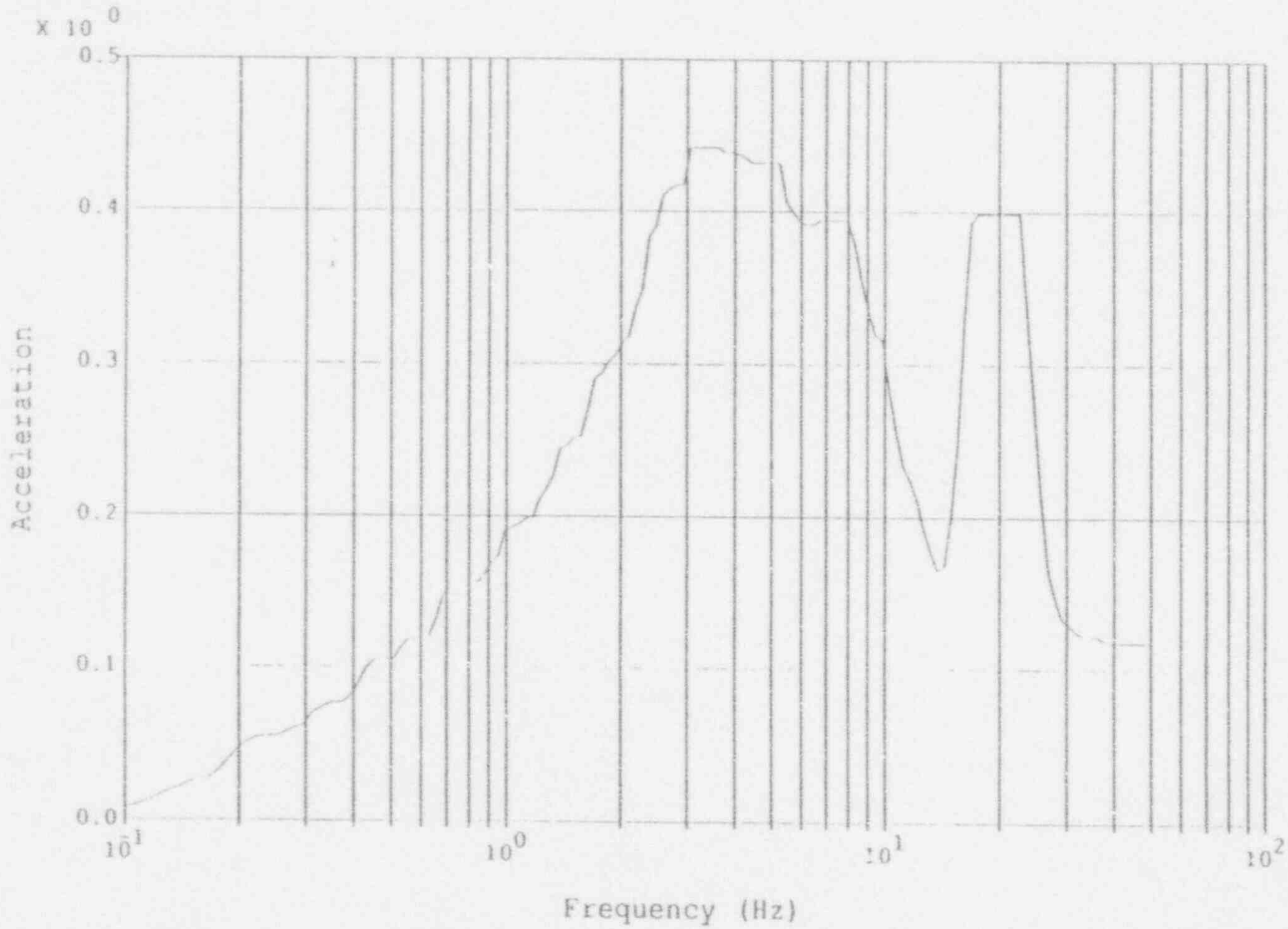
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 28.00', Translation in the EW Direction

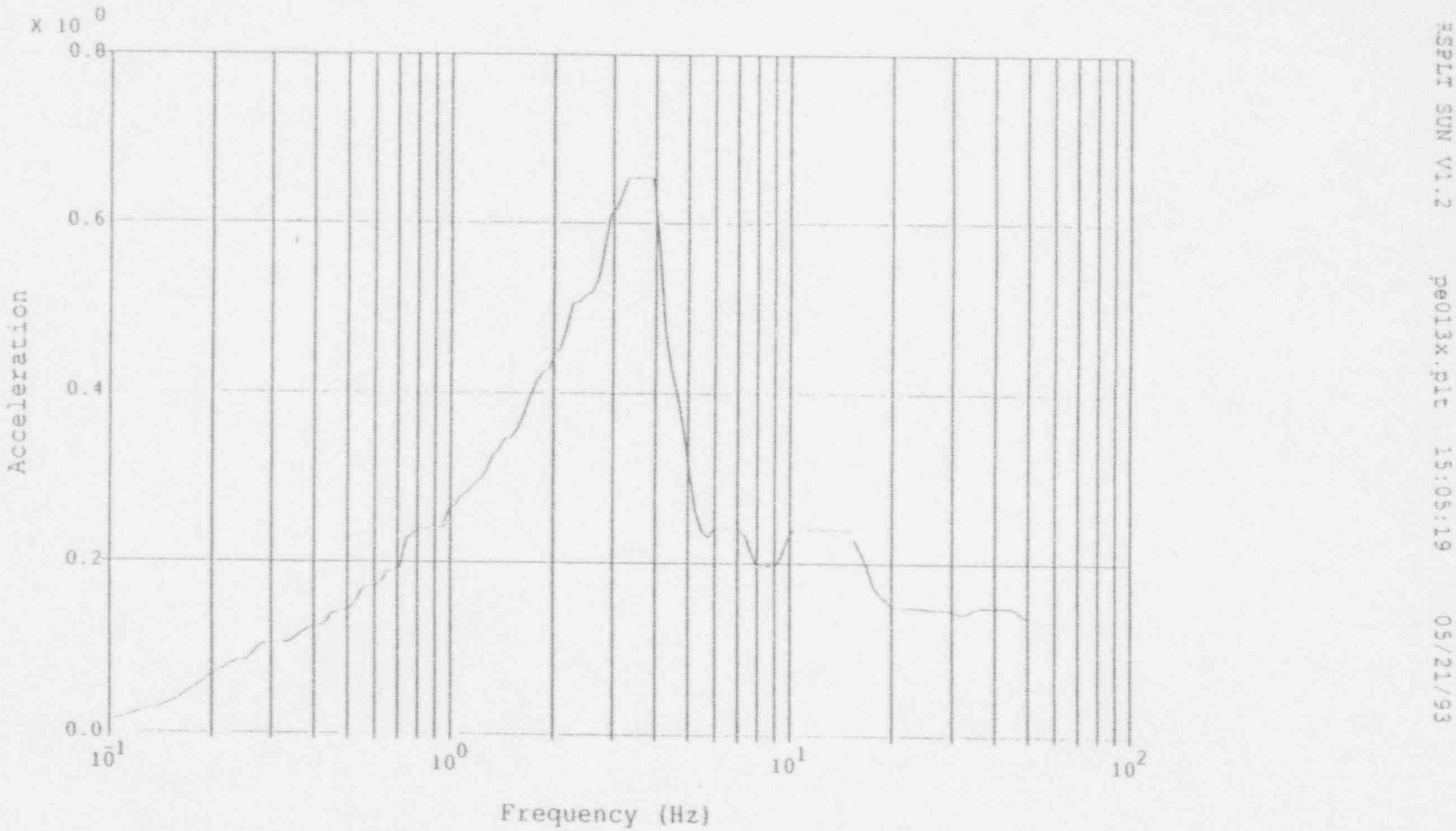


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 28.00', Translation in the Vertical Direction

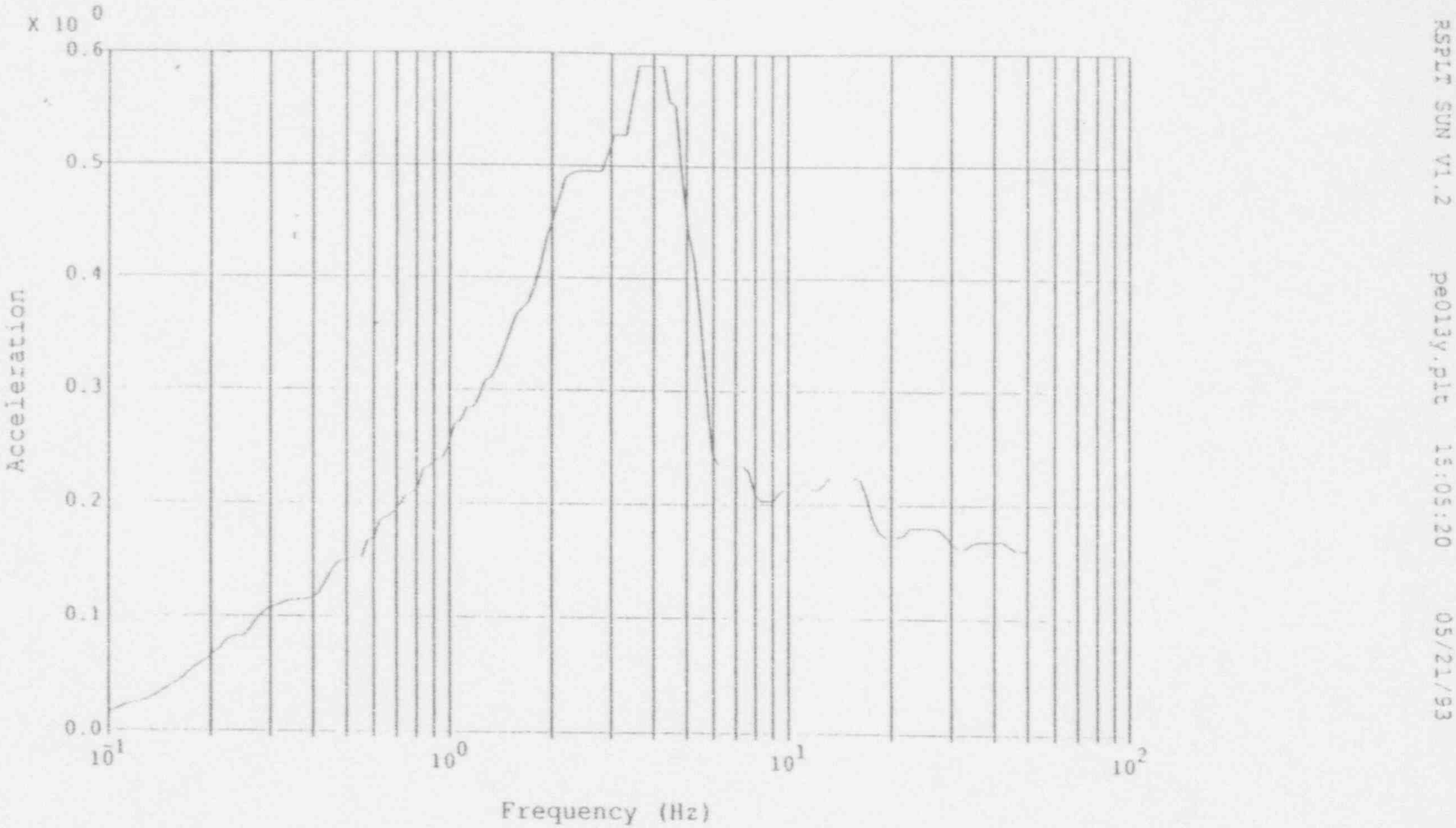
RSPLT SUN V1.2 pe012z.plt 15:05:18 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

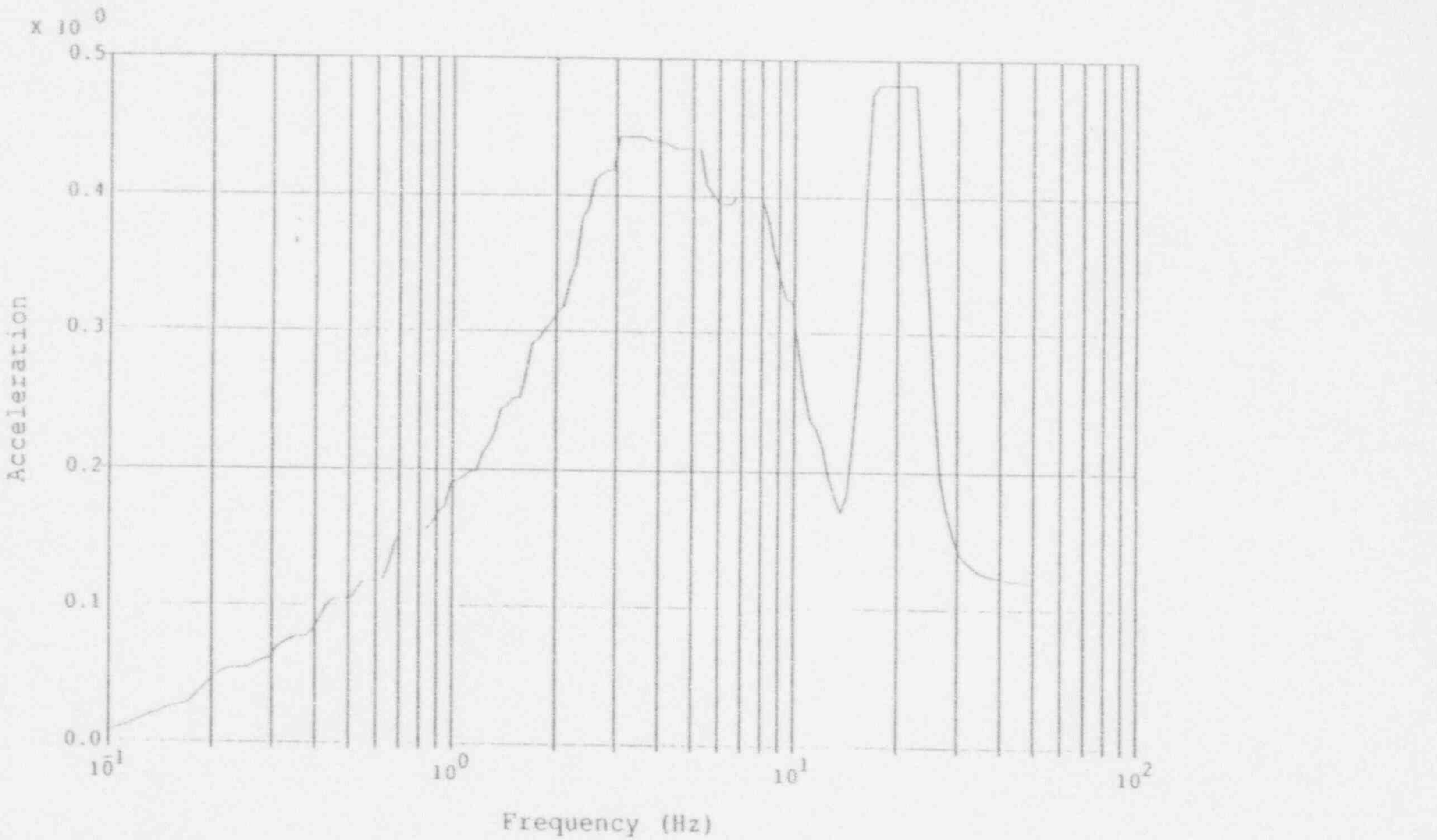
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 35.42', Translation in the NS Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

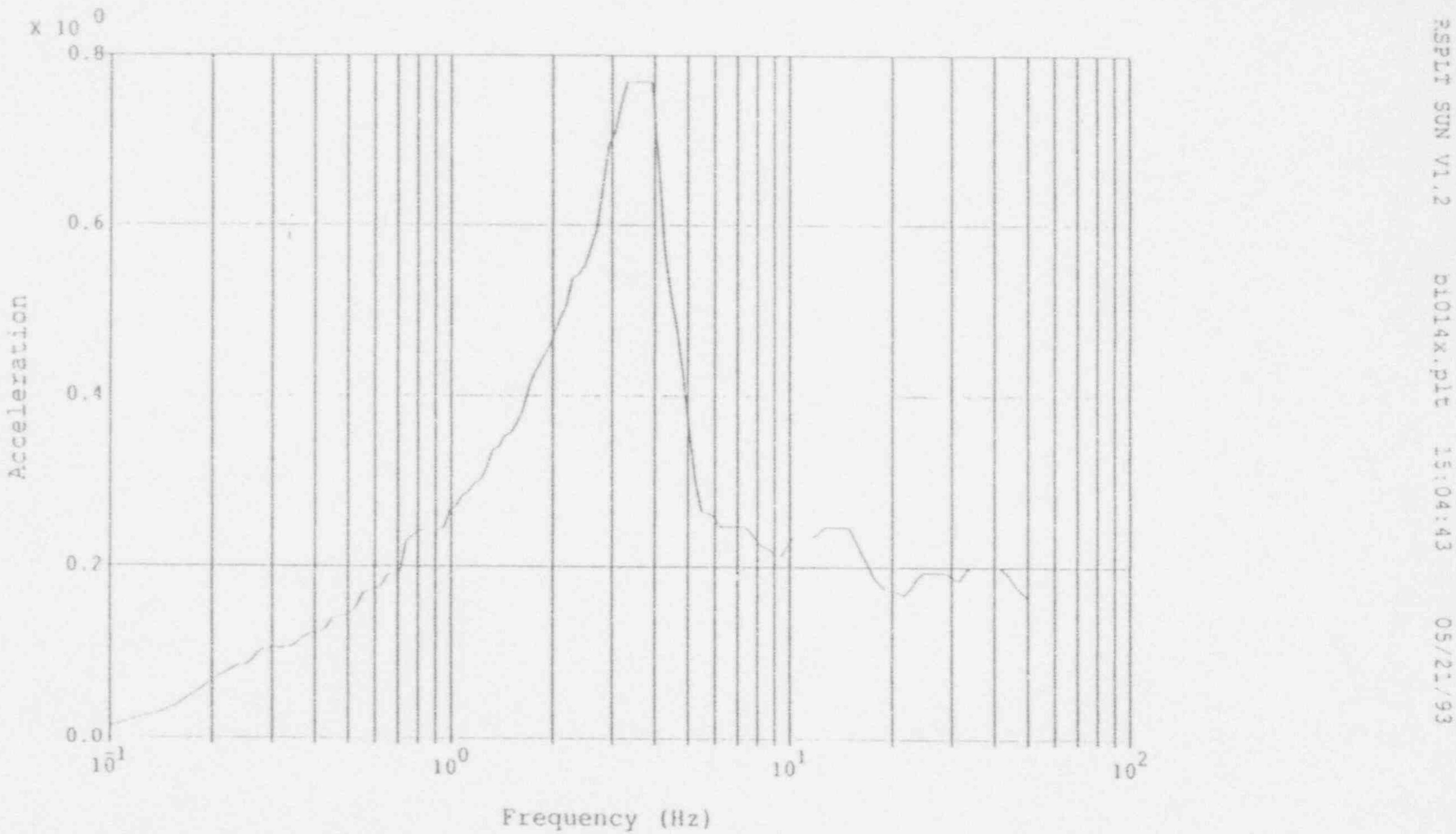
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 35.42', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Pedestal, El. 35.42', Translation in the Vertical Direction

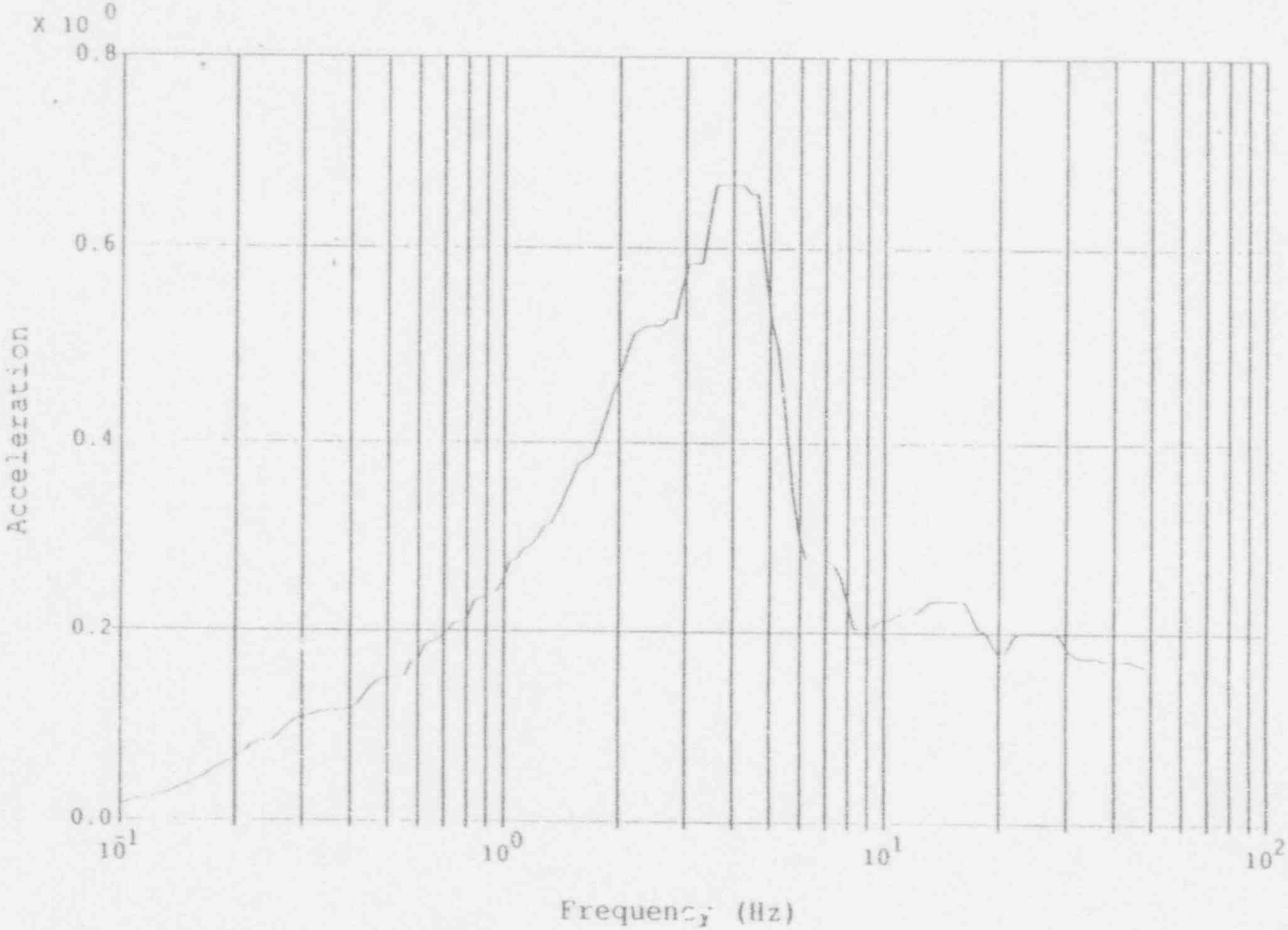


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 47.35', Translation in the NS Direction

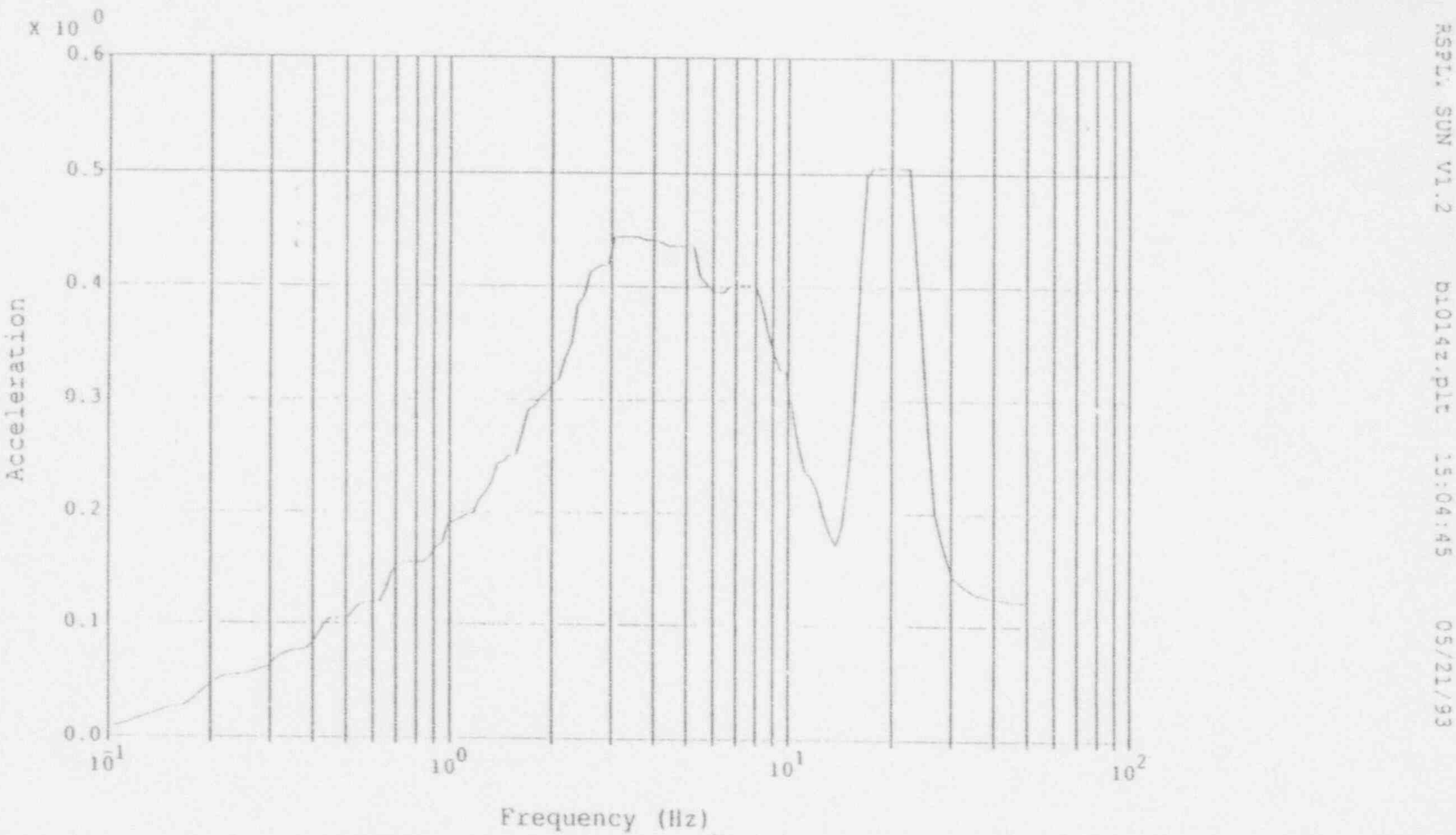
RSPLT SUN V1.2 b1014y.plt 15:04:44 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

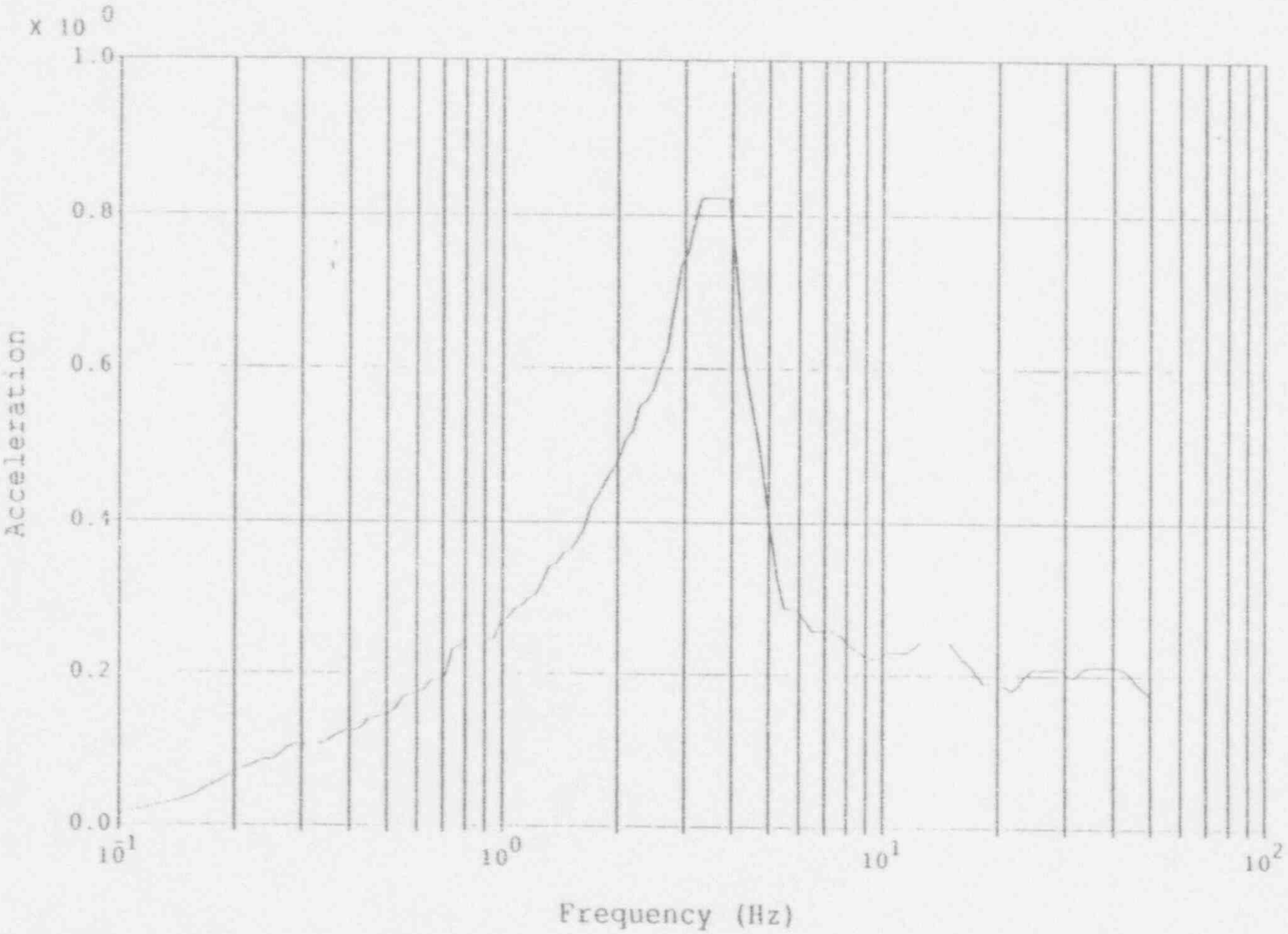
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 47.35', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

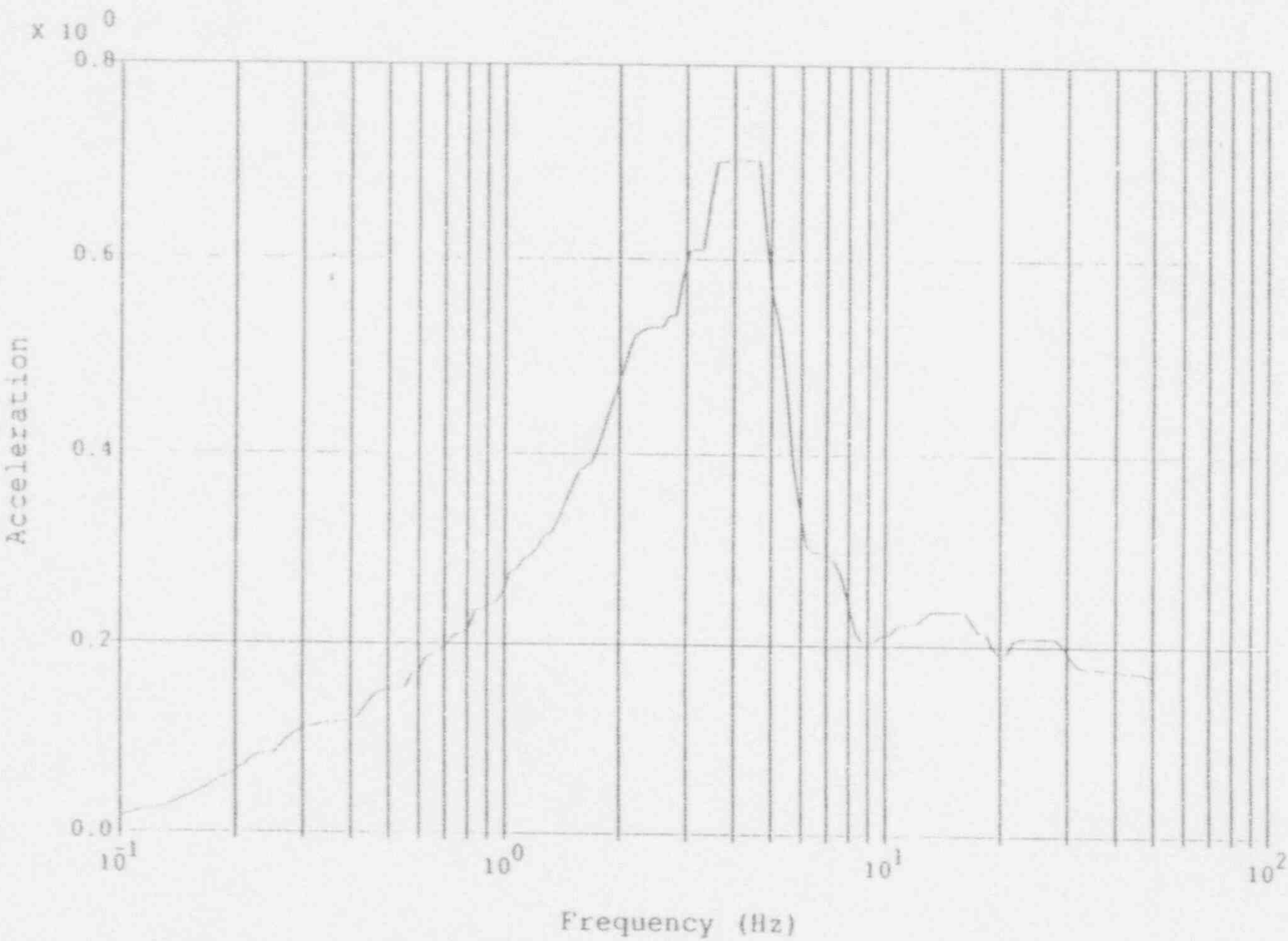
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 47.35', Translation in the Vert. Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 52.81', Translation in the NS Direction

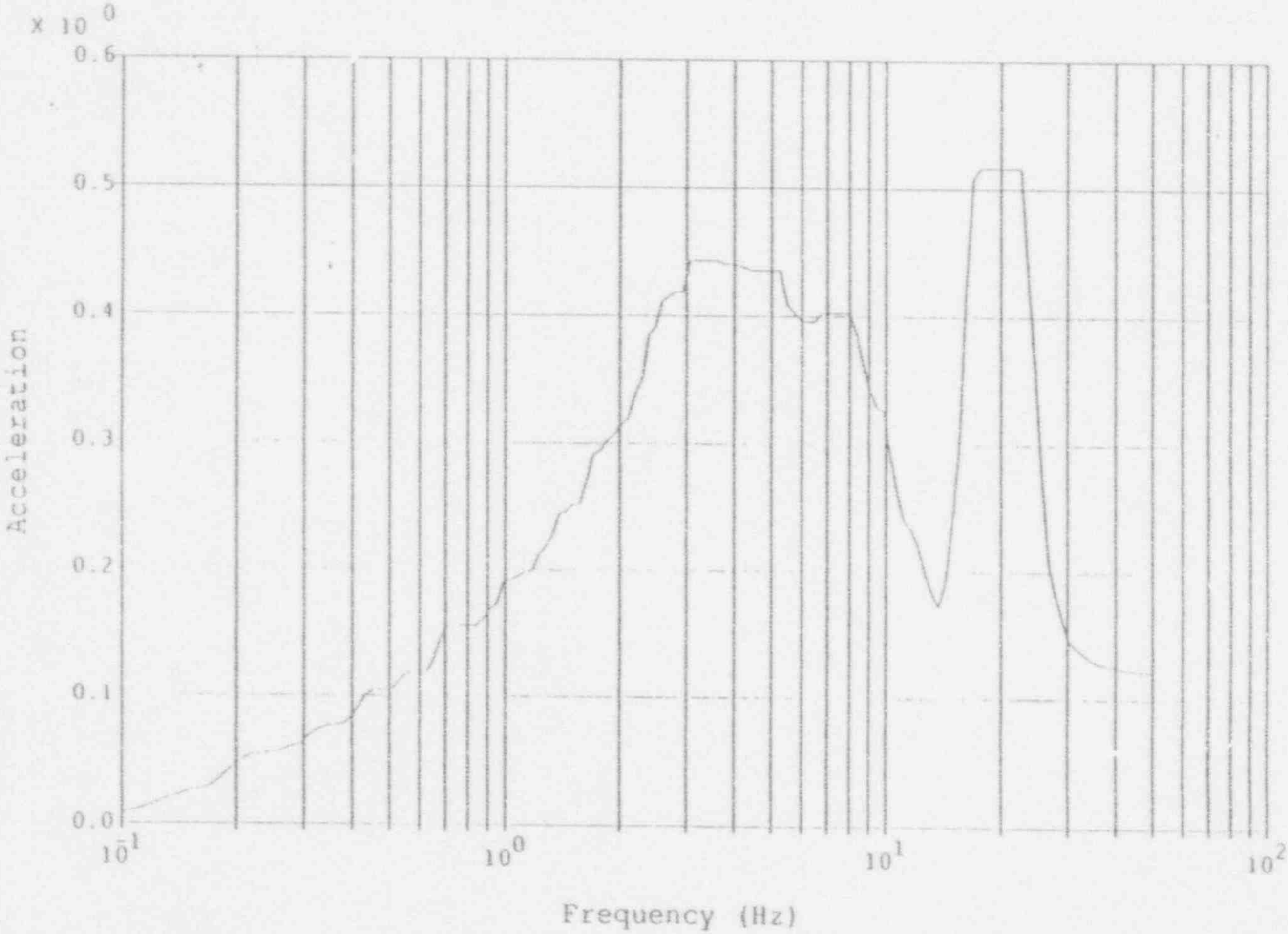


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

RSPLT SUN V1.2   D1015y.plt   15:04:47   05/21/93

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 52.81', Translation in the EW Direction



Notes:

N-411 Damped Spectrum

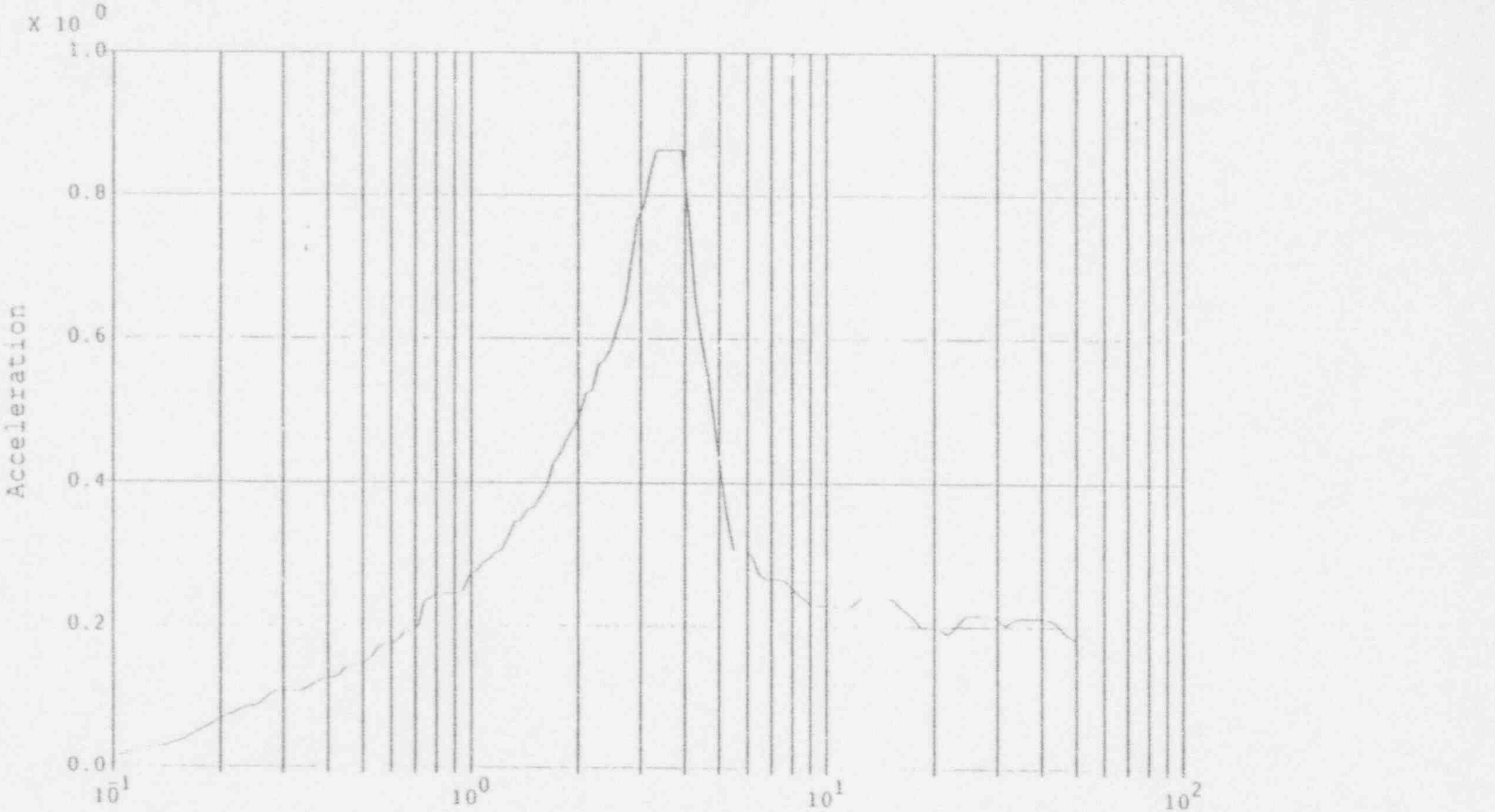
Accelerations in g's

1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE

Biological Shield Wall, El. 52.81', Translation in the Vert. Direction

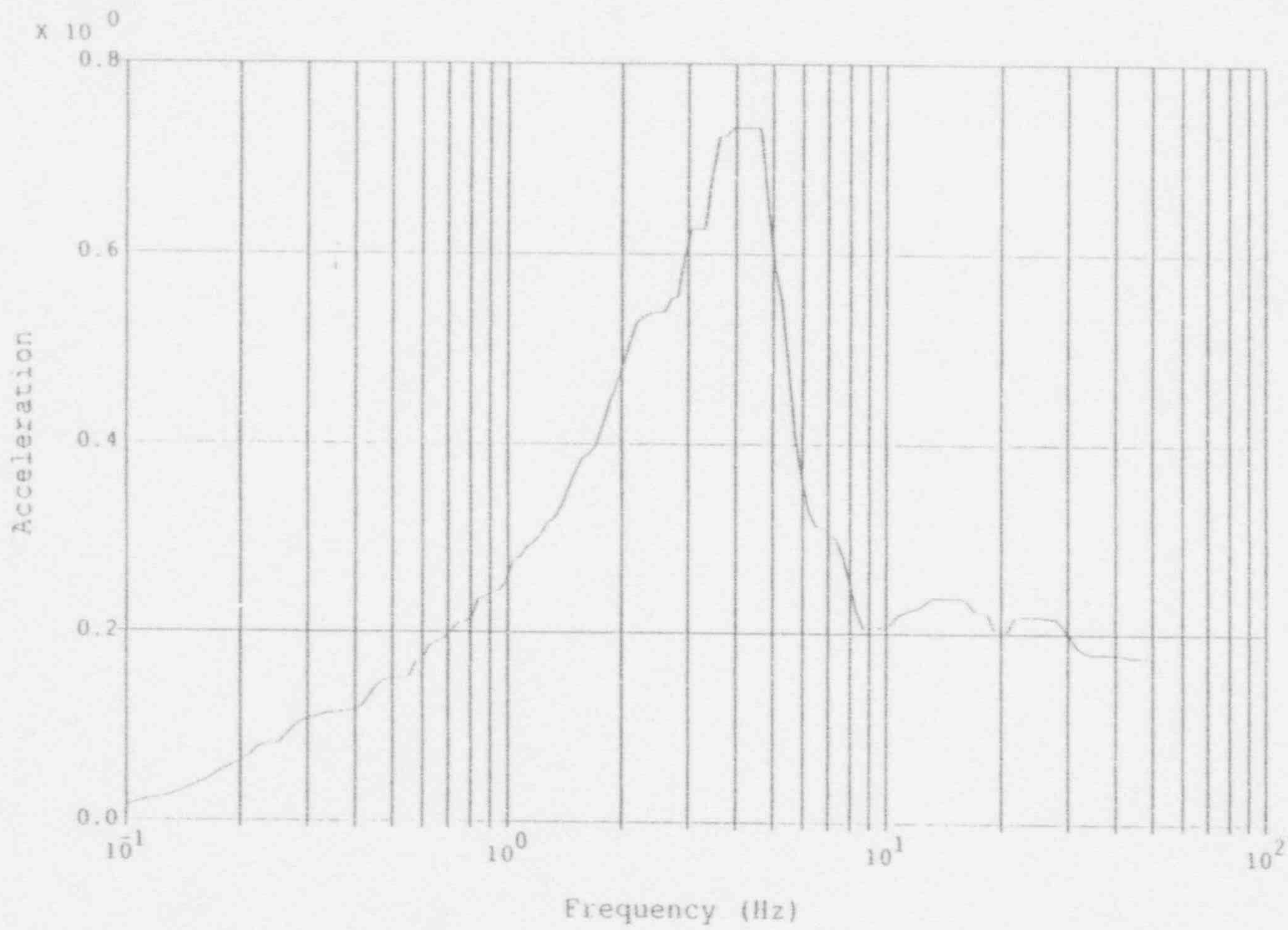
RSPLT SUN V1.2 bi015z.plt 15:04:48 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

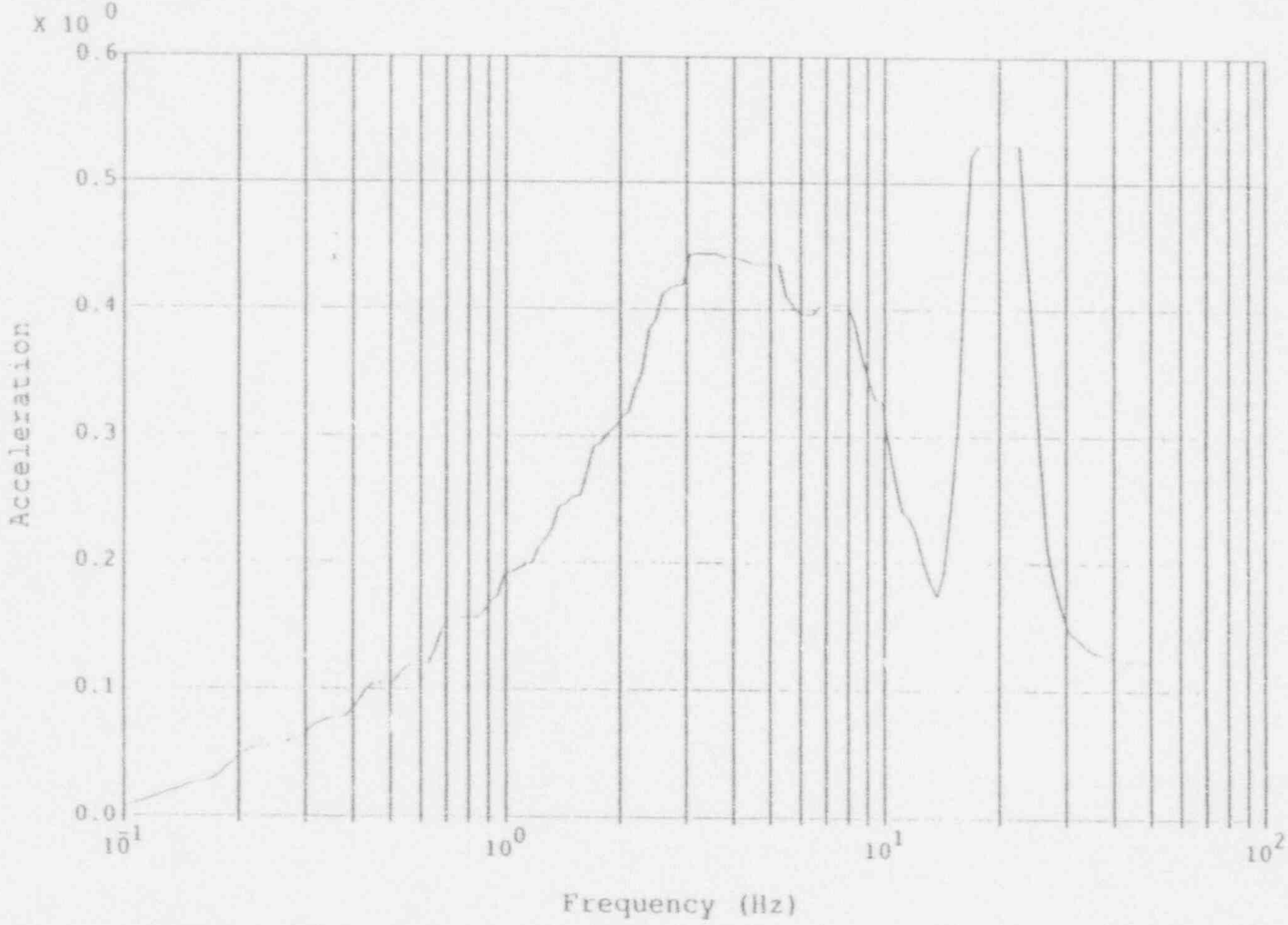
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 56.64', Translation in the NS Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 56.64', Translation in the EW Direction

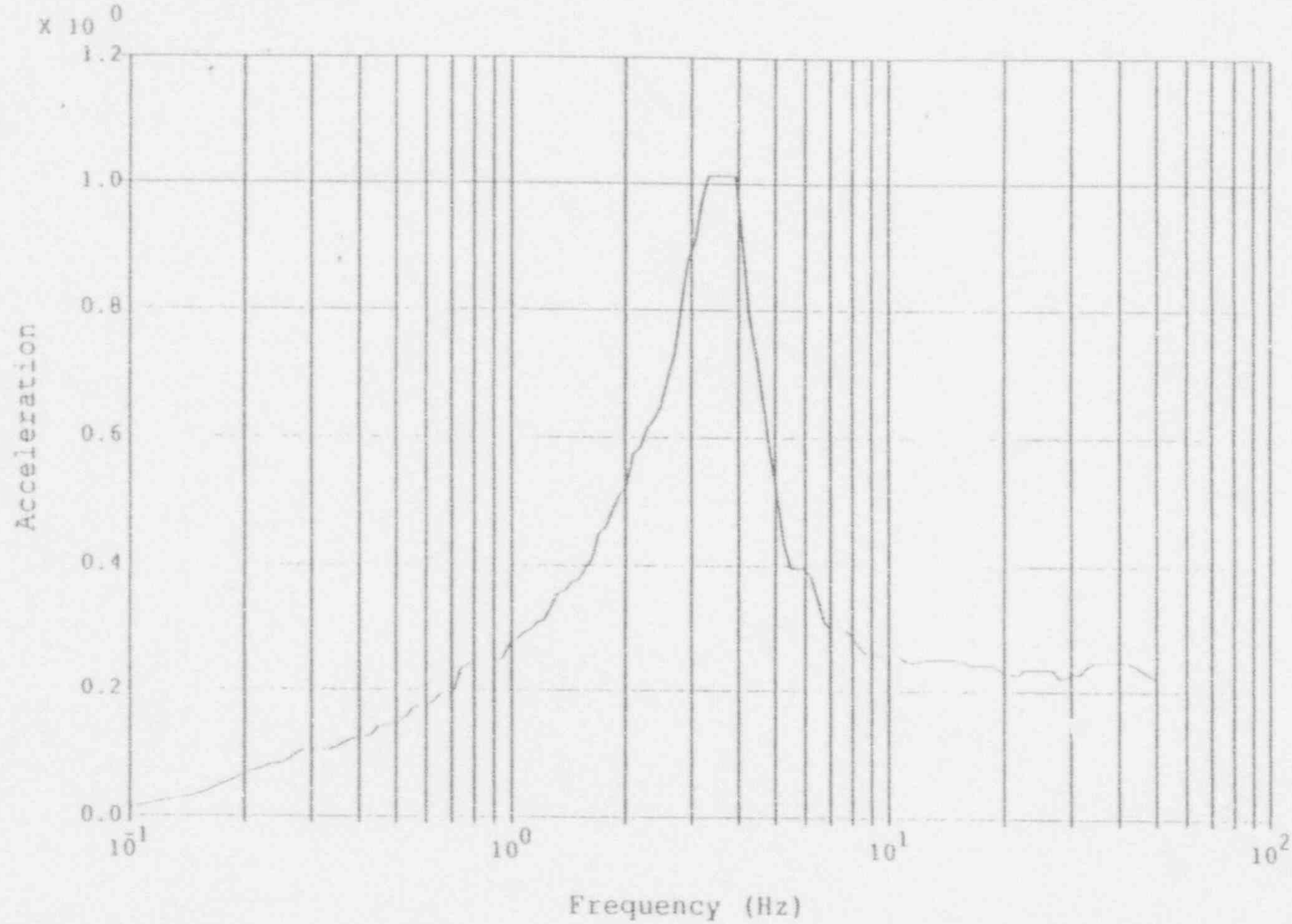


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 56.64', Translation in the Vert. Direction

RSPLT SUN V1.2 b:016z.plt 15:04:53 05/21/93

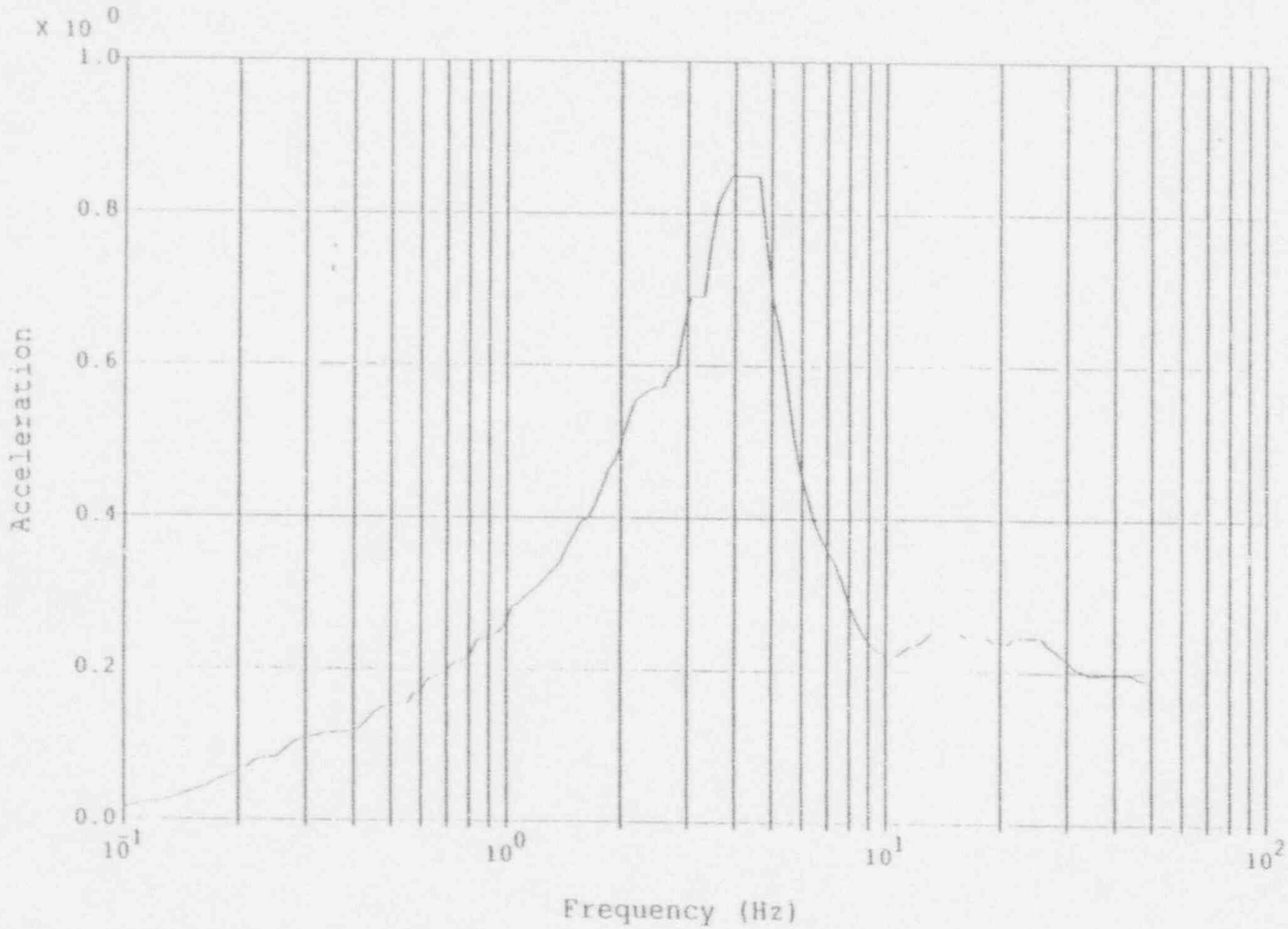


Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 71.50', Translation in the NS Direction

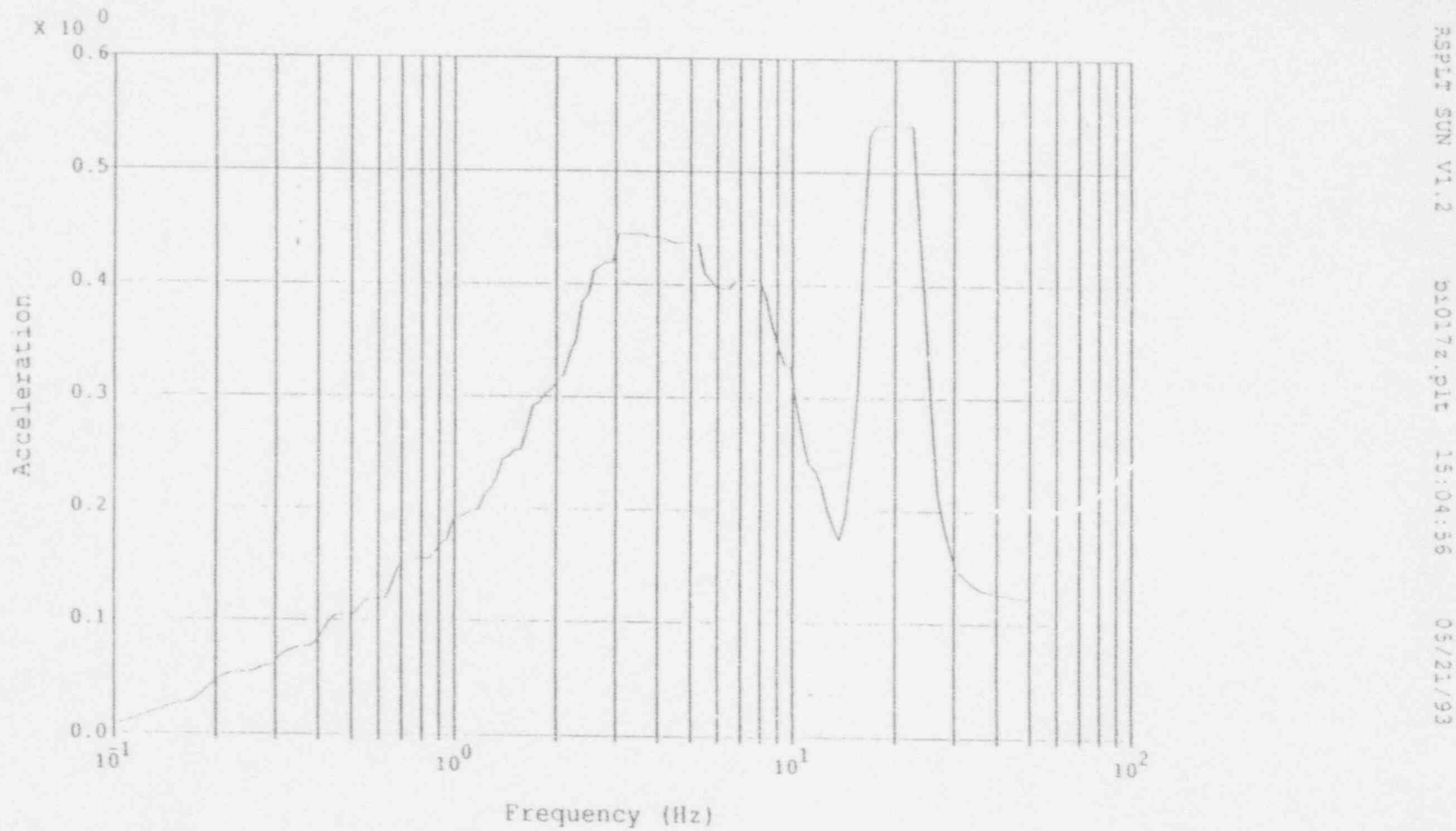
RSPLT SUN V1.2 b1017x.plt 13:04:54 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

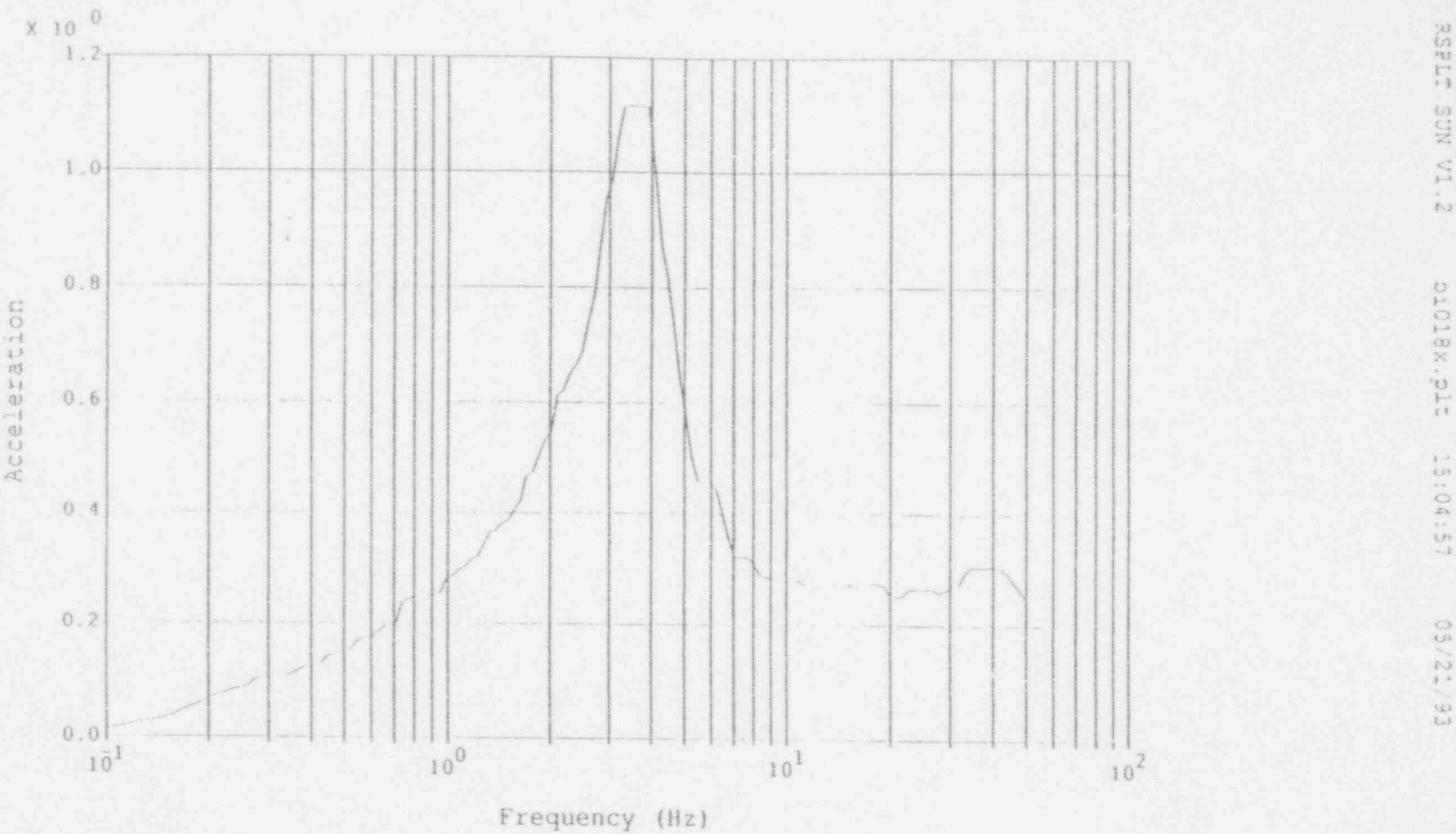
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 71.50', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 71.50', Translation in the Vert. Direction



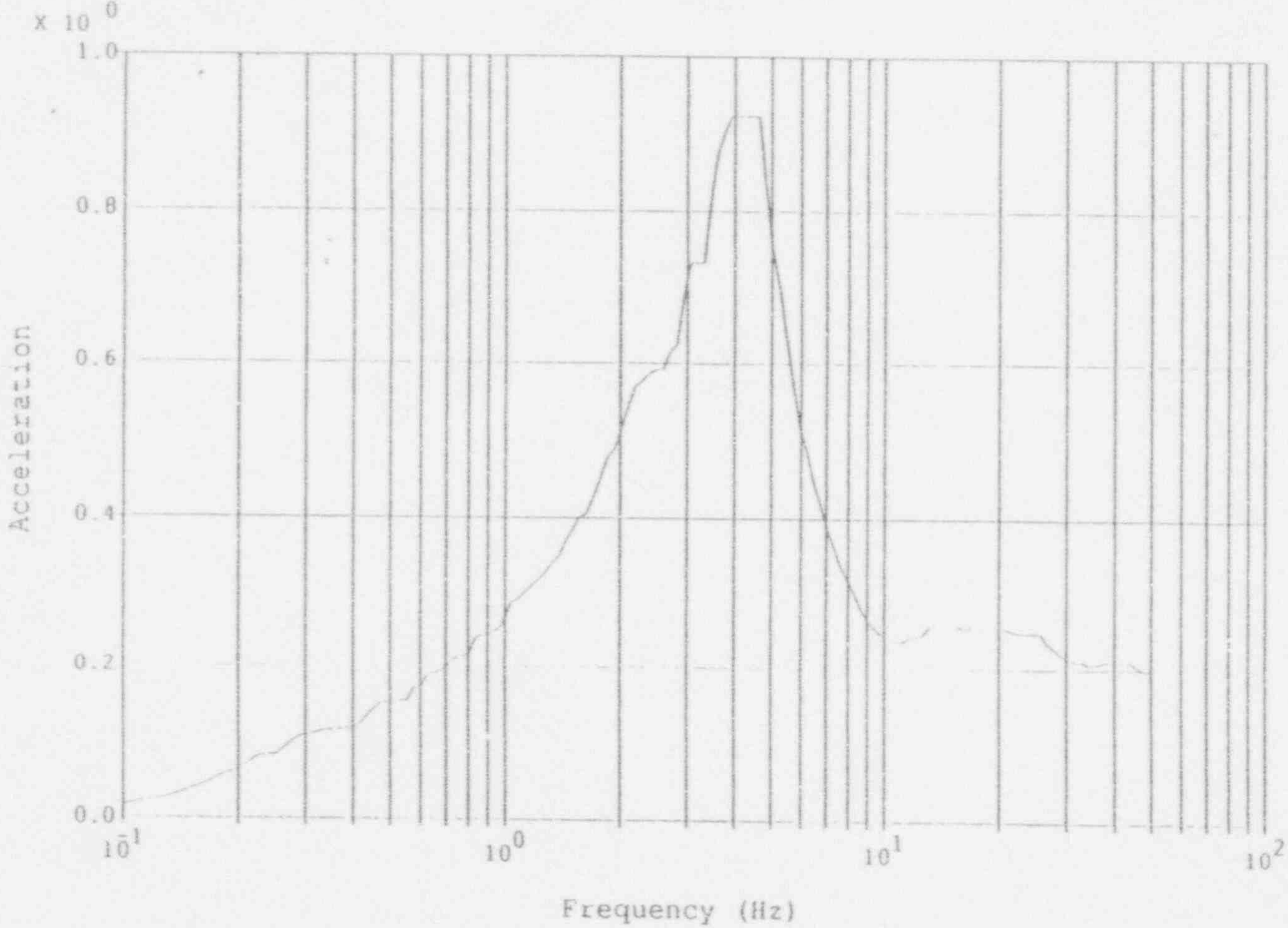
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

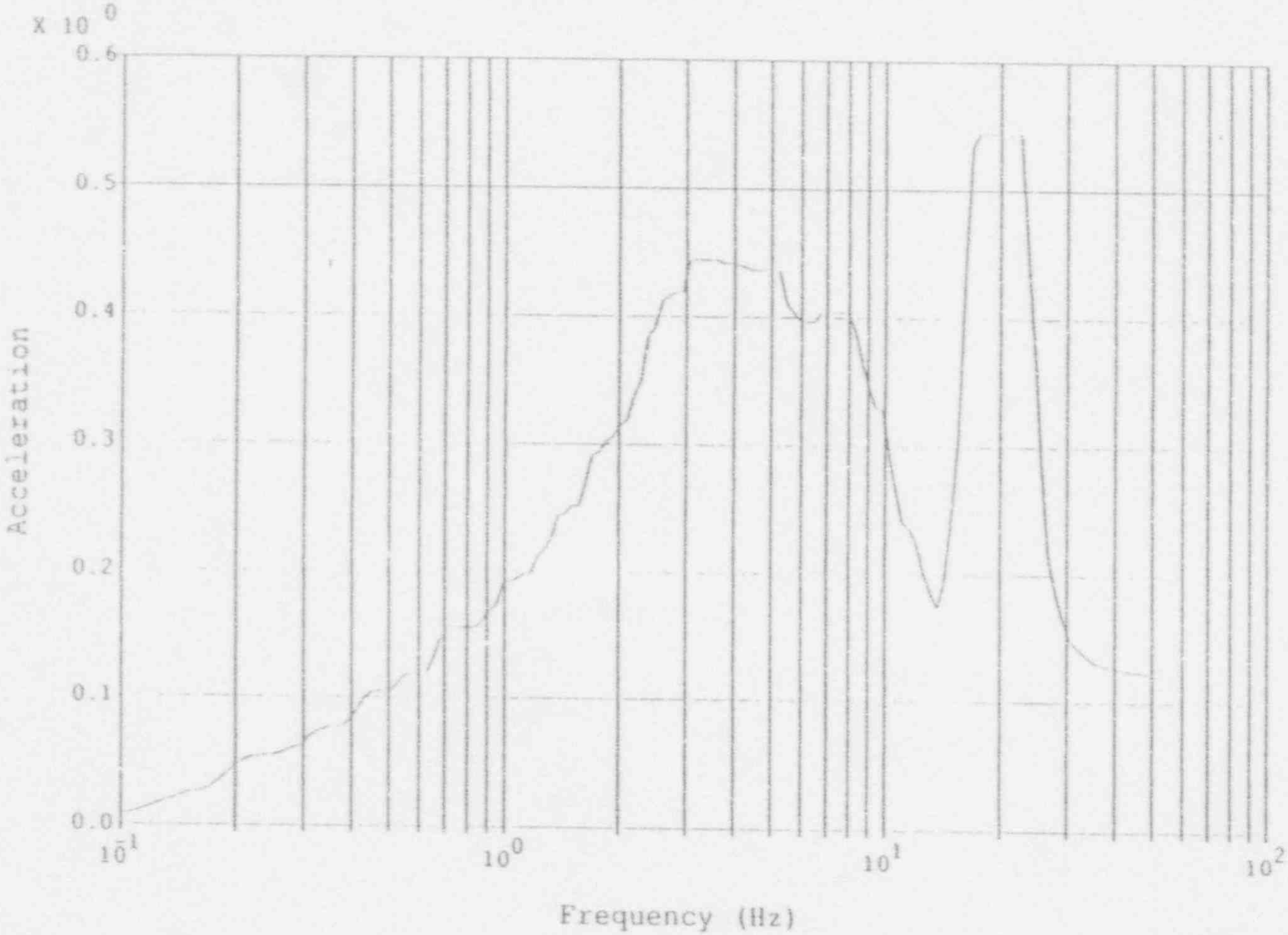
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 81.80', Translation in the NS Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

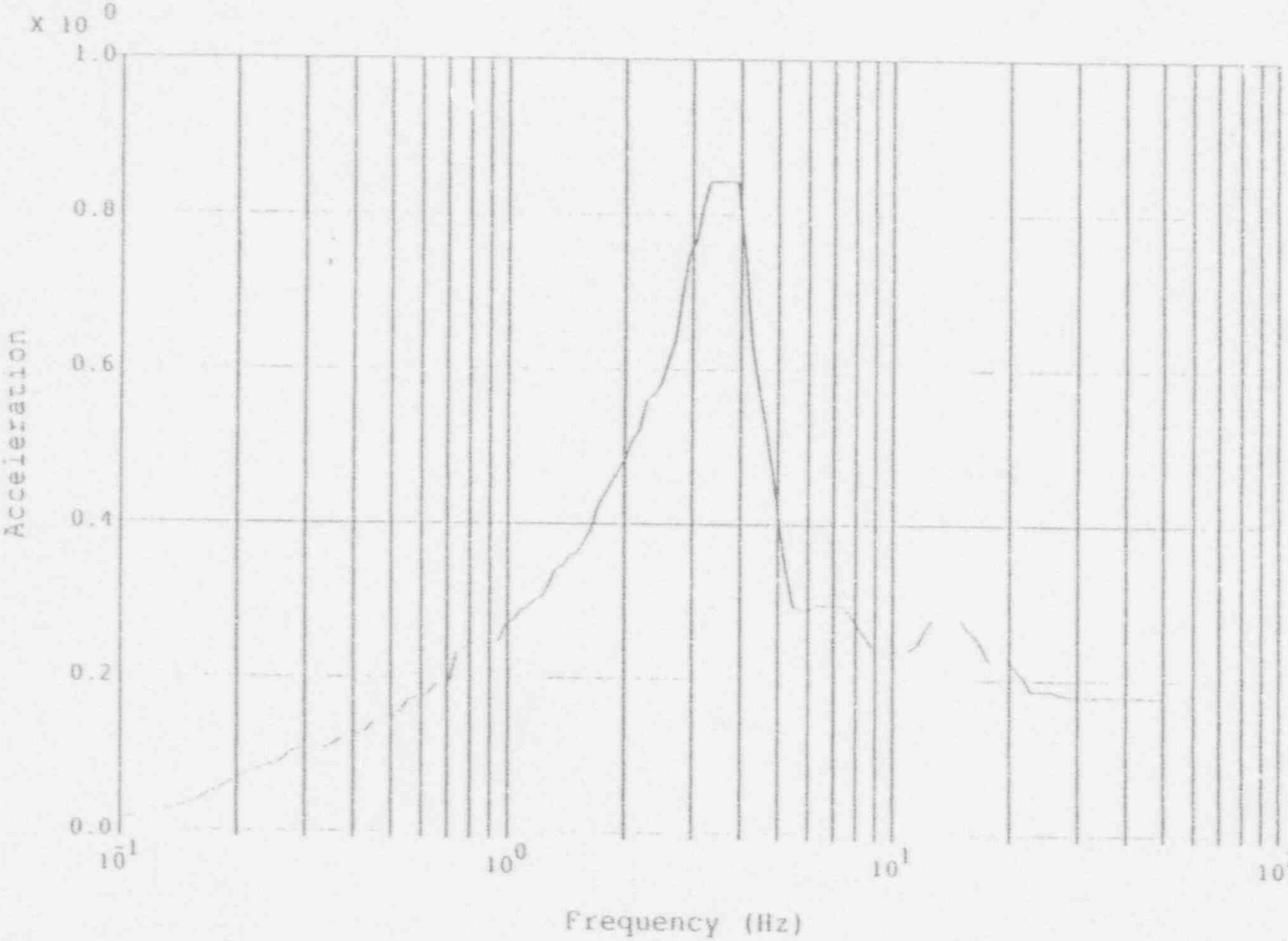
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 81.80', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Biological Shield Wall, El. 81.80', Translation in the Vert. Direction



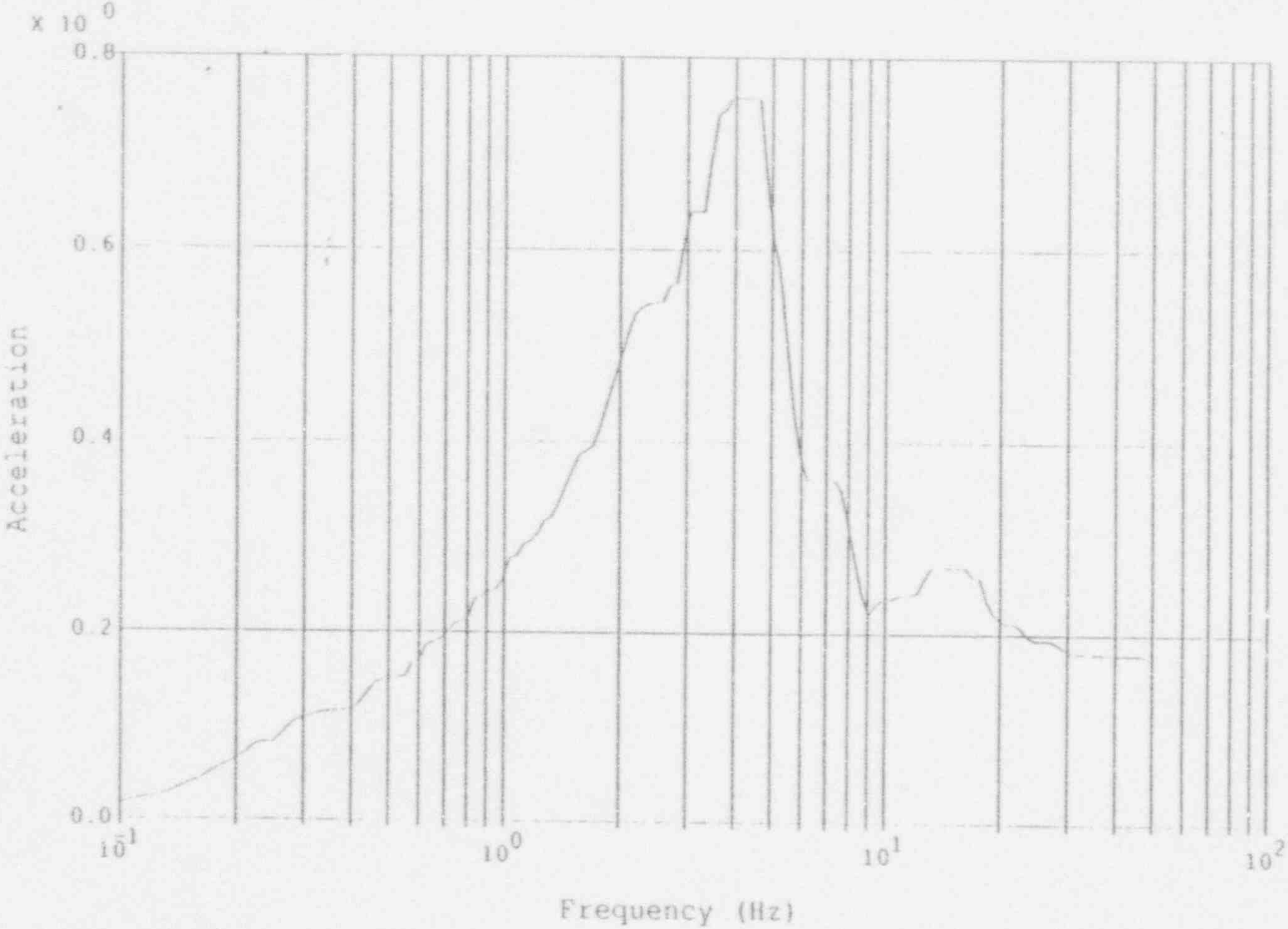
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 47.27', Translation in the NS Direction



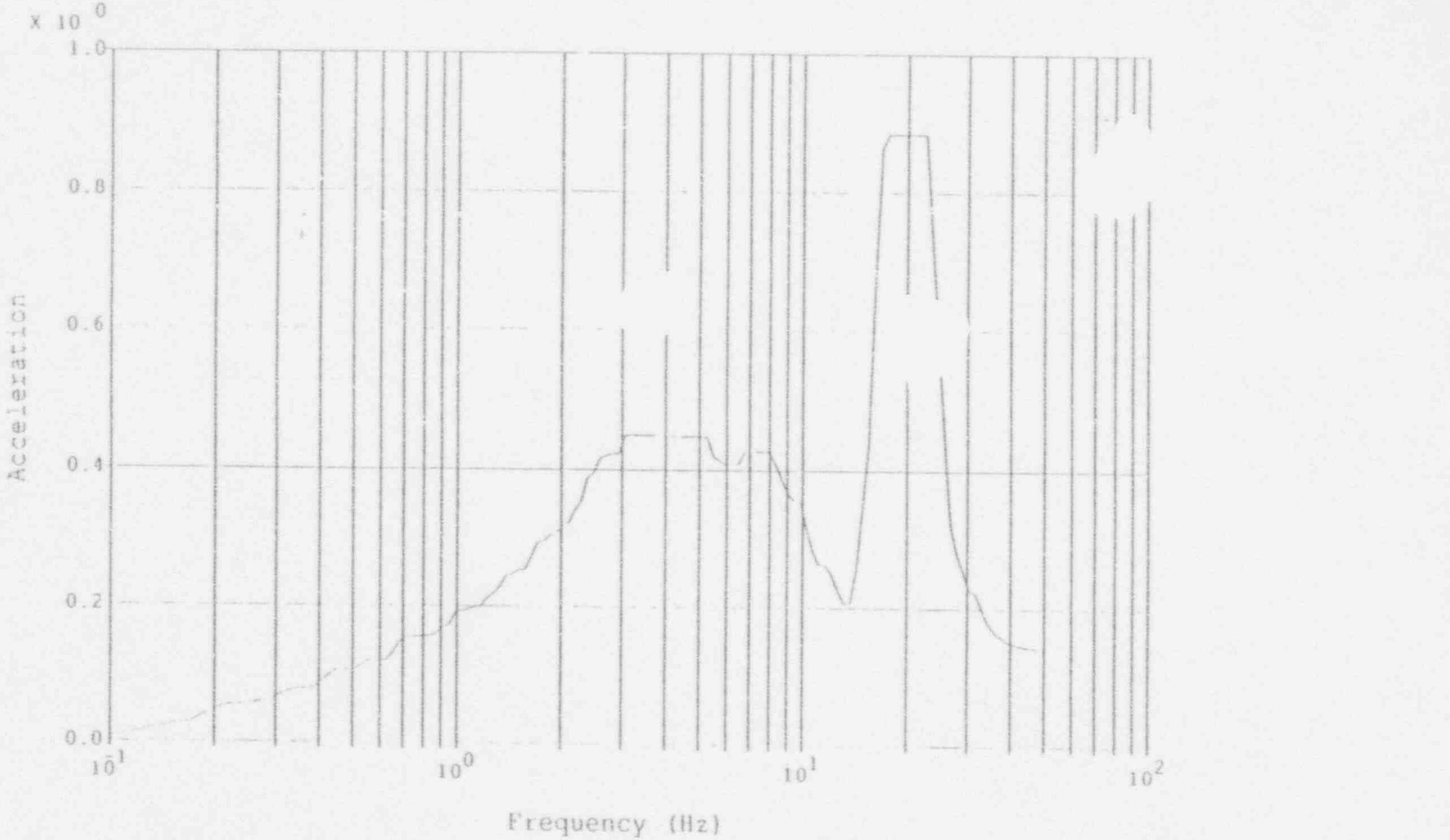
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

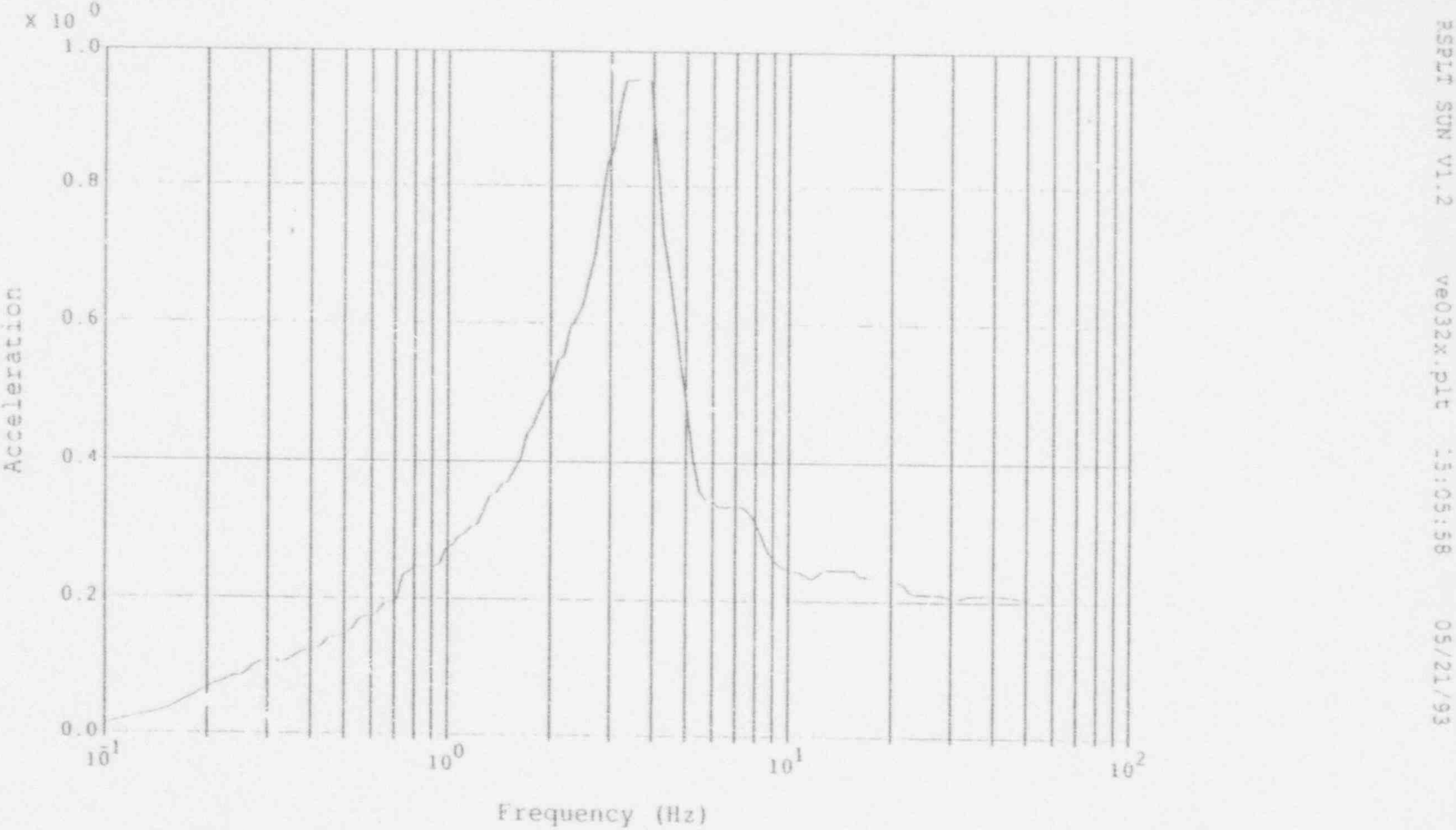
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 47.27', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 47.27', Translation in the Vertical Direction



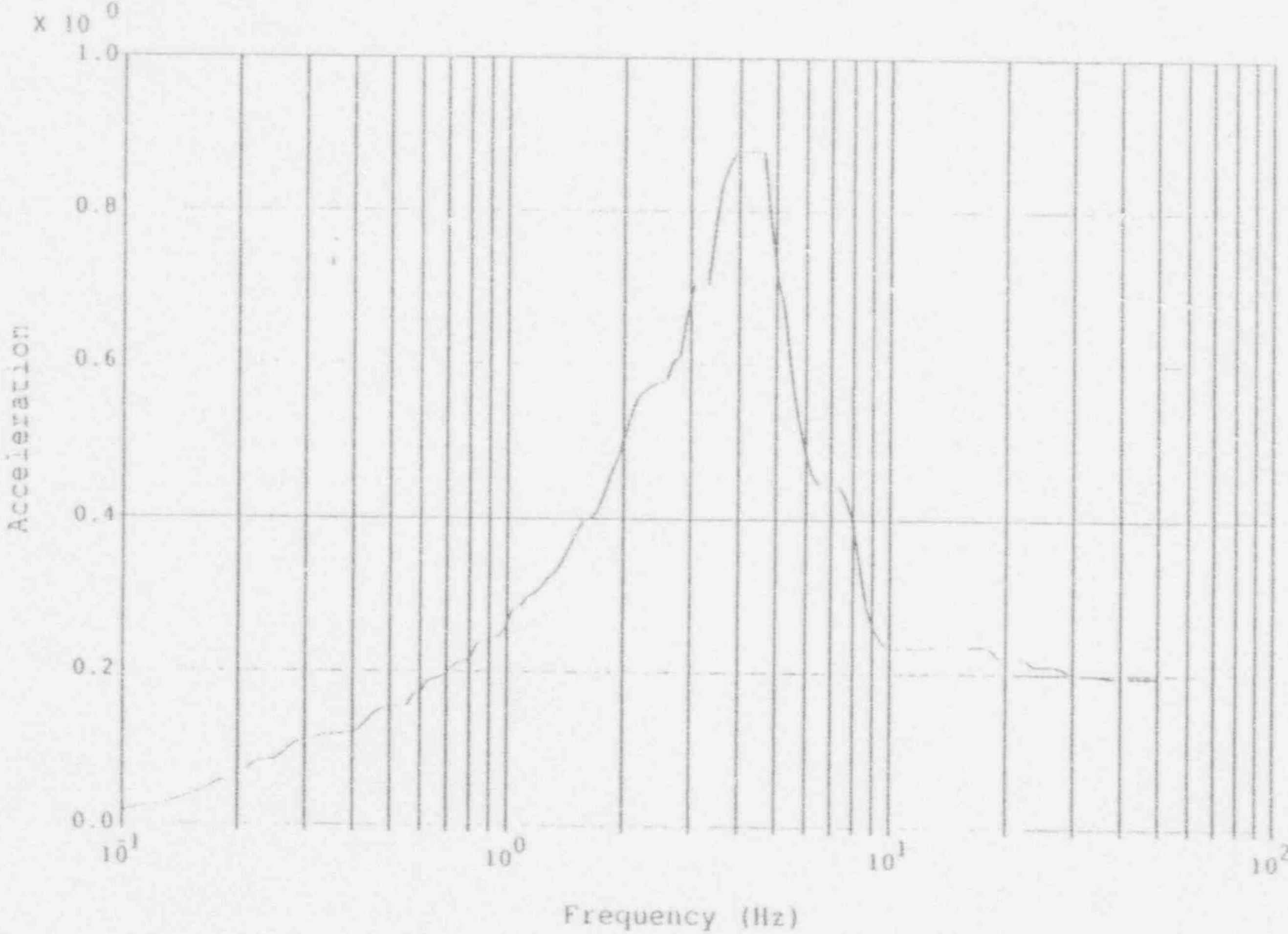
Notes:

N-411 Damped Spectrum

Accelerations in g's

1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 55.18', Translation in the NS Direction



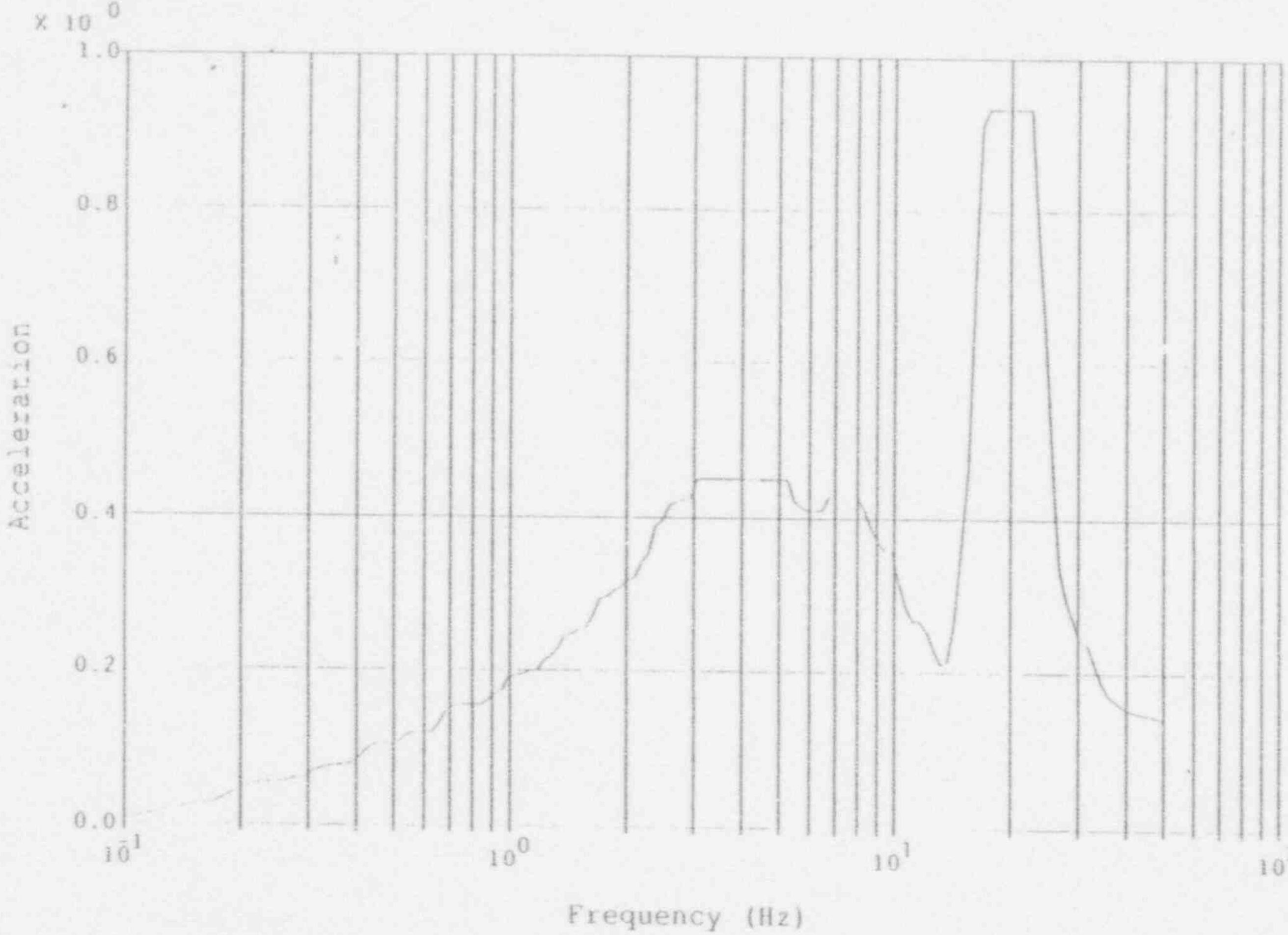
Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 55.18', Translation in the EW Direction

RSPLT SUN V1.2 ve032y.plt 15:05:59 05/21/93

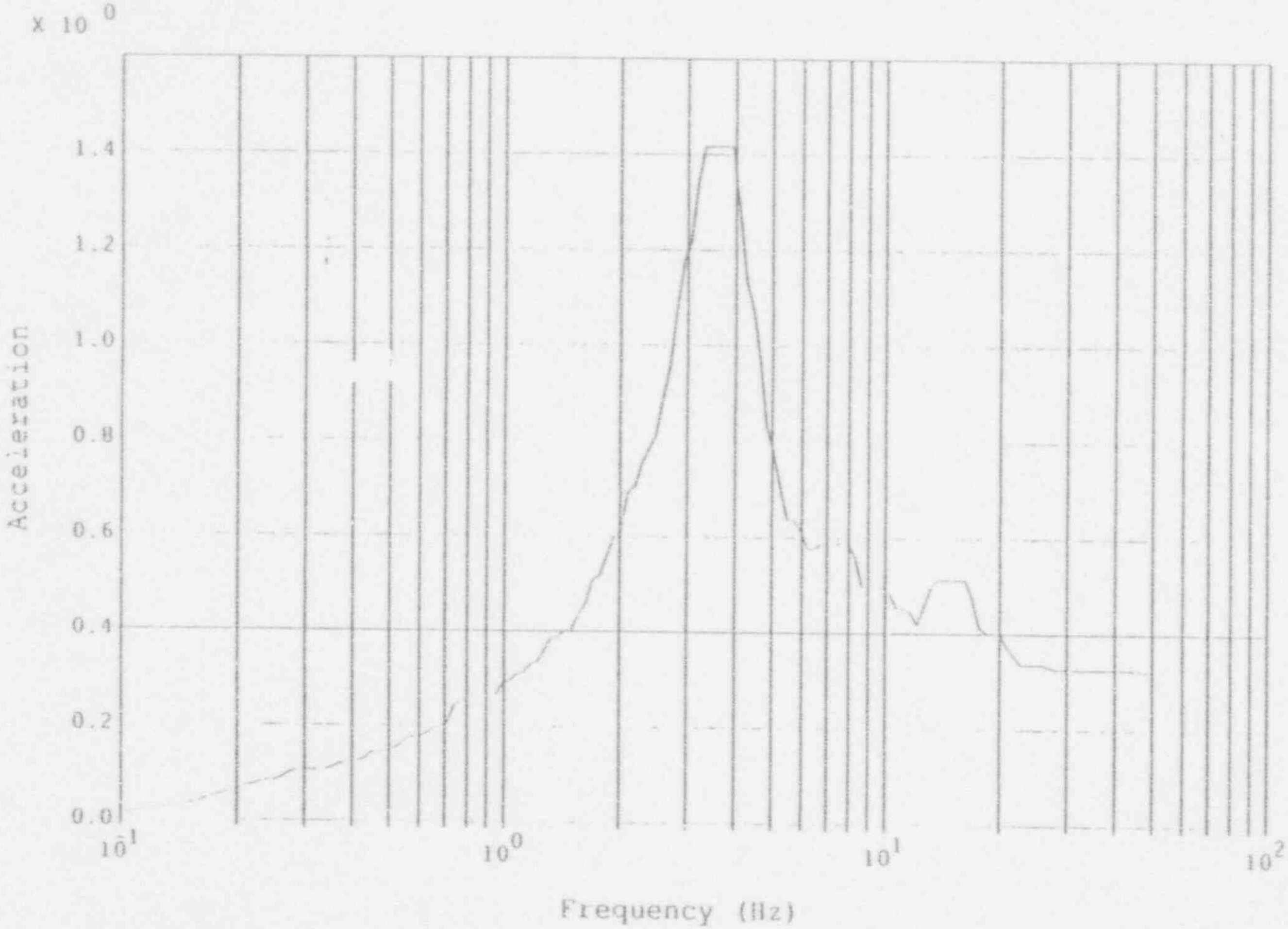
RSPLT SUN V1.2 ve032z.plt 15:06:01 05/21/93



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

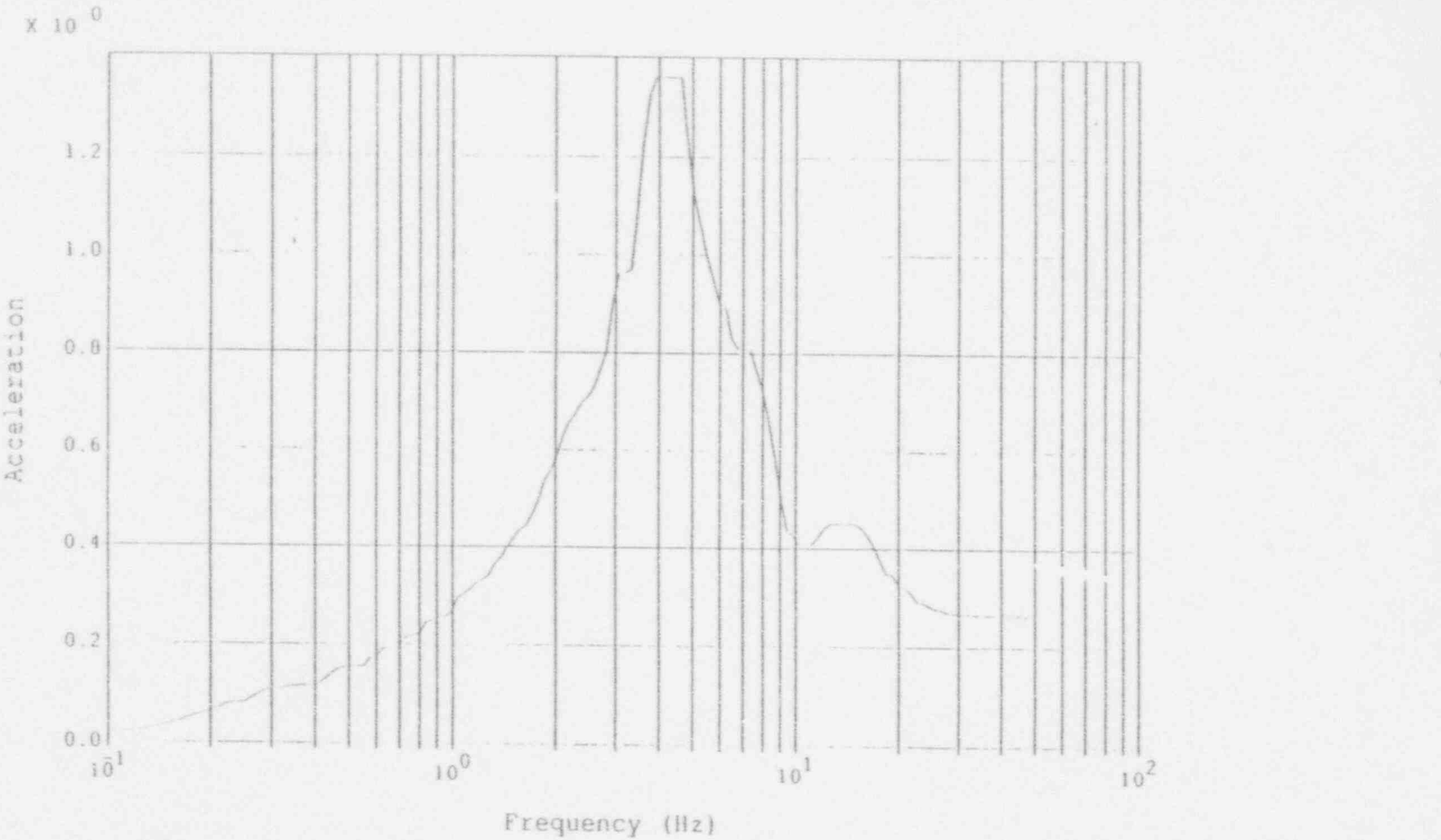
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 55.18', Translation in the Vertical Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

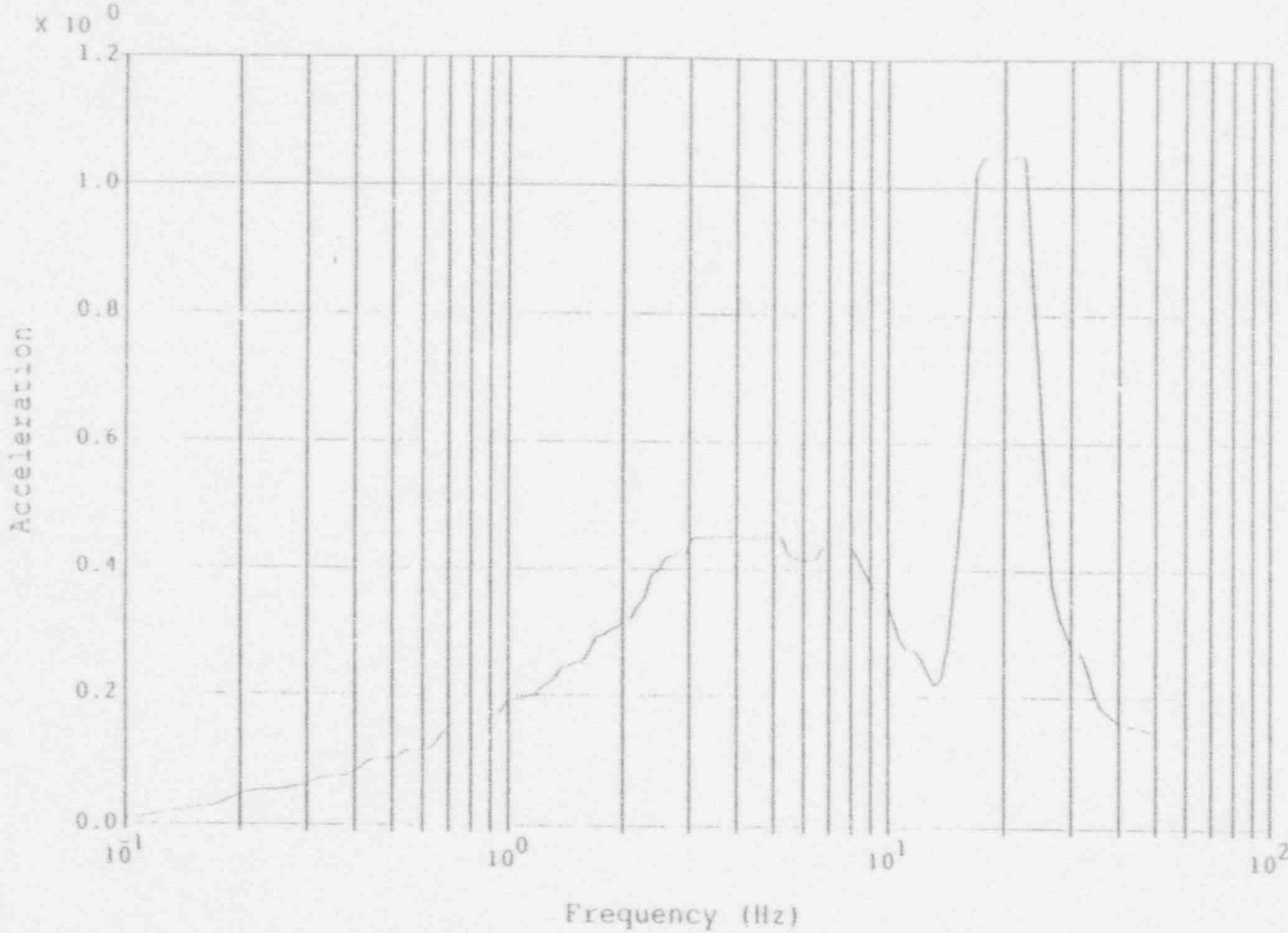
BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 86.75', Translation in the NS Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.15g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 86.75', Translation in the EW Direction



Notes:

N-411 Damped Spectrum
Accelerations in g's
1 SSE Level = 0.10g

BECO: Pilgrim Reactor Building, RG 1.60 SSE
Reactor Vessel, El. 86.75', Translation in the Vertical Direction

ATTACHMENT B

RESUMES OF PROJECT PERSONNEL

PAUL D. BAUGHMAN

PROFESSIONAL HISTORY

EQE International, Stratham, New Hampshire, Regional Manager, 1987-present
Cygna Energy Services, Boston, Massachusetts, Vice President, 1980-1987
Yankee Atomic Electric Company, Westboro, Massachusetts, Senior Structural Engineer, 1976-1980
Stone & Webster Engineering Corp., Boston, Massachusetts, Mechanical/Structural Engineer, 1969-1976

SUMMARY

Mr. Baughman has over 22 years of professional engineering and project management experience in the power and industry fields. He has held a wide variety of positions encompassing structural and mechanical design, safety and risk evaluations, and nuclear licensing.

PROFESSIONAL EXPERIENCE

Mr. Baughman manages structural engineering and evaluation programs, safety and reliability assessments, earthquake verification programs, and risk evaluations. He is currently assigned as Project Manager for the IPEEE/USI A-46 projects at Indian Point 2, Three Mile Island, and Oyster Creek Plants.

Project assignments have included acting as Projects Manager for the D.C. Cook Small Bore Piping Conf..mation Program, the Salem II/I Interaction Program, the Virginia Power STERI Procedures Project, the Indian Point 2 Control Room Seismic Verification Baseline Project, the Tokamak Fusion Test Reactor Tritium Handling Systems Review, and the Darlington Station II/I Piping Review.

He has performed mechanical equipment seismic evaluations for Boston Edison, Maine Yankee, Public Service of New Hampshire, Consolidated Edison, Gulf States Utilities, Rochester Gas and Electric, Southern Electric International, Virginia Power, Ontario Hydro, Public Service Electric and Gas, and GPU Nuclear; electrical equipment evaluations for Vermont Yankee, Boston Edison, Maine Yankee, GPU Nuclear, Philadelphia Electric, Virginia Power, Rochester Gas and Electric, and Consolidated Edison; and piping evaluations for Vermont Yankee, Tennessee Valley Authority, Ontario Hydro, Princeton Plasma Physics Laboratory, Westinghouse Savannah River, Rochester Gas and Electric, Public Service Electric and Gas, Puerto Rico Electric Power Authority, American Electric Power, Northeast Utilities, and Mesquite Lake Resource Recovery Center.

He has performed seismic verifications of cable tray, conduit, instrument tubing, and ductwork for Princeton Plasma Physics Laboratory, Tennessee Valley Authority, Public Service of New Hampshire, Consolidated Edison, GPU Nuclear, and Rochester Gas and Electric.

He has prepared procedures for seismic technical evaluation of replacement items (STERI) for Maine Yankee, GPU Nuclear and Virginia Power, and presented training in STERI and Equipment Verification at Virginia Power, GPU Nuclear and Rochester Gas and Electric.

He has carried out numerous structural engineering and design activities for nuclear power plants, fossil power plants, cogen facilities and commercial projects. Clients have included City of Boston, Hanscomb Air Force Base, Quincy City Hospital, Brocton Veterans Administration Medical Center, Boston Edison, Consolidated Edison, Northeast Utilities and Puerto Rico Electric Power Authority.

EQE

PROFESSIONAL EXPERIENCE (Continued)

At Cygna Energy Services, Mr. Baughman managed structural and mechanical activities for the eastern United States. He directed technical activities at more than 30 nuclear plants, including seismic evaluations of critical structures, piping, and equipment. Assignments included failure modes and effects analysis (FMEA) for high energy piping at Seabrook Station, probabilistic risk evaluations of the reactor containment at Seabrook Station, and FMEA of spent fuel cask handling systems at Yankee Rowe. He also provided licensing consultation services related to structural and mechanical issues for Yankee Rowe, Vermont Yankee, Maine Yankee, Pilgrim, Millstone Units 1 and 2, Seabrook, Three Mile Island Unit 1, Davis-Besse, and R. E. Ginna.

While at Yankee Atomic, Mr. Baughman was responsible for many structural and mechanical issues, including seismic upgrade of structures and equipment, spent fuel pool modifications at Yankee Rowe, and spent fuel storage expansions at Vermont Yankee, Pilgrim, and Maine Yankee. Spent fuel pool modifications at Yankee Rowe required FMEA of the 75-ton overhead crane and evaluation of smaller cranes used during construction or operation. Spent fuel storage expansions required FMEA of the spent fuel storage pools, fuel handling systems, and movement of heavy loads near stored fuel. Mr. Baughman also performed a structural safety evaluation of the polar crane in the reactor containment at Maine Yankee. He was a member of the Nuclear Safety Audit and Review Committee for Maine Yankee.

With Stone & Webster, Mr. Baughman carried out a variety of design assignments on nuclear plants under construction in the Mechanical Analysis and Structural Mechanics groups, including containment design, building seismic analysis, generation of floor response spectra, and equipment seismic qualification.

EDUCATION

NORTHEASTERN UNIVERSITY: M.B.A., 1984
NORTHEASTERN UNIVERSITY: M.S. Civil Engineering, 1978
NORTHEASTERN UNIVERSITY: B.S. Civil Engineering, 1972

AFFILIATIONS

American Society of Civil Engineers
American Concrete Institute
American Society of Mechanical Engineers

REGISTRATION

Structural Engineer: Massachusetts
Structural Engineer: New Hampshire
Civil Engineer: New Hampshire

SELECTED PUBLICATIONS

"Level 1 Seismic Technical Evaluation of Commercial Grade Replacement Items, Surry Power Station, North Anna Power Station." July 1991. Prepared for Virginia Power.

"Level 2 Seismic Technical Evaluation of Commercial Grade Replacement Items, Surry Power Station, North Anna Power Station." July 1991. Prepared for Virginia Power.

"Planning Report, Comparison of Methods for Responding to Seismic IPEEE for Pilgrim Nuclear Power Station." December 1990. Prepared for Boston Edison Company.

SELECTED PUBLICATIONS (Continued)

"Experience Data Methodology for Seismic evaluation of Alternative Commercial Grade Replacement Items (Level 1) for Oyster Creek and TMI Unit 1." June 1990. Prepared for GPU Nuclear.

"Management Report, Scoping Review for Resolution of Unresolved Safety Issue A-46, R.E. Ginna Nuclear Power Station." January 1990. Prepared for Rochester Gas and Electric Corporation.

With M. Aggarwal. 1989. "Seismic Evaluation of Piping Using Experience Data." ASME Pressure Vessels and Piping Conference, July 1989.

"Seismic Verification of Control Room Design Changes for Indian Point Unit 2." June 1989. Prepared for Consolidated Edison Company.

With H. Johnson, G. Hardy, and N. Horstman. 1989. "Use of Seismic Experience Data for Replacement and New Equipment." Second Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment, and Piping with Emphasis on Resolution of Seismic Issues in Low-seismicity Regions, May 1989.

With M. Aggarwal, S. Harris, and R. Campbell. 1989. "Seismic Evaluation of Piping Using Experience Data." Second Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment, and Piping with Emphasis on Resolution of Seismic Issues in Low-seismicity Regions, May 1989.

"Procedure for Seismic II/I Interaction Hazards Evaluation for Pilgrim Nuclear Power Station." January 1989. Prepared for Boston Edison Company.

"Seismic Evaluation of Tritium Handling System, Tokamak Fusion Test Reactor, Princeton Plasma Physics Laboratory." December 1988. Prepared for Burns and Roe.

"Generic Criteria for Seismic Evaluation of Piping at Darlington Nuclear Generating Station." March 1988. Prepared for Ontario Hydro.

"Seismic Evaluation of Non-safety Piping at Darlington Nuclear Generating Station Using Earthquake Experience Data." December 1987. Presented to the Atomic Energy Control Board of Canada.

"Procedure for Overview Walkdown for Seismic Interaction Hazards, Salem Nuclear Generating Station." November 1987. Prepared for Public Service Electric and Gas.

JAMES L. WHITE

PROFESSIONAL HISTORY

EQE International, Stratham, New Hampshire, Senior Consultant, 1987-present
Cygna Energy Services, Boston, Massachusetts, Project Manager, 1980-1987
Bechtel Power Corporation, Plymouth, Massachusetts, Senior Construction Engineer, 1977-1980
Stone & Webster Engineering Corporation, Boston, Massachusetts, Structural Engineer, 1970-1977

PROFESSIONAL EXPERIENCE

Mr. White has over 20 years experience in structural engineering and construction for existing and under-construction nuclear power plants. His responsibilities have included development of design criteria, specifications, and drawings for power plant buildings and specialized structures such as circulating water tunnels and power piping systems.

At EQE, Mr. White has acted as project manager and seismic review team member on numerous seismic evaluation projects using the EQE seismic experience data base, and the SQUG Generic Implementation Procedure (GIP). He is currently Task Leader for USI A-46 at Three Mile Island and Oyster Creek. He has completed the SQUG training for Seismic Capability Engineers. Mr. White has performed seismic qualifications of Regulatory Guide 1.97 equipment, piping, valves, control panels, and miscellaneous equipment for Boston Edison's Pilgrim Nuclear Power Plant. Mr. White acted as seismic review team member at the Savannah River Plant, performing seismic reviews of relays, raceways, control panels, tubing, valves, and various equipment in the K, L, and P reactors. In addition, he has analyzed the seismic adequacy of cranes at EDF nuclear power plant through comparison with cranes in the EQE seismic experience data base. He has also utilized the data base in analyzing the seismic adequacy and hazard potential of equipment at the Salem Nuclear Power plant. This work involved site inspection and evaluation with safety-related equipment as targets and nonsafety-related piping as sources.

Mr. White has also extensive piping experience and was Project Manager and Project Engineer on several piping and pipe support analysis and modification projects. Specific projects are described as follows:

- Performed field review of Salem Unit 2 small bore piping in containment for seismic II/I and pressure integrity using deflection screening.
- Participating in data gathering walkdowns of data base sites for tubing, piping, and piping fittings.
- Performed field walkdowns and review of piping and pipe supports for seismic II/I at Browns Ferry. Mr. White was Project Engineer in charge of piping penetration walkdowns to estimate piping movement for Browns Ferry Unit 2.
- Project Engineer for the seismic qualification of diesel air start system piping at Ginna Nuclear Power Station. Evaluated piping using seismic experience data and conventional techniques.
- BECo Pilgrim reactor water level piping modification.
- J. A. Fitzpatrick environmental enclosure chilled water piping project.

EQE

PROFESSIONAL EXPERIENCE (Continued)

In previous assignments, Mr. White implemented various design changes for the Pilgrim Nuclear Power Station. Projects for which he was responsible include H.P. checkpoint reconfiguration, seismic building separation, and reactor water level (RWL) modification. On the RWL project he was responsible for engineering interface for core drilling of two holes through the primary containment to install new ASME instrumentation penetrations. His responsibilities also included engineering interface for installation of ASME Class I piping and pipe supports, modification of reactor water level instrumentation, and cutting and replacement of Reactor Pressure vessel nozzles. This assignment was a continuation of work that he performed at Cygna as a lead structural engineer preparing the design change package for the RWL modification.

Mr. White served as Project Manager and Project Engineer for analysis and modification of many nuclear plants, including the J. A. Fitzpatrick, Salem, Maine Yankee, Vermont Yankee, Pilgrim, and Millstone Unit I stations. Several important projects for which he held primary responsibility, including supervision of staffs of multi-disciplined engineers and designers, are described below.

- o Engineering and designing environmental enclosures for Class 1E electrical equipment. This project included pipe stress analysis, piping layout and design, structural design of steel-frame enclosure structures, and specification and qualification of HVAC equipment in accordance with IEEE 344.

- o Assessing management and work practices for piping, pipe support, and as-built documentation for the Public Service Electric and Gas Company.

- o Analyzing safety related pipe support baseplates for Maine Yankee in response to NRC Bulletin 79-02. Designing modifications for baseplates that failed analytical criteria.

- o Designing on-site structural, HVAC, electrical, and piping modifications at Millstone Unit 1 in relation to 79-01B.

- o Analyzing and designing piping and pipe supports for Vermont Yankee to resolve NRC Bulletins 79-02 and 79-14.

While with Bechtel, Mr. White implemented plant modifications for Boston Edison's Construction Management Group, a position that required supervision of approximately 16 engineers. In previous assignments for Boston Edison he managed completion of a security building, access roads, and parking lot modifications. Prior to this period, as a structural engineer for Stone and Webster, Mr. White engineered major plant structures and foundations and prepared design criteria, cost estimates, calculations, specifications, drawings, and reports. He was also responsible for evaluating, awarding, and administrating various procurement and construction contracts as well as resolving construction problems.

Additional projects in which Mr. White was involved include the following:

- o ***Project Manager:*** *Seismic review and evaluation of piping, pipe supports, equipment, and structures for maintaining integrity of main steam system at Iowa Electric power plant. Evaluated steel-frame structures and subcomponents for seismic capacity.*

- o ***Structural Engineer.*** Participated in the design review of tritium piping and related equipment at the Princeton Plasma Physics Laboratory in New Jersey. Performed seismic review and evaluated structural and mechanical components.

- o ***Structural Engineer.*** Participated in seismic qualification and anchorage evaluation of motor generator sets, control panels, battery chargers, and miscellaneous electrical equipment for Consolidated Edison's Indian Point Power Plant.

PROFESSIONAL EXPERIENCE (Continued)

- *Project Manager*: Structural evaluation for second-story addition to a 20,000-square-foot vocational school bldg. Reviewed existing building components and design of foundations, and structural/steel concrete slabs.

- *Structural Engineer*: In charge of structural engineering services for renovation of Hanscomb Air Force Base's officer's club building. Responsible for structural design, construction specifications, and installation drawings for building and HVAC renovations.

- *Structural Engineer*: Responsible for evaluation and review of retrofit work for the Massachusetts College of Art. Review included structural assessment of a six-story reinforced concrete-frame building with concrete masonry partition walls. Renovation work was performed to incorporate classroom use changes.

- *Project Manager*: Seismic evaluation and upgrade of HVAC system for Boston Edison's Pilgrim Nuclear Power Plant. Project included evaluating and modifying seismic loadings. Equipment included large centrifugal fans, motor control centers, dampers, control panels, plenum structures, electrical raceways, and other mechanical and electrical equipment.

- *Project Engineer*: Seismic evaluation of service water piping, pipe supports, and equipment for the Vermont Yankee Nuclear Power Plant. Project included seismic review of large steel-frame power plant structures to ensure structural integrity.

- *Project Manager*: Seismic evaluations of diesel generator building fire protection piping for Boston Edison's Pilgrim Nuclear Power Plant. Seismic review/modification of sprinkler & deluge fire protection systems.

- *Structural Engineer*: In charge of design of new diesel generator building for Boston City Hall. Project included structural design, drawing preparation, cost estimates, and preparation of construction specifications. Interior building renovations were also performed as part of this project.

- *Project Manager*: Structural design of modifications to the BioEnergy wood-burning power plant. Projects included design of catalytic converter stack and ductwork modifications, and building floor strengthening for addition of water treatment tank and clean-up system. Projects included structural design, specification, and drawing preparation.

- *Project Engineer*: Responsible for seismic review and design modifications for control room electrical cabinets and panels for the Consolidated Edison Indian Point Power Plant.

- *Project Manager*: Seismic qualification of skid-mounted 12-cylinder diesel generators for SEI/PEICO. Seismic analysis and review of diesel generator anchorage and installation at five different power facilities.

- *Structural Engineer*: Responsible for structural evaluation of 500 MW power plant structure for Boston Edison's balanced draft stack conversion project. Structural analysis of ten-story structural steel boiler support structure for wind, seismic, and operating loading conditions.

- *Structural Engineer:* Investigation of structural cracking and deterioration of swimming pool/gymnasium building at the Brackton Veterans Administration Hospital. Design and review of structural renovations and repair work including construction drawings and specifications.

PROFESSIONAL EXPERIENCE (Continued)

o *Project Engineer:* Seismic evaluation of bridge cranes and structures for Electricity de France power plants. Project required site inspection and seismic evaluation of various bridge cranes and crane structures.

o *Structural Engineer:* Responsible for due diligence review of several commercial buildings for a King of Prussia, Pennsylvania, realty company. Project included the structural review of large warehouse type buildings for commercial office space.

EDUCATION

TUFTS UNIVERSITY, Medford, Massachusetts: B.S. Civil Engineering, 1970

REGISTRATION

Professional Engineer: Massachusetts
Professional Engineer: Maine
Civil Engineer: Vermont

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GORDON S. BJORKMAN, JR.

PROFESSIONAL HISTORY

EQE International, EQE Engineering Consultants Division, Stratham, New Hampshire,
Senior Technical Manager, 1991-present
ABB Impell Corporation, Technical Manager, 1986-1991
Cygna Energy Services, Senior Consultant, 1981-1986
United Engineers and Constructors, Consultant, 1978-1981
Drexel University, Assistant Professor of Civil Engineering, 1975-1978, and
Adjunct Associate Professor, 1978-1981.
University of Delaware, Visiting Assistant Professor, 1974-1975
Stone & Webster Engineering Corporation, Design Engineer, 1969-1970

PROFESSIONAL EXPERIENCE

Dr. Bjorkman is Senior Technical Manager of EQE's Engineering Consultant's Division and has over 24 years of combined experience in nuclear power plant evaluation, university teaching, and government research. More than 16 of those years have been spent in the analysis and design of nuclear power plant structures, piping, and components. He is expert in the areas of structural dynamics, seismic qualification, finite element analysis, structural behavior, and reinforced and prestressed concrete design.

Dr. Bjorkman has provided expert testimony before the Atomic Safety and Licensing Board on finite element modeling and dynamic analysis of civil structures, piping systems and raceways and has made numerous presentations to utility management and the NRC staff. In addition, he has twice been a Principal Research Investigator for the National Science Foundation working on inverse problems in mechanics and stress concentration minimization. This research lead to the discovery of Harmonic Shapes, which are a class of hole and inclusion geometrys that are invisible to La Placian fields.

Dr. Bjorkman is currently involved in several projects. These include:

- Independent review of a design basis analysis for a Fuel Storage Facility.
- Development and implementation of a 42 hour training program on Seismic Equipment Qualification.
- Operability Evaluation of a spent fuel pool.
- Development of a Reactor Building dynamic model and generation of design floor response spectra using state-of-the-art soil-structure interaction methods.
- Independent review of the structural aspects of replacing steam generators through the primary containment dome.

Recently, Dr. Bjorkman completed teaching a 28 hour training course on Structural Dynamics and Seismic Analysis for Rochester Gas and Electric's Civil/Structural, Mechanical, and Site Support Staff. The course stressed the fundamental simplicity of structural dynamics, its link to the finite element method, and its relationship to the overall seismic analysis process, as applied to nuclear power plant facilities. In the area of piping, topics such as mass point spacing and missing mass were discussed and illustrated in detail. Issues related to A-46, such as anchorage flexible and in-cabinet amplification, were discussed and demonstrated using EQE's direct generation software, EQE FSG, the ANSYS program, and the response spectra database management program, SpectraDb.

PROFESSIONAL EXPERIENCE (Continued)

For Carolina Power & Light, Dr. Bjorkman performed an evaluation of prestress losses in the large girders which support the spent fuel pool. He also determined the root cause of cracks in the bottom of the spent fuel pool slab which had puzzled CP&L and its consultants for a number of years.

At ABB Impell, Dr. Bjorkman was Technical Manager for the Engineering Mechanics Division. He was Project Engineer for the resolution of Generic Letter 87-02/Unresolved Safety Issue A-46 at Northeast Utilities' Connecticut Yankee, and Millstone Units 1 and 2 stations.

For Rochester Gas and Electric's Ginna Station, Dr. Bjorkman developed a strategy to address NRC concerns regarding the behavior and integrity of the neoprene joint detail between the vertically prestressed containment shell and basemat. Using an axisymmetric ANSYS model, which extended from below the prestressed rock anchors to the containment dome, and a 180° containment shell model, Dr. Bjorkman investigated numerous limiting boundary conditions including slip between the various concrete/rock interfaces and failure of radial tension ties. In addition, dynamic analysis using the shell model substantiated the original seismic design basis for the containment. Dr. Bjorkman's presentation before the NRC staff and subsequent discussions resolved the NRC's concerns and allowed RG&E to obtain a three year extension to their operating license.

At GPU Nuclear's Oyster Creek Plant, cracks in the concrete girders supporting the spent fuel pool (SFP) prompted safety concerns for the storage of high density racks. To address the safety concerns, Dr. Bjorkman developed a nonlinear analysis strategy to account for the redistribution of internal forces caused by concrete cracking due to mechanical and thermal loads. To implement the nonlinear strategy and to account for force redistribution within the entire reactor building structure, a large ANSYS model, consisting primarily of solid elements, was created. The results showed that the location and orientation of existing cracks in the girders, SFP walls, reactor shield wall, and operating floor slab were predicted by the analysis, and that the high density rack loads were within the load carrying capacity envelop of the SFP and its supporting members.

Prior to these projects, Dr. Bjorkman was Project Consultant to the Three Mile Island 1 Skewed Pipe Clamp Evaluation Project. He developed project instructions and special criteria for the nonlinear (gaps and friction) analysis of pipe clamps, as well as an evaluation methodology for pipe wall stresses when lug-induced stresses exceed Code Case N-318 values. This project was highly successful and resulted in no modifications to any of the 56 clamps involved.

In support of the Nine Mile Point Unit 1 (NMP1) restart effort, Dr. Bjorkman performed a structural integrity investigation to determine the significance of 1,400 pipe support deficiencies found during the ISI Program. In addition, he performed an extensive technical quality review for the NMP1 static and dynamic finite element building models, which ranged in size from 2,000 to 60,000 degrees-of-freedom and which will be used during NMP1's Design Basis Reconstitution Program.

For Rochester Gas & Electric, Dr. Bjorkman developed an innovative methodology to inexpensively analyze, evaluate, and qualify the major braced column line between the turbine and intermediate buildings, which other consultants' evaluations (NUREG-1821) had reported to be significantly overstressed under safe shutdown earthquake loads. Dr. Bjorkman's final report was submitted directly to the NRC by Rochester Gas & Electric and resolved the seismic safety issue.

Based on the success of Dr. Bjorkman's 1981 training program on piping system analysis, Virginia Power's Civil Structures Group asked him to return in 1987 to deliver a 40-hour training program on structural dynamics. Complete example problems of actual Virginia Power buildings were developed on the STARDYNE computer program and were used to demonstrate the finite element modeling of structures for dynamic applications.

PROFESSIONAL EXPERIENCE (Continued)

Prior to joining Impell, Dr. Bjorkman was the Senior Consultant for the Engineering Mechanics Division at Cygna Energy Services. In this capacity, he was responsible for providing corporate-wide technical guidance and directing special projects.

While at Cygna, Dr. Bjorkman served for three years as a member of the Senior Review Team for the Comanche Peak Steam Electric Station Independent Assessment Program. In this capacity, he provided expert witness testimony at the hearings before the Atomic Safety and Licensing Board of the NRC on all technical issues involving finite element, structural dynamics, piping, pipe supports, and cable trays.

In a previous assignment, Dr. Bjorkman functioned as the Project Engineer on the Rochester Gas & Electric Corporation project related to NUREG-0612 for the Ginna Station. On this project, Dr. Bjorkman directed the analytical efforts, which evaluated the structural safety consequences of postulated load drop accidents from plant cranes. The work involved finite element modeling and elastoplastic time history impact analysis (using ANSYS) for an accidental drop of the reactor pressure vessel (RPV) head and upper reactor internals onto the RPV. Additionally, numerous smaller load drops onto concrete floor systems were postulated and evaluated. Dr. Bjorkman developed special-purpose software for these analyses and supervised the project staff in the evaluations.

As a Consultant for both Maine Yankee and Vermont Yankee piping and pipe support reanalysis projects, Dr. Bjorkman was responsible for reviewing technical criteria and developing modeling techniques for piping systems and baseplates.

Previously, Dr. Bjorkman was the Director of a 10-week piping system analysis and design training program for Virginia Power's newly formed Engineering Mechanics Group. He was responsible for structuring and reviewing all lecture and workshop materials, and taught the two-week modules on dynamic analysis and the use of the STARDYNE computer program.

Prior to joining Cygna, Dr. Bjorkman worked at United Engineers and Constructors, where he managed the vent system analysis and design of modifications for a Mark I nuclear power plant. He supervised personnel in the proper development and use of large finite element shell and beam models, which incorporated numerous superelements in both static and dynamic analyses. He also developed computer programs to evaluate fatigue damage at highly stressed intersections. In addition, Dr. Bjorkman completed a stability and stress analysis of a discontinuously stiffened containment shell liner, and acted as a Consultant to the Seabrook project on matters concerning liner stability during construction.

As a facility member of Drexel University and the University of Delaware, Dr. Bjorkman taught graduate and undergraduate courses in experimented mechanics, advanced structural analysis, solid mechanics, finite element analysis, and prestressed and reinforced concrete design. During this period, Dr. Bjorkman was twice Principal Research Investigator for the National Science Foundation working on Problems in inverse elasticity and stress concentration minimization.

Prior to earning his Ph. D., Dr Bjorkman worked as a Design Engineer for Stone & Webster Engineering Corporation, where he performed the finite element analysis and complete reinforced concrete design of the turbine building mat foundation and retaining walls for the Beaver Valley Nuclear Power Plant. He also developed an analysis procedure and performed the initial finite element analysis of the reinforced concrete containment shell and suppression chamber for Bell Station and Brunswick nuclear power plants while with Jackson and Moreland (DE&C). Dr. Bjorkman has been a Consultant to a number of corporations including the Boeing Vertol Company, for whom he developed and taught a 40-hour lecture series on the finite element method.

EDUCATION

UNIVERSITY OF DELAWARE: Ph.D. Applied Mechanics
CORNELL UNIVERSITY: M.S. Structural Engineering
PRINCETON UNIVERSITY: B.S. Civil Engineering

REGISTRATIONS

Pennsylvania: Professional Engineer

AFFILIATIONS

American Society of Civil Engineers (ASCE)
ASCE Committee on Structural Computations
ASCE Technical Committee on Optimal Structural Design
Reviewer, American Society of Mechanical Engineers Journal of Applied Mechanics
Sigma Xi

JOURNAL AND CONFERENCE PUBLICATIONS

With R. Richards. 1993. "Harmonic Inclusions: Elastic Inclusions of Uniform Strength." To be published in *Journal of Applied Mechanics*.

"Benchmark Problems for Plane Stress Shape Optimization." *Proceedings of the ASCE Tenth Conference on Electric Computation*. Indianapolis, IN., April 1991.

"On The Behavior and Qualification of Pipe Clamps Used in Nonstandard Applications." *Proceedings of the ASME Pressure Vessel and Piping Conference*. San Diego, CA., June 1991.

With R. Richards. August 1984. "Optimum Shape and Pressure Vessel Attachments." In *Proceedings of the 5th ASCE Engineering Mechanics Division Specialty Conference*. Laramie, WY: University of Wyoming.

With R. Richards. May 1983. "On the Derivation of Harmonic and Neutral Holes Using Complex Variable Methods." In *Proceedings of the 4th ASCE Engineering Mechanics Division Specialty Conference*. West Lafayette, ID: Purdue University.

With R. Richards. October 1982. "Neutral Holes: Theory and Design." In *Journal of the Engineering Mechanics Division*. Vol. 108: 945-960. American Society of Civil Engineers.

With R. Richards. December 1980. "Harmonic Shapes and Optimum Design." In *Journal of the Engineering Mechanics Division*. Vol. 106, No. EM6: 1125-1134. American Society of Civil Engineers.

With R. Richards. May 1979. "Inverse Elasticity for Harmonic Shapes." In *Proceedings of the 7th Canadian Congress of Applied Mechanics*. Sherbrooke.

With R. Richards. September 17-19, 1979. In *Proceedings of the 3rd ASCE Engineering Mechanics Division Specialty Conference*. Austin, TX.

With R. Richards. September 1979. "Harmonic Holes for Non-constant Field." In *Journal of Applied Mechanics*. ASME No. 78-APM-30. Vol. 46, No. 3: 573-576.

JOURNAL AND CONFERENCE PUBLICATIONS (Continued)

With R. Richards. 1978. "Optimum Shapes for Unlined Tunnels and Cavities." In *Engineering Geology*. Vol. 12: 171-179. Amsterdam, The Netherlands.

With R. Richards. 1976. "Optimum Shapes for Tunnels and Cavities." In *Proceedings of the 17th United States Symposium on Rock Mechanics*: 5A7-1 - 5A7-6. Salt Lake City, UT: University of Utah.

With R. Richards. November 1976. "Harmonic Holes: An Inverse Problem in Elasticity." In *Journal of Applied Mechanics*. Vol. 43, Series E, No. 3: 414-418. American Society of Mechanical Engineers.

ALEJANDRO P. ASFURA

PROFESSIONAL HISTORY

EQE International, San Francisco, California, Associate and Technical Manager, 1990-present
Impell Corporation, San Ramon, California, Senior Technical Specialist, 1984-1990
PMB Systems Engineering, San Francisco, California, Lead Engineer, 1983-1984
University of California, Berkeley, California, Research Assistant, 1980-1984
Consultant, Santiago, Chile, 1975-1980
Institute of Engineering, Mexico City, Mexico, Research Assistant, 1973-1975
University F. Santa Maria, Valparaiso, Chile, Associate Professor, 1972-1973

SUMMARY

Dr. Asfura, Technical Manager for EQE's Engineering Consultants Division, has 20 years of combined practice in industry and in the academic world. He possesses a wide range of practical, research, and teaching experience in structural engineering, earthquake engineering, dynamic analysis, and structural mechanics.

Practical experience includes analysis and design of major steel and concrete structures for industrial and mining plants; analysis and design of highway bridges, residential concrete buildings, and offshore structures; analysis of nuclear power plants and equipment; and development of several computer programs for application in structural and offshore engineering.

Dr. Asfura has expertise in the areas of earthquake engineering and dynamic analysis, random vibration techniques, and direct generation of in-structure response spectra. His responsibilities at EQE includes project management, technical support for related projects, marketing, technical presentations, preparation of proposals, and licensing support.

Dr. Asfura's theoretical background and research experience in the areas of Earthquake Engineering, Structural Dynamics, Random Vibrations, Soil Dynamics, and Optimum Design have been achieved through advanced degrees from prestigious universities, individual research, and joint research with such renowned professors as Professor Emilio Rosenblueth at the Institute of Engineering in Mexico, and Professor Armen Der Kiureghian at the University of California, Berkeley.

PROFESSIONAL EXPERIENCE

Dr. Asfura's practical experience in the United States is described as follows:

From June 1990 to present, Dr. Asfura has been a Technical Manager for the Engineering Consultants Division at EQE International. Some of the projects on which he is or has been in charge are the following:

- o *Toledo Edison Company.* Project Manager for the generation of in-structure spectra for USI A-46 and seismic margins for Davis-Besse Nuclear Power Station. This project involves review/development of structural models and deterministic soil-structure interaction analysis.
- o *GPU Nuclear Corporation.* Project Manager for the generation of probabilistic median-centered and conservative in-structure spectra at all Class I buildings for resolution of IPEEE and USI A-46 at Three Mile Island. This project involves development of structural models and deterministic and probabilistic soil-structure interaction analysis.

PROFESSIONAL EXPERIENCE (Continued)

- *Northern State Power Company.* Project Manager for the soil-structure interaction analysis of the intake structure at Brunswick Steam Electric Plant for resolution of USI A-46. This project involves development of structural models and deterministic soil-structure interaction analysis.
- *Virginia Electric and Power Company.* Project Manager for the soil-structure interaction analysis of all Class I structures at Surry and North Anna Nuclear Power Plants. These analyses involve development of structural models and probabilistic and deterministic soil structure interaction analysis.
- *Northern State Power Company.* Project Engineer for the seismic analysis of all Class I buildings at the Monticello and Prairie Island Nuclear Power Plants. This project involves probabilistic and deterministic soil-structure interaction analyses for the generation of 50th percentile and A-46 floor acceleration response spectra.
- *GPU Nuclear Corporation.* Project Manager for the soil-structure interaction analysis of the Reactor Building at the Oyster Creek Nuclear Generating Station. The analyses are being performed to generate design floor acceleration response spectra according to the Nuclear Regulatory Commission's recommendations and to develop probabilistic response spectra for seismic PRA.
- *Carolina Power and Light Company.* In charge of the soil-structure interaction analyses of Class I buildings at the Robinson Nuclear Power Plant to generate 50th percentile floor acceleration response spectra for PRA and fragility studies. This project involved development of structural models and probabilistic and deterministic soil-structure interaction analysis.
- *Sydkraft/OKG Aktiebolag, Sweden.* Project Engineer for the development of median-centered response spectra and the probabilistic assessment of the capacity of the reactor/containment buildings at three nuclear power plants in Sweden. This program consists of the probabilistic dynamic analysis (considering SSI effects and structural and soil properties variability) of the structure to calculate the statistics of the floor response spectra and the structural stresses. Factor of safety and confidence level are estimated from the ultimate capacity of the structure and the statistics of the stresses.
- *Washington Public Power Supply System.* Project Manager for the generation and quality assurance verification of codes EQEFSG and EQEMPF for the direct generation of floor response spectra and the calculation of modal participation factors from modal test results, respectively.
- *Amoco.* In charge of the soil dynamic analysis for the generation of design site-specific response spectra and acceleration time histories at the Caspian Sea in Azerbaijan for two earthquake levels. These site-specific seismic excitations will be used for the design and ductility analyses of a fixed offshore platform.
- *California Department of Transportation (Caltrans).* Project engineer for the seismic analysis of the Carquinez Bridge in the San Francisco Bay Area. This project involves the structural modeling and analysis of two double cantilever through truss bridges construction circa 1927 and 1958. Soil-structure interaction, multiple support excitation, and nonlinear effect are included in the analyses.
- *SASSI QA Verification.* Project Manager for the modification, installation, and QA Verification of the computer code SASSI in the EQE computer environment.

PROFESSIONAL EXPERIENCE (Continued)

- *Sandia National Laboratory*. Project Engineer for the study to assess the effect of the degradation of the stiffness of shear walls on floor spectra and on fragility studies. This project involved probabilistic SSI analyses of several large soil-structure models for several seismic excitation levels.
- *Pacific Gas & Electric* (PG&E). Consultant for the direct generation of floor spectra at two PG&E buildings in San Francisco. In this project, modal participation factors were evaluated directly from an estimated set of mode shapes.
- *Superconducting Super Collider Laboratory*. Project Engineer for the seismic and transportation analysis of the finite element model of the magnets for the superconducting super collider system.

From February 1984 to May 1990, Dr. Asfura worked at Impell Corporation in the San Ramon, California, offices. Dr. Asfura's responsibilities at Impell Corporation included management of projects, technical support for all Impell's offices in the United States and Europe, marketing, technical presentations, preparation of proposals, and licensing support.

Some of the main projects on which he was in charge at Impell were:

- *Brookhaven National Laboratories*. Project Engineer for a Brookhaven National Laboratories Project for the post-test analytical prediction of the nonlinear dynamic response of a reactor coolant loop tested at the Tadotsu Engineering Laboratory at Japan.
- *Texas Utilities Electric Company*. Project Engineer for the Maintenance Mitigation Program for the Comanche Peak Nuclear Power Plant. This program consisted of developing the technical justification to substantiate the assertion that the non-safety-related electrical conduit Train C systems at the Comanche Peak Steam Electric Station would maintain their structural integrity during or after a Safe Shutdown Earthquake event. This project involved dynamic analyses of conduit lines and statistical analysis of previous experience.
- *Texas Utilities Electric Company*. Project Engineer for the Validation of Design Basis Floor Response Spectra Program for the Comanche Peak Nuclear Power Plant. In this Program, the design basis floor spectra at all Category I buildings at the Comanche Peak Steam Electric Station were validated by demonstrating their adequacy and assessing their conservatism. Soil-structure interaction and direct generation of floor response spectra methodologies were used to generate state-of-the-practice floor response spectra at all safety related buildings in the plant.
- *Texas Utilities Electric Company*. Project Engineer for the Secondary Walls Program for the Comanche Peak Nuclear Power Plant. This project consisted of the calculation of the maximum relative displacements between floor slabs and the top of disconnected secondary walls for Category I buildings at the Comanche Peak Steam Electric Station. This involved use of finite elements, soil-structure interaction, and direct generation of floor response spectra techniques.

PROFESSIONAL EXPERIENCE (Continued)

- *Southern California Edison.* Return to Service and Long-term Services Programs for the Southern California Edison's San Onofre Nuclear Generating Station, Unit 1. Dr. Asfura was involved in the generation of floor response spectra, nonlinear analyses of structural components and piping systems, special studies, and licensing efforts.

From September 1983 to January 1984, Dr. Asfura worked as a Lead Engineer at PMB Systems Engineering, San Francisco, California, in the analysis of the Sohio Arctic Mobile structure (SAMS). This was a conceptual design for a mobile exploration structure to be initially utilized in water depth of 40 to 60 feet in the Diapir Basin of Harrison Bay, Alaska

Some of the main engineering projects in which Dr. Asfura participated during his practice in Chile between 1975 and 1980 are listed as follows:

Industrial Plants

- *Chilean Copper Corporation (CODELCO).* Expansion of the Chuquicamata Smelting Plant, Chuquicamata Copper Mine
- *La Disputada de las Condes Mining Company.* Expansion of the Chagres Smelting Plant, La Disputada de las Condes Copper Mine
- *La Disputada de las Condes Mining Company.* Expansion of the San Francisco Concentration Plant, La Disputada de las Condes Copper Mine
- *Chilean Copper Corporation (CODELCO).* Technical quality review of the complete project for the expansion of the El Salvador Concentration Plant, El Salvador Copper Mine

All of the above projects included analysis and design of major concrete and steel underground, at grade, and elevated structures. Analysis and design of foundations for structures, equipment, and vibratory machinery. Analysis and design of chimneys, conveyors, storage tanks, and minor structures.

- *National Mining Corporation (ENAMI).* Analysis and design of steel chimneys for the Paipote Smelting Plant

Bridges

- *Secretary of Transportation.* Analysis and design of 39 highway bridges (lengths between 20 and 100 meters).

Offshore Structures

- *Empresa Nacional del Petroleo.* Development of computer code for the analysis of offshore structures including automatic generation of wave and current loads. Costa Afuera Project.
- *Empresa Nacional del Petroleo.* Analysis and design of a steel offshore jacket and another marine structure. Costa Afuera Project

Residential Buildings

- Analysis and design of 30,000 square meters of residential reinforced concrete buildings.

RESEARCH EXPERIENCE

During 1972 and 1973, Dr. Asfura worked as an Associate Professor at the department of Civil Engineering of the Federico Santa Maria University in Chile in the area of Dynamic Analysis.

From 1973 to 1975, he worked as a Research Assistant at the Institute of Engineering of the Autonomous University of Mexico in Mexico. He worked in the areas of Earthquake Engineering and Structural Optimization with Professor Emilio Rosenblueth and in Soil Dynamics with Professor Gustavo Ayala.

From 1981 to 1984, he worked as a Research Assistant at the Division of Structural Engineering and Structural Mechanics of the University of California, Berkeley. He worked in Finite Elements with Professor Robert L. Taylor and with Professor Armen Der Kiureghian in the area of Random Vibrations of Structures. Dr. Asfura's Doctoral Dissertation was performed under Professor Der Kiureghian's supervision. While at Berkeley, he developed the Cross-Cross Floor Spectrum method for the analysis of multi-supported system using the response spectrum approach.

Based on his research work, he had developed several computer codes for application in structural dynamics. Examples of these codes are a computer program for the generation of modal properties from in situ tests results, and a computer module to allow the direct generation of floor spectra considering soil-structure interaction.

EDUCATION

UNIVERSITY OF CALIFORNIA, Berkeley, California: Ph.D. Civil Engineering, 1984
AUTONOMOUS UNIVERSITY OF MEXICO, Mexico City, Mexico: M.S. Structural Engineering, 1975
UNIVERSITY OF CHILE, Santiago, Chile: B.S. Civil Engineering, 1972

REGISTRATION

Professional Engineer: California
Structural Engineer: Chile

AFFILIATIONS

American Society of Civil Engineers
Earthquake Engineering Research Institute
Co-spokesman of the Working Group on Multiple Input Floor Spectra Analysis of the Nuclear Structures and Materials Committee of the ASCE Dynamic Analysis Committee
Member of the Working Group on Generation of Floor Spectra of the Nuclear Structures and Materials Committee of the ASCE Dynamic Analysis Committee

PUBLICATIONS

"Soil-structure Interaction Observations, Data, and Correlative Analysis." In Proceedings of the NATO Advanced Study Institute on Development in Soil-structure Interaction, Antalya, Turkey, July 1992.

"A Simplified Analytical Method to Evaluate Pipe-To-Pipe Impact Loads." June 1992. ASME PVP Conference, New Orleans, Louisiana.

PROFESSIONAL EXPERIENCE (Continued)

"An Evaluation of Approximate Methods for Correcting Amplified Floor Response Spectra." May 1990. Fourth National Conference on Earthquake Engineering, Palm Springs.

"Methodologies for Rapid Evaluation of Seismic Demand Levels in Nuclear Power Plants Structures." December 1988. Second Symposium on Current Issues Related Nuclear Power Plant Structures, Orlando, Florida.

"Random Vibration Methods for the Seismic Qualification of Secondary Systems." June 1988. ASME PVP Conference, Pittsburgh, Pennsylvania.

"Floor Response Spectrum Method for Seismic Analysis of Multiply Supported Secondary Systems." 1986. *Earthquake Engineering and Structural Dynamics*. Vol. 14, pp. 245-265.

"Modal Participation Factors from In-Situ Test Data." August 1985. Transaction, Eighth International Conference on Structural Mechanics in Reactor Technology, Brussels, Belgium.

"A New Combination Rule for Seismic Analysis of Piping Systems." June 1985. ASME PVP Conference, New Orleans, Louisiana.

"A New Floor Response Spectrum Method for Seismic Analysis of Multiply Supported Secondary Systems." 1984. Report No. UCB/EERC-84/04, Earthquake Engineering Research Center, University of California, Berkeley.

"Earthquake Response of Multiply Supported Secondary Systems by Cross-Cross Floor Spectrum Method." January 1984. Proceedings, ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability.

"Seismic Response of Multiply Supported Piping Systems." August 1983. Transactions, Seventh International Conference on Structural Mechanics in Reactor Technology, Chicago, Illinois.

"Stochastic Method for Seismic Analysis of Secondary Systems." June 1983. Proceedings, International Workshop of Stochastic Methods in Structural Mechanics, Department of Structural Mechanics, University of Pavia, Pavia, Italy.

"Optimum Seismic Design of Linear Shear Buildings." May 1976. Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. ST5, pp. 1077-1084.

"Method of Developing Optimum Tolerances." February 1976. Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. ST2, pp. 323-336.

"Dynamic Behavior of a Soil-Structure Model Considering Absorbent Boundaries." July 1976. Second Chilean Conference on Earthquake Engineering and Seismology, Santiago, Chile.

"Absorbent Boundaries in Soil Dynamics." November 1975. Fourth National Conference on Earthquake Engineering, Oaxaca, Mexico.

PROFESSIONAL EXPERIENCE (Continued)

"Optimum Tolerance in Rolled Steel Sections." 1974. Revista de Ingenieria, Vol. 44, No. 4, pp. 337-348. Mexico

"Vibrations of Chimneys with Variable Inertia." 1974. XVI South American Conference on Structural Engineering, Buenos Aires, Argentina.

"Dynamic Analysis of Chimneys with Variable Inertia. Comparison between Continuous and Discrete Models." 1972. University of Chile report, Santiago, Chile.

DAVID J. DOYLE

PROFESSIONAL HISTORY

EQE International, San Francisco, California, Lead Engineer, 1987-present
Skidmore, Owings, and Merrill, Chicago, Illinois, Summer Intern, 1984-1986

PROFESSIONAL EXPERIENCE

Mr. Doyle is an engineer in EQE's Engineering Consultants Division. Mr. Doyle has been involved in a variety of seismic engineering projects involving detailed finite element analyses, in-plant screening evaluations, and soil-structure interaction analyses. He performed a structural computer modeling and analysis of SSC magnet and supports of the Super Conducting Super Collider and assisted computer modeling and analysis of four reactor structures for the Hatch Nuclear Power Plant. In addition he has been involved in a time history and response spectra generation for soil-structure interaction analysis for United Nuclear Corporation. Mr. Doyle has completed the SQUG certified seismic evaluation training course.

Notable examples of Mr. Doyle's work has included the following projects.

- o Soil-structural interaction analysis of the Oskarshamn Power Plant for the Swedish utility company Sydkraft.
- o Deterministic and probabilistic soil-structure interaction analysis of the Peach Bottom and Zion Power Plants to determine the effects of shear wall degradation as a function of shear stress for Sandia National Laboratory.
- o In-plant screening evaluations of seismic qualification operability issues at the Brunswick Nuclear Power Plant for safety-related equipment components and systems.
- o Computer modelling and soil-structure interaction analysis of buildings at the Savannah River Site.
- o Modelling and response spectrum analysis of large steel-frame structures at the Savannah River Site.
- o Soil-structure interaction analysis of a Pacific Bell facility in Northern California.
- o Inspection of a structure for Carter Hawley Hale for structural damage after the October 17, 1989 Loma Prieta Earthquake.
- o Generation of in-structure response spectra for the Belene Nuclear Power Plant in Romania.
- o Equipment anchorage calculations and in-plant screening evaluation of plant systems and components at the Comanche Peak Steam Electric Station.
- o Various in-house computer code quality assurance verification work.

Mr. Doyle worked three consecutive summer internships with Skidmore, Owings, and Merrill. His miscellaneous jobs included finite element structural analysis and beam and column design. In addition, he worked with computer-aided structures programs.

EDUCATION

University of California, Berkeley: M.S. Structural Engineering, 1986
University of Illinois, Champaign-Urbana: B.S. Civil Engineering, 1985

REGISTRATION

Certified Engineer-in-Training: Illinois

AFFILIATIONS AND HONORS

Tau Beta Pi Engineering Honor Society
Chi Epsilon Civil Engineering Honor Society (Treasurer - one year)
Phi Kappa Phi Senior Honor Society

BASILIO N. SUMODOBILA, JR.

PROFESSIONAL HISTORY

EQE Incorporated, San Francisco, California, Principal Engineer, 1986-present
East Bay Municipal Utility District, Oakland, California, Associate Engineer, 1984-1986
URS/John A. Blume and Associates, San Francisco, California, Senior Engineer, 1982-1984
Bechtel Power Corporation, San Francisco, California, Senior Engineer 1979-1982
URS/John A. Blume and Associates, San Francisco, California, Senior Engineer, 1973-1979

PROFESSIONAL EXPERIENCE

Mr. Sumodobila has over 19 years of experience in seismic evaluations, structural dynamic analysis, seismic analysis, structural design, linear and nonlinear analysis, and finite element software development. As Principal Engineer for EQE's Engineering Consultants Division, he provided support for the equipment qualification at the Savannah River Site. Mr. Sumodobila is responsible as a seismic capability engineer for Toledo Edison. This includes resolution of USI A-46 using the SQUG GIP methodology, and IPEEE using the EPRI margin assessment methodology at the Davis-Besse nuclear power plant.

At EQE Mr. Sumodobila has performed various aspects of seismic evaluation and analysis of a variety of electrical, mechanical and structural components. He has extensive experience in seismic evaluation of electrical raceways and components, mechanical equipment, piping, and structures. He has also performed seismic interaction evaluations, including II/I interaction, and seismic-induced spray hazards evaluation. In addition, he has performed building structure analysis and evaluation, including soil-structure interaction effects. He is well versed with the actual performance of industrial components and structures in actual earthquake, and has applied the seismic experience approach in qualification of equipment.

For the Browns Ferry Nuclear Plant, Cooper Station, and Savannah River Plant, Mr. Sumodobila was involved with the seismic evaluation of electrical raceways. For the Browns Ferry Nuclear Plant, and Savannah River Plant he has performed II/I interaction hazards evaluation. For the Sequoyah Nuclear Power Plant, Beznau Nuclear Power Plant (Switzerland), High Flux Isotope Reactor (HFIR-Oakridge), and Savannah River Plant he has performed piping analysis and evaluation. For the Winfrith Generating Station (UK), and Savannah River Plant he was involved with the seismic evaluation of confinement system. For the Browns Ferry Nuclear Power Plant, he was involved with seismic induced spray hazards evaluation.

Mr. Sumodobila has also performed a number of seismic analysis of structures, including soil-structrure interaction effects. For the SRS 105-K, L, and P Reactors, he performed the structural analysis of the VTS monorail frames. He performed the seismic analysis including soil-structure interaction for the Tower Shielding Reactor (TSR-Oak Ridge), Surry Nuclear Power Plant, N-Reactor Intake Pump Structure, and the Bellene Nuclear Plant (Bulgaria). He also performed the seismic analysis and evaluation of the HFIR Reactor Building.

At East Bay Municipal Utility District, Mr. Sumodobila was responsible for seismic analysis of Water Storage Tanks. He developed a computer code for seismic analysis and design of water storage tanks per AWWA D-100 Code. He was also involved with layout of filter plants for the San Ramon Valley Filter Plant.

EQE

PROFESSIONAL EXPERIENCE (Continued)

As a senior engineer at URS/Blume, he was responsible for the dynamic analysis of structures using finite element methods, which included mathematical modeling, calculation of structural response, and determination of critical sections. In addition, he provided modifications to structures to reduce stresses.

He completed the analysis of several nuclear power plant structures. For the Diablo Canyon Nuclear Plant, he completed the analysis of the Turbine Buildings for the Hosgri Earthquake load. As a lead engineer, his responsibilities included mathematical modeling for finite element analysis, time history analysis, calculation of dynamic time history response, generation of response spectra, preparation of calculations and reports, and supervision of other engineers working on the specified task. He was also responsible for the dynamic seismic analysis of the Turbine and Administration buildings of the Nine Mile Point Unit 1 Power Plant.

While employed at Bechtel Power Corporation, he completed several aspects of design, structural analysis, and stress evaluation for the Limerick Nuclear Power Plant. He was involved in the stress analysis of various structural components such as the containment primary structures, suppression chamber columns, downcomers and downcomer bracing system for dead, seismic and various hydrodynamic loads such as safety relief valve actuation, chugging, condensation oscillation and thermal loads. Tasks included the development of mathematical models for ANSYS, BSAP (a Bechtel program), STRUDL and NASTRAN computer programs. He also performed design assessment of these structural components and was responsible for the complete analysis and design of the downcomer bracing system constructed of stainless steel, which was designed by analysis iterative process due to the numerous loadings. Various methods were developed in the analysis for the hydrodynamic loads. Some unusual design approaches were used. He developed a computer program to check member stresses for numerous loading combinations for acceptability.

He was also involved in the stress evaluation of the concrete slab and walls for the spent fuel pool for the Limerick Plant for dead, seismic and thermal loads. Performed a finite element nonlinear analysis of the spent fuel pool to determine the stress distribution and the capacities of the critical sections in the concrete slab and walls of the spent fuel pool.

While employed at URS/Blume, he was responsible for the seismic and stress analysis of structures, equipment, and piping systems of nuclear facilities.

For the Diablo Canyon Nuclear Power Plant, he performed the dynamic analysis of the containment structure, (using axisymmetric finite element method) the auxiliary building, (including torsional modes of vibration) and the turbine building, as well as performing the seismic analysis of piping systems for the DE and DDE.

He was involved in the stress analysis of several underground waste storage tanks for the Hanford Reservation in Washington, for dead, live, and thermal loads and earthquake ground motions, and evaluated stresses at the steel tank shell in accordance with the ASME Section VIII Division 2 code.

Also, he assisted in the development and debugging of various computer programs for structural analysis. He developed a module for direct integration and modal superposition time history analysis for a piping analysis program and other algorithms for time series analysis.

PROFESSIONAL EXPERIENCE (Continued)

In addition, he is proficient in the use of the following computer programs: SAPIV, ANSYS, BSAP, STRUDL, AXIDYN, NASTRAN, DRAIN-2D, STARDYNE.

EDUCATION

MAPUA INSTITUTE OF TECHNOLOGY, Manila, Philippines: B.S. Environmental Engineering, 1973
MAPUA INSTITUTE OF TECHNOLOGY, Manila, Philippines: B.S. Civil Engineering, 1970
U.C. BERKELEY EXTENSION: Courses in structural dynamics, design and computer programming

REGISTRATION

California: Civil Engineer
Philippines: Civil Engineer

HONORS

Philippine Board Examination for Civil Engineers, First Place, 1970
Philippine Association of Civil Engineers, Certificate of Merit, 1971

PUBLICATIONS

With J. J. Johnson and R. L. Stover. 1989 "Seismic and Cask Drop Excitation Evaluations of the Tower Shielding Reactor." Second DOE Natural Phenomena Hazards Mitigation Conference.

With S. J. Eder and J. P. Conoscente. 1989. "Seismic Fatigue Evaluation of Rod Hung Systems." Tenth Conference on Structural Mechanics in Reactor Technology.

With S. P. Harris, P. S. Hashimoto, J. O. Dizon, G. M. Zaharoff, and L. J. Bragagnolo. March 1988. "Seismic Evaluation of the High Flux Isotope Reactor Primary Containment System." Report prepared for Martin Marietta Energy Systems, Inc. San Francisco: EQE Engineering.

JAMES J. JOHNSON

PROFESSIONAL HISTORY

EQE International, San Francisco, California, Division President, 1986-present
NTS/Structural Mechanics Associates, San Ramon, California, Vice President, 1984-1986
Structural Mechanics Associates, San Ramon, California, Vice President, Project Manager, 1980-1984
Lawrence Livermore National Laboratory, Livermore, California, Project Manager, 1978-1980
General Atomic Company, San Diego, California, Branch Manager, Staff Engineer, Senior Engineer, 1972-1978

PROFESSIONAL EXPERIENCE

Dr. Johnson has participated in the development, implementation, and teaching of seismic risk and seismic margin assessment methodologies. He has participated in seismic PRAs of over 20 nuclear power pl[illegible] His participation encompasses many aspects including hazard definition, seismic respons[illegible]d uncertainty determination, detailed walkdowns, and fragility assessment. A major element of seismic PRAs and seismic margin assessments is best estimate response analyses. Dr. Johnson participated in the development of best estimate or median-centered response procedures and has participated in its application to over 60 nuclear facilities. Dr. Johnson was responsible for several portions of the U.S. Nuclear Regulatory Commission Seismic Safety Margins Research Program (SSMRP) -- soil-structure interaction, major structure response, subsystem response, and the seismic analysis calculational procedures (SMACS). Dr. Johnson has presented numerous seminars and training courses on seismic PRA and seismic margin methodologies.

Dr. Johnson has played a significant role in the development of general and plant-specific seismic evaluation procedures. This project participation has ranged from the SQUG General Implementation Procedure (GIP) to plant-specific procedures for the Savannah River Site. Procedures include criteria for assessing equipment and component functionality and structural integrity, seismic systems interaction, anchorage, and other issues.

Dr. Johnson has extensive theoretical and practical experience in the soil-structure interaction (SSI) analysis of major facilities and has written a comprehensive assessment of the state-of-the-art of SSI. Most recently, Dr. Johnson was principal investigator for EQE on the SSI modeling, predictive analysis, and resolution of measured and predicted response for the combined EPRI/NRC Lotung, Taiwan scale model project. He has performed SSI analyses of a wide variety of surface and embedded structures using simplified to sophisticated substructure methods and linear and nonlinear finite element techniques. Nonlinear analyses included geometric effects (sliding and separation) and soil material behavior. He has made extensive use of comparative analyses and parametric studies to benchmark techniques and soil and structure configurations. Dr. Johnson was a consultant to the U.S. Nuclear Regulatory Commission (NRC) concerning revisions to the Standard Review Plan for seismic analysis and design.

Dr. Johnson has developed, verified, maintained, and extensively applied several large computer programs to perform stress and seismic analysis. Among these are: MODSAP, a general purpose finite element program with special capability in the dynamic analysis of structures with localized nonlinearities; and SMACS, a probabilistic response analysis program for soil, structures, equipment, and piping systems.

PROFESSIONAL EXPERIENCE (Continued)

Dr. Johnson was responsible for the analysis and design of components subjected to extreme internally and externally generated loading conditions. This work includes seismic qualification of control room equipment and motor control centers, fuel handling components, core and core support structures, heat exchanger shell and tubes subjected to a tube burst loading, and shipping casks of irradiated fuel and equipment subjected to impact loading.

Dr. Johnson has taught Earthquake Engineering of Major Facilities at the University of California, Berkeley. This course covered all phases of the earthquake engineering process, including seismic hazard definition; seismic analysis and design of structures, equipment and tanks; and seismic risk analysis. Dr. Johnson coordinated and taught portions of the SQUG training course that covered the seismic evaluation of equipment, cable trays and conduit, piping, anchorage, and seismic systems interaction.

Dr. Johnson is a member and chairman of the Working Group on Input to Secondary Systems of the ASCE Nuclear Structures and Materials Committee, Dynamic Analysis Committee, and the ASCE Committee on Nuclear Standards, Seismic Analysis of Safety Class Structures.

EDUCATION

UNIVERSITY OF ILLINOIS: Ph.D. Civil Engineering, 1972
UNIVERSITY OF ILLINOIS: M.S. Civil Engineering, 1969
UNIVERSITY OF MINNESOTA: B.C.E. Civil Engineering, 1967

REGISTRATION

California: Civil Engineer

SECURITY CLEARANCE

Department of Energy: Q-Clearance

AFFILIATIONS

Phi Kappa Phi Honor Society
Sigma Xi
American Society of Civil Engineers
Earthquake Engineering Research Institute

PUBLICATIONS AND REPORTS

Dr. Johnson has contributed to over 40 technical reports and journal articles. The following is a selection of documents for which he is the principal author.

Seismic Margin Studies and Risk Analyses

With A. P. Asfura. July 1992. "Soil-structure Interaction Observations, Data, and Correlative Analysis." In Proceedings of the NATO Advanced Study Institute on Development in Soil-structure Interaction, Antalya, Turkey, July 1992.

PUBLICATIONS AND REPORTS (Continued)

With M. K. Ravindra. June 1991. "Treatment of Seismically Induced Common Cause Failures in Nuclear Power Plant PSA." In *Proceedings of Sixth International Conference on Applications of Statistics and Probability in Civil Engineering.* Mexico City, Mexico.

"A Methodology for Assessment of Nuclear Power Plant Seismic Margin." October 1988. Electric Power Research Institute. EPRI NP-6041.

With D. P. Moore et al. 1990. "Seismic Margin Assessment of Edwin I. Hatch Nuclear Plant Unit 1." Electric Power Research Institute.

With O. R. Maslenikov and D. J. Doyle. 1987. "Review of Seismic Analysis of Hatch Units 1 and 2: In-Structure Response Spectra." UCID-21015. Lawrence Livermore National Laboratory.

With O. R. Maslenikov et al. 1987. "Soil-Structure Interaction Analysis and In-Structure Response Spectra Generation for the N-Reactor Facility." Vol. 1 and 2. Prepared for UNC Nuclear Industries. San Ramon, CA: EQE Engineering.

With P. S. Hashimoto et al. March 1988. "N-Reactor River Pump House and Gantry Crane (181-N) Seismic and Tornado Analysis." Prepared for Westinghouse Hanford Company. Newport Beach, CA: EQE Engineering.

With B. J. Benda et al. June 1988. "Quantification of Calculational Margins in Piping System Seismic Response: Methodologies and Damping." *Seismic Engineering, 1988*, The Pressure Vessels and Piping Division, ASME, PVP-Vol. 144. (Received "Certificate of Recognition," July 1989.) San Ramon, CA: EQE Engineering.

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With O. R. Maslenikov et al. March 1989. "Analysis of Large-Scale Containment Model in Lotung, Taiwan: Forced Vibration and Earthquake Response Analysis and Comparison." In *Proceedings: EPRI/NRC/TPC Workshop on Seismic Soil-Structure Interaction Analysis Techniques Using Data From Lotung, Taiwan.* NP-6154, Vol. 1, Paper 13. Electric Power Research Institute.

With P. S. Hashimoto et al; Geomatrix Consultants; and Westinghouse Energy Systems International. March 1990. "Seismic Review of the Belene Construction Project (Units 1 and 2)." Prepared for Association Energetika and Techno-Import-Export. Sofia, Bulgaria.

With A. P. Asfura et al. March 1990. "Pilot Study of Reactor/Containment Building: Oskarshamn 2 and Barsebeck 1 and 2, Probabilistic Response and Capacity." Rev. 1. Prepared for Sydkraft and OKG Aktiebolag, Sweden. San Francisco, CA: EQE Engineering.

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With G. E. Cummings and R. J. Budnitz. October 1984. "NRC Seismic Design Margins Program Plan." UCID-20247. Lawrence Livermore National Laboratory.

With L. C. Shieh et al. August 1985. "Simplified Seismic Probabilistic Risk Assessment: Procedures and Limitations." NUREG/CR-4331. UCID-20468. Lawrence Livermore National Laboratory.

PUBLICATIONS AND REPORTS (Continued)

With A. P. Asfura and O. R. Maslenikov. 1990. "Topics in Soil-Structure Interaction." Paper presented at the Ninth Earthquake Engineering Conference, December 1990, Roorkee, India.

With B. J. Benda et al. 1988. "SSC Dipole Magnet System: Stress Analysis for Seismic and Transportation Loading." Prepared for the University Research Association. San Ramon, CA: EQE Engineering.

With O. R. Maslenikov et al. 1991. "Seismic Analysis of the Vertical Tube Storage System Monorail Support Frame in Building 105-K at the Savannah River Plant Using Upgraded Seismic Input Motions, Volume 1: Soil-Structure Interaction Analysis of Building 105-K, Volume 2: Response Spectrum Analysis of the VTS Monorail Support Frame." Prepared for Westinghouse Savannah River Company. San Francisco, CA: EQE International.

With L. J. Bragagnolo and S. J. Eder. February 1991. "Seismic Evaluation of the Energy Management System." Prepared for Pacific Gas & Electric Company. San Francisco, CA: EQE Engineering

With G. S. Hardy. August 1988. "Technical Basis, Procedures, and Guidelines for Seismic Characterization of SRP Reactors." Savannah River Report RTR 2582. Costa Mesa, CA: EQE Engineering.

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With S. P. Harris et al. October 1989. "Seismic and Cask Drop Excitation Evaluation of the Tower Shielding Reactor." In *Proceedings of the Second DOE Natural Phenomena Hazards Mitigation Conference.* Knoxville, Tennessee.

With P. S. Hashimoto et al. December 1990. "U. S. NRC Structural Damping Research Program." Paper IV-4. In *Proceedings of the Third Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment, and Piping.* Orlando, Florida.

With M. P. Bohn et al. April 1990. "Analysis of Core Damage Frequency Due to External Events at the DOE N-Reactor." SAND89-1147. Sandia National Laboratories. Albuquerque, New Mexico.

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With B. J. Benda. 1986. "Seismic Fragility Analysis: Methodology and Application." Prepared for Earthquake Engineering Technology. San Ramon, CA.

With R. D. Campbell et al. 1985. "LaSalle Seismic Probabilistic Risk Assessment: Responses and Fragilities." Report SMA 12211.21. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

PUBLICATIONS AND REPORTS (Continued)

With B. J. Benda and M. J. Mraz. 1985. "Specification of Seismic Qualification Environment for Equipment." Paper presented to DOE Natural Phenomena Hazards Mitigation Conference, Las Vegas, Nevada.

With O. R. Maslenikov and R. P. Kennedy. 1985. "Washington Public Power Supply System WNP-1 Containment Building: SSI Analysis and the Effect of Control Point Location." Report SMA 46001.03. Prepared for United Engineers and Constructors. San Ramon, CA: Structural Mechanics Associates.

With R. P. Kennedy. 1985. "Summary of Observations on Control Point Location and Spatial Variation of Free-Field Ground Motion." Report SMA 46001.02. Prepared for United Engineers and Constructors. San Ramon, CA: Structural Mechanics Associates.

With J. C. Chen. August 19-23, 1985. "Influence of the Local Site Condition on Seismic Response of a PWR-Containment Building." In *Proceedings Eighth SMiRT Conference*. Brussels, Belgium.

With T. Y. Chuang et al. August 19-23, 1985. "Seismic Risk Assessment of a BWR: Status Report." Preprint, *Proceedings Eighth SMiRT Conference*. Brussels, Belgium,

With O. R. Maslenikov and E. C. Schewe. August 19-23, 1985. "SSI Response of a Typical Shear Wall Structure." In *Proceedings Eighth SMiRT Conference*. Brussels, Belgium.

With O. R. Maslenikov et al. August 19-23, 1985. "Seismic Analysis of the MFTF Facility." In *Proceedings Eighth SMiRT Conference*. Brussels, Belgium.

With B. J. Benda et al. 1985. "The Effects of Basemat Uplift on the Seismic Response of Structures and Interbuilding Piping Systems." Report SMA 12211.44.01. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With O. R. Maslenikov et al. 1984. *SMACS: a System of Computer Programs for Probabilistic Seismic Analysis of Structures and Subsystems.* 2 vols. Report SMA 12211.31.01/12211.31.02. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With O. R. Maslenikov and B. J. Benda. 1984. "SSI Sensitivity Studies and Model Improvements for the U.S. NRC Seismic Safety Margins Research Program." UCID 20212; NUREG/CR-4018. Livermore, CA: Lawrence Livermore National Laboratory.

With B. J. Benda et al. May 16-18, 1983. "Response Margins of the Dynamic Analysis of Piping Systems: Best Estimate vs. Evaluation Method." In *Proceedings of the Second CSNI Specialist Meeting on Probabilistic Methods in Seismic Risk Assessment for Nuclear Power Plants.* Livermore, CA,

With B. J. Benda et al. 1984. "Response Margins of the Dynamic Analysis of Piping Systems." UCID-20067, rev. 1; NUREG/CR-3996. Livermore, CA: Lawrence Livermore National Laboratory.

With E. C. Schewe and O. R. Maslenikov. 1984. "SSI Response of a Typical Shear Wall Structure." 2 vols. UCID-20122. Livermore, CA: Lawrence Livermore National Laboratory.

With R. D. Campbell and L. W. Tiong. 1984. "Neutral Beam Pivot Point Bellows Fatigue Evaluation per ASME Code." Report SMA 18503.01. Prepared for Lawrence Berkeley Laboratory. San Ramon, CA: Structural Mechanics Associates.

PUBLICATIONS AND REPORTS (Continued)

With O. R. Maslenikov and M. J. Mraz. 1984. "Seismic Analyses of the Mirror Fusion Test Facility Building 431." Report SMA 12210.03. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With O. R. Maslenikov and L. W. Tiong. 1984. "Seismic Analysis of the Mirror Fusion Test Facility: Soil Structure Interaction Analyses of the Vault." Report SMA 12210.02. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With O. R. Maslenikov and L. W. Tiong. 1984. "Seismic Analysis of the Mirror Fusion Test Facility: Soil Structure Interaction Analyses of the Vessel." Report SMA 12210.01. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With R. D. Campbell and L. W. Tiong. 1984. "Re-design of the Neutral Beam Pivot Point Bellows: Validation of Stress Analysis." Report SMA 18502.01. Prepared for Lawrence Berkeley Laboratory. San Ramon, CA: Structural Mechanics Associates.

With M. P. Bohn et al. 1984. "Application of the SSMRP Methodology to the Seismic Risk at the Zion Nuclear Power Plant." UCRL-53483; NUREG/CR-3429. Livermore, CA: Lawrence Livermore National Laboratory.

With J. C. Chen et al. 1984. "Uncertainty in Soil-Structure Interaction Analysis of a Nuclear Power Plant Due to Different Analytical Techniques." In *Proceedings of the Eighth World Conference on Earthquake Engineering.*

With B. J. Benda and L. Y. Cheng. 1983. "Evaluation of PVRC Proposed Changes for the Seismic Analysis and Design of Piping Systems: Damping and Peak Broadening." Report SMA 12209.03-01. Prepared for Lawrence Livermore National Laboratory. San Ramon, CA: Structural Mechanics Associates.

With T. Y. Chuang et al. 1983. "Impact of Changes in Damping and Spectrum Peak Broadening on the Seismic Response of Piping Systems." UCRL-53491; NUREG/CR-3526. Livermore, CA: Lawrence Livermore National Laboratory,

With M. P. Bohn et al. August 22-26, 1983. "Application of the SSMRP Methodology to the Seismic Probabilistic Risk Analysis at the Zion Nuclear Power Plant." In *Proceedings Seventh SMiRT Conference.* Chicago, Illinois.

With J. C. Chen and D. L. Bernreuter. August 22-26, 1983. "The Effect of Local Soil Conditions on Site Amplification." Paper presented at the Seventh SMiRT Conference, Chicago, Illinois.

With O. R. Maslenikov and J. C. Chen. 1983. "Uncertainty in Soil-Structure Interaction Analysis Arising from Differences in Analytical Techniques." UCRL-53026; NUREG/CR-2077. Livermore, CA: Lawrence Livermore National Laboratory.

With P. D. Smith et al. 1981. "SSMRP Phase I Final Report: Overview." UCRL-53021, vol. 1; NUREG/CR-2015, vol. 1. Livermore, CA: Lawrence Livermore National Laboratory.

With O. R. Maslenikov et al. 1982. "SSMRP Phase I Final Report: Soil Structure Interaction (Project III)." UCRL-53021, vol 4; NUREG/CR-2015, vol. 4. Livermore, CA: Lawrence Livermore National Laboratory.

With B. J. Benda and T. Y. Lo. 1981. "SSMRP Phase I Final Report: Major Structure Response (Project IV)." UCRL-53021, vol. 5; NUREG/CR-2015, vol. 5. Livermore, CA: Lawrence Livermore National Laboratory.

PUBLICATIONS AND REPORTS (Continued)

With G. L. Goudreau et al. 1981. "SSMRP Phase I Final Report: SMACS (Seismic Methodology Analysis Chain with Statistics) (Project VIII)." UCRL-53021, vol. 9; NUREG/CR-2015, vol. 9. Livermore, CA: Lawrence Livermore National Laboratory.

"Soil Structure Interaction: the Status of Current Analysis Methods and Research." 1981. UCRL-53011, NUREG/CR-1780. Livermore, CA: Lawrence Livermore National Laboratory.

With B. J. Benda and P. D. Smith. 1981. "Variability in Dynamic Characteristics and Seismic Response Due to the Mathematical Modeling of Nuclear Power Plant Structures." UCRL-85713. Preprint submitted to *Nuclear Engineering and Design*. Livermore, CA: Lawrence Livermore National Laboratory.

With P. D. Smith et al. 1981. "A Review of a Seismic Risk Analysis of the Decay Heat Removal Capability of Nuclear Power Plants." UCID-18692. Livermore, CA: Lawrence Livermore National Laboratory.

With C.M. Charman. August 17-21, 1981. "An Isoparametric Shell of Revolution Finite Element for Harmonic Loadings of Any Order." In *Proceedings Sixth SMiRT Conference*. Paris, France.

"Seismic Response Calculations for the U.S. NRC Seismic Safety Margins Research Program." August 17-22, 1981. In *Proceedings Sixth SMiRT Conference*. Paris, France.

With R. C. Chun et al. August 17-21, 1981. "Uncertainty in Soil-Structure Interaction Analysis of a Nuclear Power Plant: a Comparison of Linear and Nonlinear Analysis Methods." In *Proceedings Sixth SMiRT Conference*. Paris, France.

With B. J. Benda. August 17-21, 1981. "Uncertainty in Mathematical Models of a Typical Nuclear Power Plant Structure." In *Proceedings Sixth SMiRT Conference*. Paris, France.

With S. E. Bumpus and P. D. Smith. August 17-21, 1981. "Best Estimate vs. Evaluation Method Seismic (BE-EMS): an Introduction and Demonstration." In *Proceedings Sixth SMiRT Conference*. Paris, France.

With P. D. Smith et al. 1980. "An Overview of Seismic Risk Analysis for Nuclear Power Plants." UCID-18680. Livermore, CA: Lawrence Livermore National Laboratory.

With S. E. Bumpus and P. D. Smith. 1980. "Best Estimate Method vs. Evaluation Method: a Comparison of Two Techniques in Evaluating Seismic Analysis and Design." UCID-52746; NUREG/CR-1489. Livermore, CA: Lawrence Livermore National Laboratory.

"Soil Structure Interaction Analysis for the U.S. NRC Seismic Safety Margins Research Program." August 13-17, 1979. In *Proceedings Fifth SMiRT Conference*. Berlin, Germany.

"Subsystem Response Determination for the U.S. NRC Seismic Safety Margins Research Program." August 13-17, 1979. In *Proceedings Fifth SMiRT Conference*. Berlin, Germany.

With W. Schlafer III and D. Tow. August 13-17, 1979. "Seismic Response Comparisons for an Embedded High Temperature Gas-Cooled Reactor (HTGR) on a High Seismic Site." In *Proceedings Fifth SMiRT Conference*. Berlin, Germany.

"SOILST: a Computer Program for Soil-Structure Interaction Analysis." 1979. GA-A15067 UC-77. San Diego, CA: General Atomic Company.

PUBLICATIONS AND REPORTS (Continued)

"MODSAP: a Modified Version of the Structural Analysis Program SAPIV for the Static and Dynamic Response of Linear and Localized Nonlinear Structures." GA-A-14006. San Diego, CA: General Atomic Company.

"Preliminary Seismic Analysis of the GCFR Core and Core Support Structure." June 22-23, 1978. Paper presented at the Third SAP User's Conference, University of Southern California, Los Angeles, California.

With R. P. Kennedy. October 17-21, 1977. "Earthquake Response of Nuclear Power Facilities." Paper presented at the ASCE Fall Convention and Exhibit, San Francisco, California.

With D. A. Wesley and L. T. Almajan. August 15-19, 1977. "The Effects of Soil-Structure Interaction Modeling Techniques on In-Structure Response Spectra." In *Proceedings Fourth SMiRT Conference*. San Francisco, CA.

"MODSAP: a Modified Version of the Program SAPIV for the Static and Dynamic Response of Linear and Localized Nonlinear Structures." June 22-23, 1977. Paper presented at the Second SAP User's Conference, University of Southern California, Los Angeles, California.

Dr. Johnson was also a contributing author to the following publications:

"Shutdown Decay Heat Removal Analysis of a Combustion Engineering 2-Loop Pressurized Water Reactor -- Case Study (St. Lucie)." August 1987. NUREG/CR-4710, SAND86-1797. Sandia National Laboratories. Albuquerque, New Mexico.

"Shutdown Decay Heat Removal Analysis of a Westinghouse 3-Loop Pressurized Water Reactor -- Case Study (Turkey Point)." March 1987. NUREG/CR-4762, SAND86-2377. Sandia National Laboratories. Albuquerque, New Mexico.

"Shutdown Decay Heat Removal Analysis of a General Electric BWR4/Mark 1 -- Case Study (Cooper)." July 1987. NUREG/CR-4767, SAND86-2419. Sandia National Laboratories. Albuquerque, New Mexico.

"Shutdown Decay Heat Removal Analysis of a General Electric BWR3/Mark 1 -- Case Study (Quad Cities)." March 1987. NUREG/CR-4448, SAND85-2373. Sandia National Laboratories. Albuquerque, New Mexico.

"Shutdown Decay Heat Removal Analysis of a Babcock and Wilcox Pressurized Water Reactor -- Case Study (ANO-1)." March 1987. NUREG/CR-4713, SAND86-1832. Sandia National Laboratories. Albuquerque, New Mexico.

"Shutdown Decay Heat Removal Analysis of a Westinghouse 2-Loop Pressurized Water Reactor -- Case Study (Point Beach). March 1987. NUREG/CR-4458, SAND86-2496. Sandia National Laboratories. Albuquerque, New Mexico.

Item #2.

Client: Boston Edison

Calculation No. C-002

Title: Soil Properties for the Soil Structure Interaction Analysis for the Pilgrim Site

Project: IPEEE - Seismic / A-46

Method:

Acceptance Criteria: ASCE 4-86

Remarks:

INFORMATION ONLY

REVISIONS

No.	Description	By	Date	Chk.	Date	App.	Date
0	Initial Issue	TMT	1-25-93	MSL	1-26-93	[signature]	1-26-93

S&A Stevenson and Associates	CALCULATION COVER SHEET FIGURE 1.3	CONTRACT NO. 91-C2672

~~9403230348~~

For the Reactor Building, the Radwaste Building, the Diesel Generator Building, and the Intake Structure, the compacted fill layer has a depth of 45 ft according to the GEI report. For the Turbine Building, the compacted fill layer has a depth of 35 ft.

For the SSI analysis, the average shear wave velocity across each layer is calculated. The input data for the SSI programs is summarized in the following tables:

Layer No.	Thick (ft)	Shear Wave Velocity (ft/sec)	Density (lb*sec^2/ft)	Damping Ratio (%)	Poisson's Ratio
1	10	535	3.92	0.02	0.33
2	10	745	3.92	0.02	0.33
3	10	860	4.26	0.02	0.4
4	10	925	4.26	0.02	0.4
5	5	963	4.26	0.02	0.4
6	5	1215	4.01	0.02	0.4
7	10	1255	4.01	0.02	0.4
8	10	1310	4.01	0.02	0.4
9	10	1365	4.01	0.02	0.4
10	10	1415	4.01	0.02	0.4
11	10	1465	4.01	0.02	0.4
Rock	-	3000	5.22	0.02	0.4

Table 2 - Reactor Building, Radwaste Building, Diesel Generator Building, Intake Structure

Layer No.	Thick (ft)	Shear Wave Velocity (ft/sec)	Density (lb*sec^2/ft)	Damping Ratio (%)	Poisson's Ratio
1	10	535	3.92	0.02	0.33
2	10	745	3.92	0.02	0.33
3	10	860	4.26	0.02	0.4
4	5	913	4.26	0.02	0.4
5	5	1153	4.01	0.02	0.4
6	10	1200	4.01	0.02	0.4
7	10	1255	4.01	0.02	0.4
8	10	1310	4.01	0.02	0.4
9	10	1365	4.01	0.02	0.4
10	10	1415	4.01	0.02	0.4
11	10	1465	4.01	0.02	0.4
Rock	-	3000	5.22	0.02	0.4

Table 3 - Turbine Building

The soil material damping ratio is assumed to be 2 percent. The final soil damping values, however, were calculated from LAYSOL iterated properties. The Poisson ratio is assumed to be 0.33 for soil above the water table, and 0.40 for saturated soil. The soil densities are given in GEI report (Appendix A-1).

Water Table

As reported by GEI, the water table ranges from +1 to +6 feet above the mean sea level for the Reactor Building and varies from +2 to +7 feet for the Turbine Building. The location of the water table is not critical for the SSI analysis, it affects only the unit weight and the Poisson ratio. The effect will be much less significant than the variation of the shear modulus.

In the SSI analysis, the water table is assumed to be located at +1 feet for all buildings. The level of water will the subject of a parameter study in a separate calculation.

Variation of the Soil Shear Wave Velocities

For the PRA analysis, the variation of soil properties must be taken into account. Among the soil properties, the shear wave velocity or shear modulus has the highest uncertainty. Each analysis in this study is based on three representative runs, namely, the best estimate, the low bound, and the high bound soil properties.

The best estimate properties are the values recommended in previous sections. The low bound and the high bound properties are taken at the plus and minus one standard deviation estimates. According to the recommendations by Professor Whitman, the standard deviation of the shear wave velocity is 15% of the best estimate at the base of the stratum increasing to 35% at ground surface to reflect the greater uncertainty concerning wave velocity at shallow depth in cohesionless soil. The standard deviation of the outwash is 35% of the best estimate considering the wide spread between the available data.

In this study the standard deviation of the shear wave velocity is taken as 35% of the best estimate. This variation in shear velocity corresponds to 82% (1.35 * 1.35 - 1) variation in the shear modulus, which is greater than the minimum of 50% required by the ASCE Standard, but lower than the 100% required by the Standard Review Plan.

In the SSI high bound analyses, the shear wave velocities in tables 2 and 3 are multiplied by a factor of 1.35. In the low bound analyses, the shear wave velocities are divided by 1.35.

Foundation Depth

According to the design drawings, the foundation base level are approximately

Building	Common Z	Reference
Reactor Building	-23 ft	GEI Report
Turbine Building	-3 ft	GEI Report
Radwaste Building	-3 ft	Drawing 6498M-26 Rev.E4
Diesel Generator Building	23 ft	Drawing 6498M-26 Rev.E4
Intake Structure	-24 ft	Drawing 6498C-47 Rev.E2

The closest soil layer elevation is selected for the foundation embeddment depth in the LAYSOL analyses. The grade level is approximately 22 ft for all buildings. These foundation depths are used in the EKSSI input as Common Z which ties the model fixed-base to the foundation impedance matrix at this level.

S&A	JOB NO. 91C2672 Calculation C-002	SHEET #5
	SUBJECT BECo IPEEE/A-46	OF 5
STEVENSON & ASSOCIATES a structural-mechanical consulting engineering firm	SSI Soil Properties	Revision 0
		By TMT 1-25-93
		Chk. [illegible] 1-25-93

Appendix A

A-1 Letter from Eugene A. Marciano, GEI Consultants, Inc., February 28, 1992, 91C2672-LRS2-002

A-2 Letter from Eugene A. Marciano, GEI Consultants, Inc., February 28, 1992, 91C2672-LRS2-003

A-3 Letter from Robert V. Whitman, Massachusetts Institute of Technology, November 30, 1992, 91C2672-LRS6-001

A-4 Letter from Robert V. Whitman, Massachusetts Institute of Technology, December 18, 1992, 91C2672-LRS6-002

GEI Consultants, Inc.

1021 Main Street
Winchester, MA 01890-1943
617-721-4000

February 28, 1992
Project 92012

Mr. Thomas J. Tracy
Vice President
Stevenson & Associates
Ten State Street
Woburn, MA 01801

Dear Mr. Tracy:

Re: **Shear Wave Velocities, Unit Weights, and Ground Water Table**
Pilgrim IPEEE, Pilgrim Station, Plymouth, Massachusetts

This letter provides a description of the stratigraphy, unit weights, and shear wave velocities for the soils beneath and surrounding the reactor and turbine buildings of Pilgrim 1. In addition, the ground water fluctuation in this area is provided.

Stratigraphy

The stratigraphy in the area of the reactor and turbine buildings is shown in the attached Fig. 1. It consists of approximately 35 to 45 feet of compacted fill materials, designated as type A and type B fills on Bechtel Drawing C8, above approximately 45 to 35 feet of glacial outwash deposits, which are underlain by bedrock at a depth of approximately 80 feet. The type A and B fills are specified to have been compacted to a minimum of 98% and 96%, respectively, of the maximum dry density as determined by ASTM D1557 and have similar ranges of values for unit weight and shear wave velocity. The outwash deposits are very dense as a result of loading due to glaciation subsequent to their deposition. The outwash deposits are granular, consisting predominately of poor- to well-graded sands. The limits of the compacted fill areas beyond the area of the reactor and turbine buildings are also shown on Drawing C8.

Sections F and H of Drawing C8 indicate that the reactor building is founded on the outwash material. Section A indicates that at least a portion of the turbine building foundation is underlain by type A fill. The elevations of the building foundations and thicknesses of fill are approximate and should be verified when a complete set of drawings becomes available from BECO.

Groundwater Table

The elevation of the ground water table in this area can be expected to experience the following fluctuations due to tidal effects and normal rainfall:

Reactor Building	+1 to +6 feet above mean sea level (depths of 21 to 16 feet)
Turbine Building	+2 to +7 feet above mean sea level (depths of 20 to 15 feet)

This is based on observation well readings conducted by GEI[1] over nearly a 3-year period within and surrounding the Pilgrim 1 area. This does not include the potential effects of flooding, storm surges, or other extreme events on the ground water table.

Total Unit Weights

Based on the data available in the soils report[2] for Pilgrim 2, the average total unit weights for the soil strata are 126 pcf for the compacted fill above the water table, 137 pcf for the compacted fill below the water table, and 129 pcf for the outwash deposits. Bechtel indicates in the soils report a unit weight of 168 pcf for the bedrock.

Shear Wave Velocities

The results of seismic crosshole testing conducted by Weston Geophysical for the site of Pilgrim 2 in 1972 and 1976 is available in the soils report[2]. The results are plotted in Fig. 2 and range from 1,700 to 2,700 fps. There is no compacted fill in this area. Therefore, only the cross-hole results below a depth of about 35 feet are relevant to the Pilgrim 1 site. For the outwash deposits, the following shear wave velocities were recommended for design by Bechtel[2] based on the cross-hole results.

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[1]GEI (1983). "Analysis of Groundwater Levels, Pilgrim Station Unit 1, Plymouth, Massachusetts," February 28.

[2]Soils Report prepared by Bechtel as part of Pilgrim 2 PSAR, dated August 31, 1976, Amendment 26 (contains GEI soils data reports).

Depth (ft)	Elevation (ft)	Shear Wave Velocity (fps)
35 to 51	-13 to -29	1,950
51 to 71	-29 to -49	2,300
71 to 80	-49 to -58	2,650
>80	<-58	5,900

In addition, we have estimated the shear wave velocities of the outwash soils and compacted fills based on field exploration data and laboratory testing data from the soils report for Pilgrim 2[2]. The outwash deposits of the Pilgrim 1 and Pilgrim 2 sites have similar soil descriptions and ranges of blowcounts and are part of the same depositional history and were both subjected to glacial loading. This information indicates that the characteristics of the outwash materials at Pilgrim 1 and Pilgrim 2 can be expected to be similar.

The results of our estimates of the shear wave velocities are shown in Fig. 2. They are based on blowcount data and laboratory testing on samples obtained from the same area as Weston Geophysical's cross-hole tests for Pilgrim 2. All of the plotted points and curves in this figure are based on a ground water table elevation of +5 feet, i.e., a depth of 17 feet below the ground surface.

Values of shear wave velocity versus depth were calculated and plotted using the following field and laboratory soils data, which were obtained for the outwash deposits in the vicinity of the Pilgrim 2 cross-hole tests:

1) Blowcount data within the glacial outwash corrected for the influence of gravel content.

2) Impulse shear wave velocity tests on undisturbed samples of glacial outwash.

3) Resonant column test results on specimens prepared by compaction of materials from bulk samples obtained from the glacial outwash. The bulk samples were obtained from borings in the vicinity of the Pilgrim 2 cross-hole tests.

In addition, Hardin and Drnevich's relationship for granular materials was used to calculate curves of shear wave velocity versus depth using ranges of measured values for the unit weight and of estimated values of the at-rest coefficient of lateral earth pressure, K_o. This was done for both the compacted fill and the outwash deposits, which have different unit weights and different values of K_o. The range of unit weights of the outwash deposits were determined from *in situ* field density test results. The range of unit weights of the compacted fills were estimated using the results of compaction tests on samples of the outwash materials. The gradation of these compaction samples meets that specified by Bechtel[2] for the compacted fill.

For the compacted fills, upper and lower bound estimate curves for the shear wave velocity are plotted from depths of 10 to 50 feet. For the outwash deposits, upper and lower bound estimate curves are plotted from depths of 35 to 80 feet. The best estimate curve for the fill and the outwash materials is plotted from 0 to 80 feet, passing midway between the upper and lower bound curves.

The plotted results based on the three sources of data listed above generally fall within the range of values indicated by the curves based on Hardin and Drnevich's expression with the fourth source of data, the unit weights and estimated values of K_o, as input.

The estimated values of shear wave velocity are considerably lower than the results of the cross-hole tests. This may be the result of the specific procedures used to perform the cross-hole tests for Pilgrim 2 including the use of explosives for the signal source and the large spacings between the source and receiver holes. The use of explosives for the source generates a much larger percentage of compressive wave (P wave) energy than shear wave (S wave) energy. The velocity of the S wave is typically about half of that of the P wave, and thus the P wave always arrives before the S wave. The result of this is that the P wave tends to obscure the arrival time of the S wave recorded at the receiver holes. In addition, the large spacings (approximately 150 feet) between the source and receiver holes may have resulted in refraction of the wave through deeper, denser layers, which tends to overestimate the shear wave velocity.

It is not possible from the information available to conclusively determine if the cross-hole results are in error. Nevertheless, the similarity of the estimates obtained using four independent sources of field and laboratory data indicates that these estimates should not be ruled out either.

For the outwash materials, we recommend that whichever of the two shear wave velocity profiles will result in the more severe loading, i.e., either the best estimate curve shown in the figure or Bechtel's recommended values, which are given above, be used. In either case, the best estimate curve passing midway between the upper and lower bound curves in Fig. 2 should be used for the fills. Alternatively, cross-hole determinations of shear wave velocity could be made. These measurements should be made using closely spaced (10 to 15 feet) boreholes with signal generation that enhances shear wave propagation.

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If you have any questions, please contact me or Dr. Gonzalo Castro.

Sincerely yours,

GEI CONSULTANTS, INC.

Eugene Marciano

Eugene A. Marciano, Ph.D.
Project Manager

EAM:ms

Enclosures

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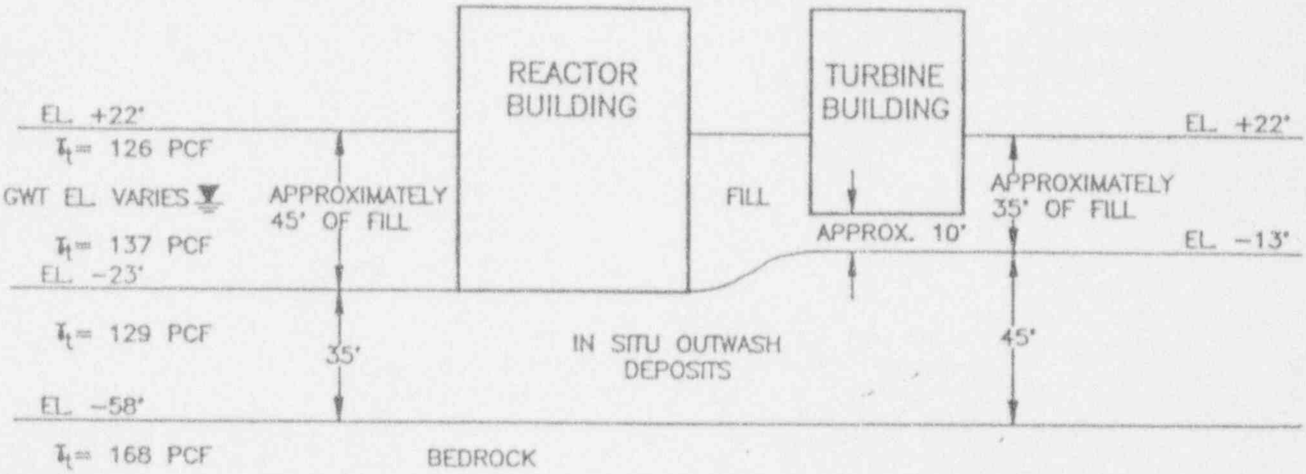

NOT TO SCALE

NOTE

THE FOUNDATION ELEVATIONS OF THE REACTOR AND TURBINE BUILDINGS AND THE THICKNESS OF FILL ARE ESTIMATED FROM SECTIONS A, F AND H OF BECHTEL DRAWING C8 AND SHOULD BE VERIFIED FROM THE DESIGN AND AS-BUILT DRAWINGS FOR PILGRIM 1.

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Stevenson & Associates Woburn, Massachusetts	Pilgram 1 IPEEE	SOIL PROFILE SCHEMATIC DRAWING
GEI Consultants, Inc.	Project 92012	February 1992 Fig. 1

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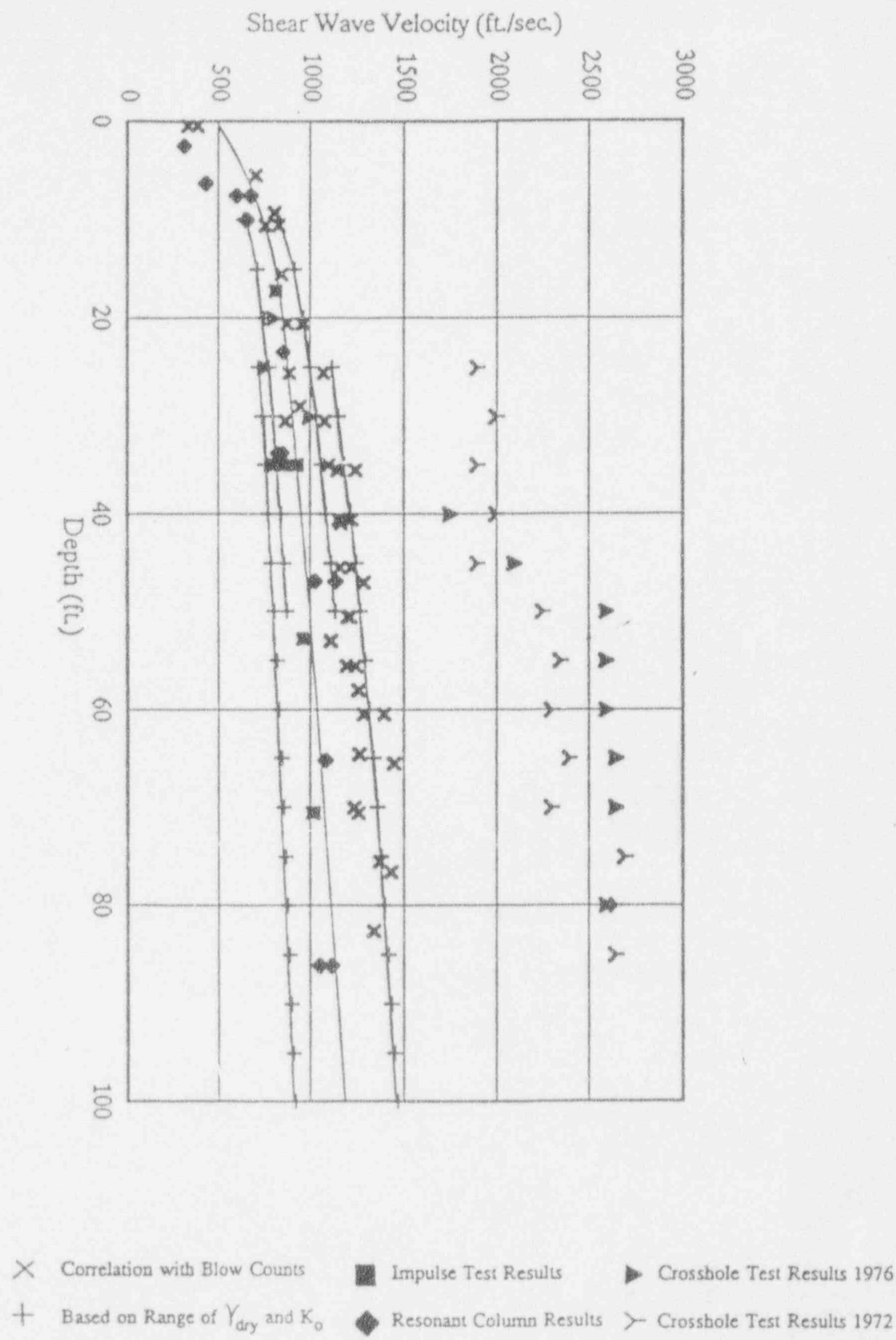

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GEI Consultants, Inc.

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March 23, 1992
Project 92012

91C2672S2-LRS2-003

Mr. Thomas J. Tracy
Vice President
Stevenson & Associates
Ten State Street
Woburn, MA 01801

Dear Mr. Tracy:

Re: **Poisson's Ratio and Small Strain Damping Values**
Pilgrim IPEEE, Pilgrim Station, Plymouth, Massachusetts

This letter is in response to Dr. Tsiming Tseng's request for recommended values of Poisson's ratio and the small strain damping ratio for the soil-structure-interaction analyses.

The outwash deposits and the compacted fills at the Pilgrim 1 site are very dense granular materials. These materials are relatively free draining and so can be expected to experience at least partial drainage during a seismic event. For this type of material, a Poisson's ratio of about 0.33 to 0.40 is reasonable. The damping ratio at small strains can be taken as 1/2 to 1% based on the range of values reported in the literature for granular materials.

If you have any questions, please contact me.

Sincerely yours,

GEI CONSULTANTS, INC.

Eugene Marciano

Eugene A. Marciano, Ph.D.
Project Manager

EAM:ms

91C2672 C002-A3 341083

ROBERT V. WHITMAN
MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA 02139

91C2672-LRS6-001

Room 1-342
November 30, 1992

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Stevenson & Associates
Attn: Thomas J. Tracy
10 State Street
Woburn MA 01801

Dear Mr. Tracy:

In response to your letter of 19 October, I have reviewed the information concerning shear wave velocities for the soils at the site of the Pilgrim Nuclear Station. In particular, I have studied the data provided in a report "Pilgrim IPEEE, Plymouth, Massachusetts", dated July 9, 1992 and prepared by GEI Consultants, Inc.

My recommendations for shear wave velocities are given on the attached figure. There are separate sets of curves for compacted fill and for glacial outwash. For each set, there is a best estimate curve plus curves for this best estimate plus and minus one standard deviation. The best estimate values may be tabulated as follows:

	Shear Wave Velocity - ft/sec	
Depth - ft	Fill	Outwash
0	400	
10	670	
20	820	
30	900	1100
40	950	1170
50	1000	1230
60	1050	1280
70		1340
80		1390
90		1440
100		1490

The standard deviation for the fill is 15% of the best estimate, increasing (above 10 foot depth) to 35% at ground surface to reflect the greater uncertainty concerning wave velocity at shallow depths in cohesionless soils. The standard deviation for the glacial outwash is 35%. This number reflects the apparent discrepancies among the reported data. I do not believe that the very large reported velocities are realistic, and - as noted in the GEI report - there are reasons for doubting these data. On the other hand, it does seem possible, or even likely, that in-situ velocities exceed those measured in laboratory tests.

Use of the original Seed-Idriss curves for modulus degradation and damping still represents the state-of-the-art. Their continuing validity has been confirmed by a recent study, in which all data pertaining to soils with near-zero plasticity were reviewed (see Vucetic and Dobry, "Effect of soil plasticity on cyclic response", J. Geotechnical Engineering, ASCE, Vol. 117, GT1, January, 1991.) While the data on which these curves are based come from laboratory tests upon reconstituted samples, these curves apply to in-situ conditions provided that cementation is not a significant factor - which it is not for the Pilgrim site.

Please do not hesitate to contact me if you need clarifications concerning these recommendations.

Best regards,

Robert V. Whitman

Robert V. Whitman

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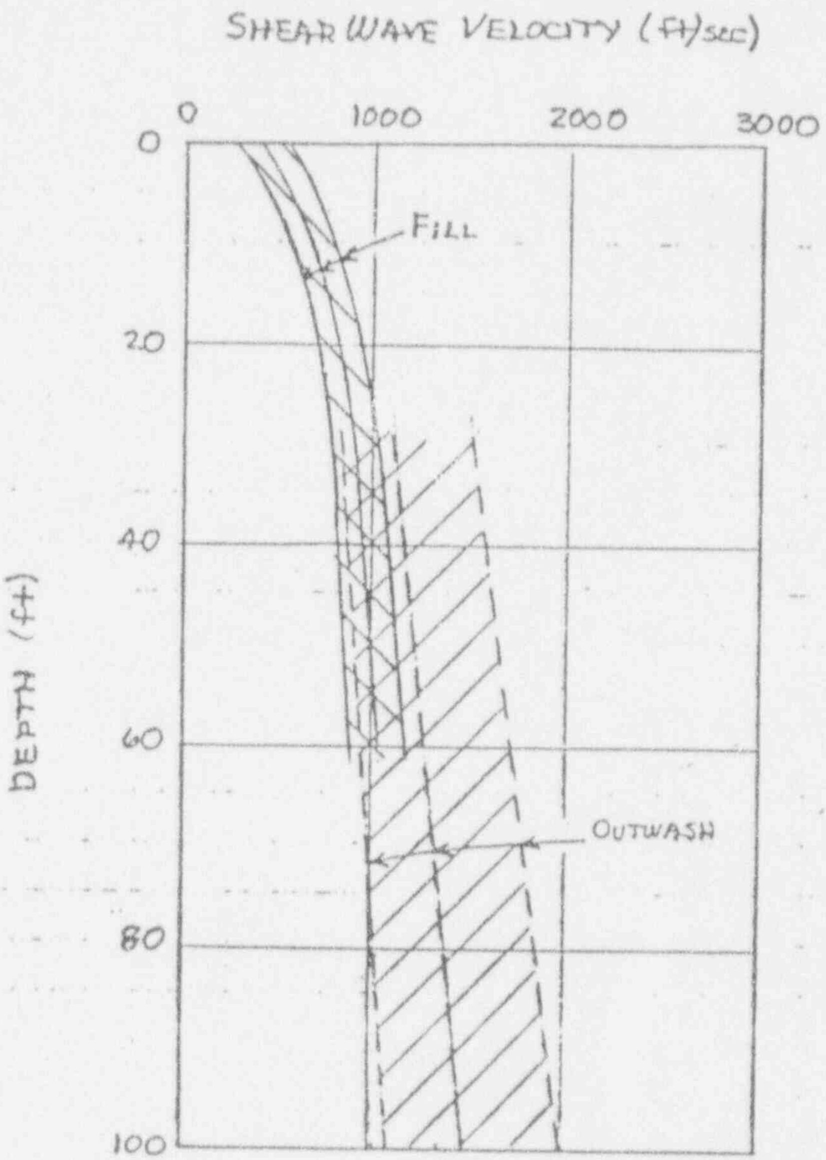

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91C2672-LRS6-002

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December 18, 1992

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Stevenson & Associates
Attn: Thomas J. Tracy
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Dear Mr. Tracy:

You have asked me to document the basis for the recommendations, concerning shear wave velocities for the Pilgrim site, made in my letter to you dated 30 November 1992.

As regards the compacted fill, I selected as most reasonable the resonant column test results in Figure 6 of the report by GEI Consultants. This is a well-developed test procedure that has been found to give results comparing well to those measured in situ. My best estimate curve is the same as the GEI recommended curve, except near the ground surface where I reduced the velocities to accord better with the results from the resonant column tests. I then made a calculation for the standard deviation of the scattered data points in this figure, with respect to the mean curve. This resulted in the recommended standard deviation of 15%, except that I rather arbitrarily increased the standard deviation near ground surface to account for the greater scatter of data in this zone.

As regards the outwash deposit, I rejected as unreasonable the large values reported from the *in situ* measurements. General experience indicates tha such large values are quite unlikely unless sands are cemented, and the record contains no such description for the outwash deposits at Pilgrim. I am aware of instances where more recent measurements of *in situ* shear velocities , using modern methods, have resulted in values substantially lower than those measured some years ago by Weston Geophysical.

At the same time, it is credible that a deposit in place for several millenia might have a velocity larger than measured in the laboratory using samples that have had at least some disturbance. I hypothesized a 50% proabability that the velocities might be 1.5 times those measured in the laboratory. This implies mean values 1.25 times those measured in the laboratory, with a 35% standard deviation. I felt quite comfortable with

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this result. The -1σ curve for outwash fell somewhat above that for compacted fill, while the $+1\sigma$ curve for outwash was credible to me as giving possible although unlikely values. Hence I felt very comfortable with the expectation that computations would be made using such a range of values.

Please let me know if I can provide any further clarifications.

Sincerely yours,

Robert V. Whitman

Robert V. Whitman